Labor migration triggered by COVID-19 and its impact on climate change adaptation of producers in *Sunsari* district, Nepal

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Amrit Shrestha
August 2023

DEDICATION

This thesis is dedicated to my family.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my advisor Dr. Sreedhar Upendram, thesis committee members Drs. Seong-Hoon Cho, Neelam Chandra Poudyal, and James Mingie for their valuable input, advice, and encouragement throughout the work without which it would not have been possible. I am also grateful for all the faculty and staff of the Department of Agricultural and Resource Economics who helped me in multiple ways during my graduate study. I am also thankful to my fellow graduate students for their help, friendliness, and moral support throughout the Master's program. A special thanks to Binaya Baral, Prahlad Bajgain, Asmita Dahal, Kusum Dahal, Bipin Pandey, David Hamal, and Aman Roy who helped me during the field work in Nepal.

ABSTRACT

Due to the COVID-19 pandemic, many temporary labor workers who were employed in foreign countries lost their jobs and had to return to their homeland. These skilled laborers are involved in daily household tasks and farming decision-making processes. This study investigates the role of labor migrants who returned to their households due to COVID-19 on the climate change adaptation of farmers. The migrant laborers are relatively better educated, willing to adopt modern technology, and receive training. An ordered logistic regression was used to analyze the impact of COVID-19 on household's access to institutional factors (Extension services, subsidies, and internet) as well as other relevant explanatory variables on the farmer's adoption of climate change adaptation practices. 443 smallholder farmers were selected from Sunsari district based on convenience, Nepal for a face-to-face interview. The results indicated migrant labor's return to households had an effect on the climate change adaptation of farmers. With the impact of COVID on labor migration being temporary, the migrant laborers are expected to return to their jobs overseas, it is expected that it may result in a potential negative impact on the local climate change adaptation of farmers. Since institutional factors (Extension, subsidy, and internet) have a positive impact on adaptation it could be used to complement the gap created by returning migrant laborers. An increase in an additional unit of access to Extension and subsidy decreased the likelihood of low-intensity climate change adaptation strategies (i.e., one or two practices adopted) whereas access increased the likelihood of adopting high intensity climate change adaptation strategies (i.e., three, four or five practices adopted). Specifically, increasing access to Extensions and subsidies should be greatly beneficial for rice producers in the Sunsari district. Among the three institutional factors, access to Extension should be prioritized over access to subsidy because of its greater impact on the adoption of climate change adaptation practices.

Keywords: COVID impact, Ordered logit, institutional factors, Extension, Subsidy, post-pandemic labor scenario

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

Climate change is defined as long-term variation of rainfall, temperature, wind, and other conditions that adversely affects ecosystems, infrastructure, settlements, and people (IPCC,2022). Climate change is a global challenge with its impacts growing in scale and across geographies every year. The oceans and lands are getting warmer, heavy precipitation and drought events are occurring more frequently, food and water security is reducing, and sustainable development goals are being hindered (IPCC,2022). From the loss of biodiversity in Africa (Matata, 2018; Sintayehu, 2018); drought hazards in Bangladesh (Alamgir et al., 2019); erratic precipitation and more exposure to natural disasters in Nepal (Manandhar et al., 2011; Piya et al., 2012), increased soil erosion (Borrelli et al., 2020); and increased degradation risk of marine, coastal and terrestrial ecosystems in North America (Sorte et al., 2010), the effects of climate change is widespread. The impact of climate change on the agricultural sectors of developing countries is substantial (Mendelsohn, 2009). This is because agricultural production in developing countries is limited by climate. The changing climate is impacting the agricultural sector mainly due to hydrologic extremes of drought and floods (Parry, 2019).

One of the regions that is impacted due to climate change is the Hindu Kush Himalaya region. The Hindu Kush Himalayan region (HKH), also known as the pulse of the planet, is a vast mountainous area of approximately 4,192,000 square kilometers (1,618,540 square miles) (Bajracharya et al., 2011). This region encompasses 8 countries: Nepal, India, Bhutan, Afghanistan, Pakistan, China, Myanmar, and Bangladesh. The Gross Domestic Product per capita for countries in this region is below $2,000 except for India and China and reaches as low as $368 for Afghanistan and $1,208 for Nepal. Excluding China, India, and Pakistan, each country in this region is categorized as a least-developed country (UNDP, 2022). Also, the HKH region constitutes the Indo-Ganga-Brahmaputra basin, the three large river basins in South Asia. The source of water in these river basins are the mountain ranges of Himalayas. The Himalayas are faced with constant climate change impacting the residents (Hamid et al., 2019; Shukla et al., 2019). This makes the livelihoods of people living in the HKH more vulnerable to climate change and specifically in regions around the river basin because of frequent flooding.

Livelihoods around the HKH are more vulnerable because of its climate-based agriculture (Tiwari & Joshi, 2012). The regions around the three river basins are more vulnerable to climate change because of frequent flooding induced by climate change (Sharma et al., 2019; Paudel et al., 2021). Overall, development status, difficult terrain, climate change, vulnerability, snowmelt-based irrigation, and poverty makes the HKH region more prone to food insecurity (Rasul, 2010; Lybbert & Sumner, 2012; Tiwari & Joshi, 2012; Gerlitz et al., 2017).

Farmers in the HKH region, especially those in least developed countries, are typically smallholder farmers that cultivate less than or around one acre of land (Roka, 2017). Smallholder farmers are more vulnerable to climate change as they have meagre resources and limited adaptation capacity (García de Jalón et al., 2018). Smallholder farmers are not typically trained in information related to adoption of climate change adaptation (Pandey et al., 2017; Kumasi et al., 2019). If they do have appropriate information, they are often unable to adapt because of financial limitations (Murray et al., 2016; Kumasi et al., 2019). South Asian countries are considered one of the most vulnerable groups to climate change because of poverty and complex socio-economics as well as demographic challenges (Omerkhil et al., 2020). Therefore, weak financial status, lack of appropriate information, and lack of support from the government makes smallholder farmers even more vulnerable to climate change.

The countries of the Hindu Kush Himalayas have integrated and adopted climate change adaptation steps into their national policy. The National Adaptation Programme of Action in Bangladesh (MOEF, 2005) and Nepal (MoE, 2010), the National Action Plan on Climate Change of India (Pandve, 2009), and the National Climate Change Policy 2012 (Chaudhry, 2017) of Pakistan are respective policies each country has adopted to develop resilience against the changing climate. Although various policies have been developed, the adoption of adaptation practices is still low and poor (MOEF, 2005; Mishra et al., 2019; Omerkhil et al., 2020). A study conducted in Nepal shows that 28.4% of the total respondents had not adopted any adaptation practice (Khanal, 2018a). Other relevant studies also found that the adoption rate is very low in Nepal, with 8.89% of respondents not adopting any practices and around 90% adopting only one adaptation practice (Khanal, 2018). Overall, the adoption of climate change adaptation practices is low and lagging. Studies have shown several reasons for the low rate of adoption in these areas. Major reasons for the low adoption of climate change adaptation practices in this area include fragmented climate policy approaches, limited funds, poverty, lack of government support, lack of appropriate scientific information, land fragmentation, and the difficult terrain of these areas (MOEF, 2005; Pandey et al., 2017; Dhakal & Khanal, 2018; Kumasi et al., 2019). Mishra et al. (2019) suggests that institutions and HKH countries should work together to better adapt. Previous studies also found that institutional factors (Extension, access to information, group membership, and agricultural subsidy) can help enhance adoption (Deressa et al., 2009a; Tazeze & Haji, 2012;Ndamani & Watanabe, 2016; Regmi et al., 2022). A rice producer that has better access to Extension has better information to adapt to climate change (Hassan, 2007; Mulwa et al., 2017). On the other hand, only having access to Extension services and information is not sufficient for smallholder farmers because of their weak financial status. As a result, the availability of credit and access to financial resources is also equally important for better adoption (Alauddin & Sarker, 2014; Mulwa et al., 2017; Ojo & Baiyegunhi, 2020).

COVID-19 came as an external shock to the world and along with several sectors it started to impact the climate change adaptation and agriculture. With the onset of the COVID-19 pandemic, households had to endure additional challenges to improve the adoption of climate change adaptation. COVID-19 is an acute respiratory syndrome caused by coronavirus 2 (SARS-CoV-2) (Yang et al., 2020). Because of the COVID-19 pandemic restrictions, many sectors such as the education system (Pokhrel & Chhetri, 2021) and those related to the environment and society (Verma & Prakash, 2020) were impacted. One of the major impacts of the COVID-19 pandemic is evident in agriculture (J. Schmidhuber, 2020; Kumar et al., 2021) and the labor market (ILO,2020). The impact on agriculture is mainly due to its effect on the restriction of the movement of laborers and agricultural inputs (Siche, 2020; Khatri et al., 2023). The impact on agriculture is also due to a shortage of inputs (seed, fertilizer, chemicals) (Mandlekar, 2020), the closure of social gathering places such as restaurants, and increased difficulties related to limited transportation options (Regmi, 2020). Overall, COVID-19 had a major impact on the agricultural sector and adversely affected labor and households.

The labor market was negatively impacted by COVID-19 (Khatri et al., 2023). The focus of this analysis is on a unique kind of labor migration that takes place in South Asian countries such as Nepal. These workers are considered temporary contract laborers. 236,208 laborers received labor certification to migrate out of Nepal from the Ministry of Labour, Employment, and Social Security during 2018-19 with 43.20% of the labor in the age group of 18 to24 years (MoLESS, 2020). Province 1[1] (Koshi Province) of Nepal has the greatest number of labor migrants (24.4%) in Nepal (MoLESS, 2020). 78.3% of people involved in labor migration from Koshi province are aged between 21 and 40 years. 56% of these migrated laborers have an average education level between grade 9 and 12 (Kharel et al., 2022) as compared to the national average of 5.1 years of schooling (UN, 2021)

Sunsari is a district in Koshi province which contributes 3.2% to the total labor migration nationwide making it one of the top 10 districts within Nepal for labor migration (MoLESS, 2020). These laborers migrate to Gulf and other countries for a specific period (one to a few years) because of the lack of high paying employment opportunities in Nepal (Malla & Rosenbaum, 2017). The laborers from Nepal predominantly work as temporary contract laborers in the unskilled construction sector and other ancillary sectors in the Gulf and other countries (S. Joshi et al., 2011). This labor migrate mostly to the Gulf and other Asian countries such as Qatar, Malaysia, Saudi Arabia, and the United Arab Emirates (Bossavie & Denisova, 2018; MoLE, 2018) in the form of contract labor for a specific period. These laborers are the source of financial remittance that supports their families, farms, and households in Nepal (Seddon et al., 2002; Thieme & Wyss, 2005). COVID-19 has impacted the labor market with the loss of jobs, reduction in working hours, and loss of income (Khamis et al., 2021). With the loss of jobs due to COVID-19, approximately 127,000 migrant laborers have returned to Nepal (ILO, 2020). This has increased the labor supply in Nepal and increased the total number of unemployed young adults. This sudden influx of labor migrants is expected to impact household climate change adaptation as found by other relevant studies (Deressa et al., 2011; Uddin et al., 2014; Ali & Erenstein, 2017).

Unlike previous external weather shocks (drought, erosion, flood), COVID-19 has impacted both labor migration and climate change adaptation. This created a situation where the impact of labor migration triggered via COVID-19 and its relationship to climate change

[1] Nepal is divided into 7 provinces and 77 districts.

adaptation of the household can be studied. The impact of labor migration and external shocks on the adoption of technology and climate change adaptation practices is varied and inconsistent. However, most studies show that there is a positive correlation between adoption, labor migration (Scheffran et al., 2012; Afifi et al., 2016), and external shocks (Holden & Quiggin, 2016; Tan et al., 2021). In addition to labor migration and external shocks, access to climate-related information, credit, and subsidies are also factors that can improve the adoption of climate change strategies. However, there is a lack of research on the impact of labor migration caused by external shocks on climate change adaptation in conjunction with institutional factors. Previous studies on labor migration and technology adoption have mostly focused on permanent immigrants and emigrants, with very few studies examining the specific impact of temporary contract laborers. None of these studies have specifically looked at the role of temporary contract labor migration triggered by an external shock on climate change adaptation.

The objectives of this study are:

a. To investigate the impact of COVID-19-triggered return of labor on climate change adaptation strategies, and
b. To investigate whether and how institutional factors can play a role in climate change adaptation after the COVID-19 pandemic.

Hypothesis of the study

The laborers who have returned from foreign employment due to COVID-19 are relatively younger, more skilled, and better educated as compared to their counterparts in their respective households. In 2020, nearly 80% of laborers who emigrated from one of the seven provinces (i.e., Province 1) in Nepal were between the ages of 21 to 40, and 56% of the emigrated laborers attained education of grade 9 to high school or equivalent (Kharel et al., 2022). In comparison, the national average years of schooling in Nepal was about 5 years in 2020 (UNDP, 2022). Also, these laborers who are away for foreign employment in developed countries are more likely to adopt newer and advanced technologies and practices. These employees are young and have a higher willingness to adopt technology. As a result, these laborers could play a role in the adoption of climate change adaptation practices and increase the household adoption of climate change adaptation practices. This increase in climate change adaptation by farmers would help them develop better resilience against ongoing climate change and reduce the loss of agricultural products and property. On the other hand, these workers might return to work during the post-pandemic scenario. This may cause the climate change adaptation to decrease in post-pandemic situation. One of the factors that may have a positive impact on adoption of climate change adaptation is institutional factors. Increasing access to these institutional factors can potentially help households increase their adaptation. However, as a result of post-pandemic labor returning to overseas jobs, it is possible that the climate change adaptation may decrease. The two hypothesis we are testing are presented below:

Hypothesis I:

H_0: Adoption of climate change adaptation strategies is not significantly higher among the households with returned migrant laborers triggered by COVID-19.

H_1: Adoption of climate change adaptation strategies is significantly higher among the households with returned migrant laborers triggered by COVID-19.

Hypothesis II:

H_0: Adoption of climate change adaptation strategies is not significantly affected by institutional factors.

H_1: Adoption of climate change adaptation strategies is significantly affected by institutional factors.

The rest of the thesis is organized as follows: Chapter two provides an overview of the literature on climate change and labor migration, external shock, and technology adoption, climate change adaptation and institutional factors and factors affecting climate change adaptation. Chapter three provides an overview of material and methods used for the study, chapter four describes the results, and the chapter three presents the conclusion and recommendations of study.

CHAPTER TWO
LITERATURE REVIEW

This section describes a review of literature that focuses on how climate change is impacted by labor migration, external shocks, technology adoption, climate change and institutional factors (access to Extension, subsidy, and internet), and other factors that could impact the adoption of climate change. This section ends with a summary of the relevant literature.

2.1. Climate change and labor migration

In this section, labor migration's impact on climate change adaptation is explained. There are numerous studies suggesting that migration plays a role in increasing resilience to climate change. Migrants help diversify sources of income, gain knowledge of different technologies, transfer new skills they have learned, and develop social capital to increase the resilience of households and communities (Mortreux & Barnett, 2009; Scheffran et al., 2011; Afifiet al., 2016). These multiple sources of income (remittances) can potentially help households to mitigate risk due to climate change and invest in adaptation strategies. Similarly, technical knowledge that migrants possess helps farms adapt efficiently to modern climate change strategies. Thus, migration contributes to building capacity and increasing the resilience of smallholder farmers to climate change.

There is a heterogeneous impact of climate change on migration of labor. Environmental hazards can induce or suppress migration depending on the situation (McLeman, 2010). A study conducted (Mueller et al., 2020) in Botswana, Kenya, and Zambia shows that climate change-induced events have a complex relationship to labor migration. The relationship and impacts differed by countries and their specific conditions. Precipitation-related changes triggered migration in Zambia. However, in Botswana and Kenya, it was found to be otherwise. In Kenya, precipitation-related unexpected events increased unemployment because of their heavily agriculture-dependent population. The decline in migration is supported by an increase in demand for local workers and increased migration to other countries is due to new opportunities in a new destination.

On the other hand, out-migration is also considered an adaptive measure to tackle climate change. A study by McMichael (2015) found that climate-induced incidents impact the migration of people to other places from the current area. This study found the primary reason for the movement of people from the Horn of Africa to Kenya and Ethiopia is drought and from the Mekong Delta to urban cities like Ho Chi Minh in Vietnam and Phnom Penh in Cambodia is flooding. These migration opportunities in return can be a source of new and additional income for dependent families to build resiliency to climate-induced vulnerabilities in their farms, households, and communities.

Similarly, a study by Maharjan et al. (2021) on various parts of the Hindu-Kush Himalayan region also found that migration can be a source of adaptation. In their study of understanding how migration can play a role in the household adaptation decisions of people living in the river basins of Gandaki, Teesta, Indus, and Upper Ganga in Nepal, the authors found that migration is also one key consideration. Mainly, the financial remittance received because of the migration is used as a source of additional household income to pay for farm and household expenses. These remittances are then used as a source of additional income as an investment in another livelihood sector to diversify income. The diversification helps to build resilience to climate change. This study supported that migration plays a positive role in adaptation to climate change due to remittances.

Migration is considered one of the tools for the adoption of climate change practices (Draper, 2022) and tackling different economic vulnerabilities (Tacoli, 2009; Barnett and Adger, 2018). The study by Draper (2022) shows that migration leads to the diversification of income sources. These additional sources of income are then invested in potentially productive ventures. In his study to identify the advantages and disadvantages of using labor migration as a practice to adapt to climate change, he concluded that more natural or sustainable ways of adaptation should also be considered because adverse climate impacts may force people to go against their will with the sole purpose of adapting to environmental vulnerabilities.

Overall, climate change is seen to have a heterogenous impact on migration of labor. Labor migration to cities and other areas has generated a diversification in income for households. More stable and diversified incomes have increased resilience and decreased risk to climate induced events. These additional income sources are used by people to adopt climate change adaptation strategies such as drought management and flood control. These studies reveal that labor migration is one of the factors that can impact the climate change adaptation. So, in our study we have included the COVID-19 impact as a variable which is a cause of labor migration during the pandemic.

2.2. External Shock and Technology Adoption

External shocks such as drought, unexpected labor demand, increased supply of labor and commodities are nothing new to the market. However, the COVID-19 pandemic is a new shock to the economy caused by the acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Yang et al., 2020). COVID-19 is seen to impact various markets including agriculture. This section provides details about how external shocks and technology adoption are related.

A study by Holden & Quiggin (2016) found that external shocks, such as droughts, can impact the adoption of certain technologies. Using a state-contingent model, the study investigated the relationship between external shocks and the adoption of drought-tolerant maize (corn) in six districts of central and southern Malawi. The results showed that farmers who had experienced a greater number of external shocks in the past three years were more likely to adopt drought-tolerant maize. However, the number of past encounters with external shocks was found to negatively impact the adoption of local varieties, leading farmers to be more inclined towards adopting technology. The study also found that risk-averse farmers were more likely to adopt drought-tolerant maize than local varieties, as these varieties of maize had characteristics that reduced risk, such as drought tolerance and improved pest risk reduction after harvest. These findings suggest that both the impact of external shocks and the risk aversion characteristics of farmers play a vital role in the adoption of certain technologies.

Similarly, a study (Tan et al., 2021) in the Gansu province of China found that there is an adverse relationship between external shocks, such as natural disasters, price fluctuations, demand fluctuations, and the adoption of modern irrigation technology (MIT). The study emphasizes the role that the economic vulnerability of the family and risk-taking choices plays in the adoption of MIT in the presence of these external shocks. External shocks are shown to directly impact the adoption of MIT and increase the economic vulnerability of households by damaging assets and human capital. On the other hand, risk-taking choices are found to have a positive relationship with the adoption of MIT, and they also play a regulatory role by reducing economic vulnerability and helping farmers mitigate the impact of natural shocks. The risk-taking networks function as a regulatory factor between the adoption of MIT by farmers and their economic vulnerability.

Additionally, in their study, Si et al. (2021) investigated the effect of natural disasters on the adoption of degradable mulch film (DMF) by corn farmers. Using a Tobit model, they found that an increase in the intensity of natural disaster shocks has a positive impact on the adoption of DMF. The study also highlighted how natural disaster shocks influence the adoption of DMF among corn farmers with varying levels of risk aversion. Specifically, farmers with high-risk aversion tend to adopt DMF more readily in response to increased natural disaster shocks. This study shows the heterogeneity of adoption of technologies by farmers of different risk characteristics, and how natural disaster shocks can play a role in encouraging corn farmers to adopt technology in China.

Another study (Gebremariam & Tesfaye, 2018) also showed the impact of an external shock on agricultural innovation adoption. In their study to understand how different idiosyncratic and covariate shocks affect the adoption of technology, a pooled multivariate probit model was used which identified shocks related to production and shocks that hindered the adoption of chemical fertilizers, improved irrigation practices, and hybrid seeds. However, it was seen to have a positive impact on the adoption of organic fertilizers. Additionally, a health shock is seen to negatively affect adoption. Health-related shocks can be somewhat compared to COVID-19 considered in our study as it is also found to impact the health of an individual.

A study in Tanzania, a country with a dominating agricultural economy, found that rainfall, diseases, and pests (a measure of rainfall shock) have a significant role in the adoption of technologies. This study used a multivariate probit model and found that adoption of legume intercropping system, conservation tillage, and application of animal manure as fertilizer was more likely if the farmers experienced exposure to disease and pests in the previous year, but producers were less likely to adopt improved crop varieties. The study also found that favorable rainfall is less likely to lead to adoption of conservation tillage practices, soil and water conservation efforts, legume intercropping systems, and use of improved seeds. On the other hand, it was more likely to improve the adoption of legume crop rotation practices.

A study by Kassie et al (2009) in the Ethiopian Highlands examined how risk exposure impacts the adoption of fertilization and soil conservation techniques. The study was conducted using a moment-based approach using panel data to estimate the production shock via the expected yield, the variance of the yield, and the skewness of the yield. The result showed that the higher the expected yield, higher were the chances of adoption of fertilizers and soil conservation techniques. On the other hand, the variance of yield negatively impacted the adoption of fertilizers and soil conservation techniques.

Xue et al. (2022) examined how natural disasters would impact the adoption of no-tillage technology adoption in China. The study was conducted in the Saanxi, Gansu, and Ningxia provinces of China. The findings showed that the natural disaster shocks positively and significantly impact the adoption decision and adoption intensity of no-tillage technology. The study also investigated how well farmers knew the systems and how they work in the form of collective action. They found that collective action had a significant and positive impact on the adoption decision and adoption intensity. Collective action also played a role in the impact of natural disasters on the adoption of no-tillage technology adoption.

Overall, the impact of an external shock on the adoption of technology is heterogenous. Most studies found a positive impact of experiencing an external shock on the adoption of technologies such as drought-tolerant maize, degradable mulch film, and no-tillage technology adoption. However, an external health shock is seen to have a negative impact on the adoption of technologies such as chemical fertilizers and hybrid seeds. An external shock can have both positive and negative impact on adoption. Similarly, our study is also focused on external shock which came in the form of COVID-19 pandemic. In our study we incorporated the household impacted by the COVID-19 pandemic to assess how this external shock has impacted climate change adaptation.

2.3. Climate change adaptation and institutional factors

Institutional factors such as Extension, subsidy programs, access to information, and the internet are factors contributing positively to the adoption of technologies and climate change adaptation strategies.

A study by Deressa et al. (2009a) showed that access to Extension services enhances a farmer's adoption of climate change strategies such as planting trees. Similarly, the same study found that having knowledge of weather-related information helps farmers adopt improved crop varieties. Another similar study from Ethiopia also indicates Extension as an efficient way to enhance the adoption of improved crop varieties and soil and water conservation techniques (Tazeze & Haji, 2012). A similar study by Tazeze & Haji showed that access to climate-related information has a positive and significant impact on the adoption of climate change adaptation strategies.

Ndamani & Watanabe (2016) found that access to weather information and access to credit positively affected climate change adoption practices (e.g., crop diversification, change planting dates, improved crop varieties, farm diversification, income generating activities, irrigation, and agroforestry) among the farmers in Lawra district of Ghana.

Examining adoption to climate change in a developing country such as Bangladesh, a study conducted by Alauddin & Sarker (2014) found that access to climate information had encouraged farmers to provide more irrigation water for *boro-type*[2] rice crop. The study also showed that access to subsidies encouraged farmers to adopt short and drought-tolerant rice varieties as well as water-saving horticultural crops.

Hassan (2007) found that adaptation to climate change in South Africa also had an impact on institutional factors similar to other studies. Their study suggests an indirect relationship between access to Extension and the adoption of climate change strategies. The analysis found those farmers who have access to Extension services have better information regarding climate-related events, making them more aware of climate hazards. This makes them more inclined toward adoption.

[2] Dry season irrigated rice crop.

A study by Regmi et al. (2022) aimed to understand the impact of various institutional factors that influence the adoption of climate change practices. This study found that Extension, training, and information increase the likelihood of adoption of irrigation practices and improved rice varieties while information was vital in the adoption of direct-seeded rice. The study also emphasized the complementary relationship between various climate change adaptation practices (e.g., improved varieties, direct seeded rice, and irrigation practices).

Although adaptation strategies should not necessarily be taxing and complicated to adopt, people are still not able to adapt small agronomic or management practices. To understand this, Mulwa et al. (2017) studied small farmers in Malawi. This study reported that farmers need to have information regarding the changing climate first before adopting the practices. Extension service was viewed to be one of the potential factors for the adoption as it helped in the dissemination of information to farmers. The study suggests that several factors play a role in adoption. Along with Extension and climate information, access to credit is one of the major determinants. Smallholder farmers have less access to information as well as Extension services and were not able to adapt because of the poor financial condition of the households. As a result, having access to credit could enhance adoption along with access to Extension and the internet.

Ojo & Baiyegunhi (2020) also studied the determinants of climate change adaptation practices in southwest Nigeria. In their study using a multivariate probit model, they found that institutional factors such as Extension and access to credit were found to be significant in selecting adaptation practices. The study also found interdependence among climate change adaptation practices used in the study. The net income of adopters was also found to be significantly higher than non-adopters, implying the economic benefit of the adaptation practices. Additionally, exposure to natural shocks such as flooding, and drought also increases the likelihood of adoption.

In summary, many research studies focus on how labor migration can function as a tool for adaptation. Here, labor migration refers to labor out-flow, not the in-flow of labor. The labor out-flow is associated with the diversifying opportunities created by it. All these studies discuss the increase in the financial status of these members' households through remittance and how resilience is developed through it. Similarly, the literature shows that there is a heterogenous relationship between the impact of an external shock on technology adoption. Also, some studies emphasize how institutional factors (subsidy, internet, and Extension) play a role in improving the likelihood of adoption and their role in overcoming the gap that was created as a response to the COVID-19 pandemic.

2.4. Factors affecting climate change adaptation.

Along with labor migration, external shocks, and institutional factors, many other factors influence the adoption of climate change adaptation practices. There are several demographic characteristics, farm characteristics, and other characteristics that influence adoption of climate change adaptation by a household (Deressa et al., 2009a; Nabikolo et al., 2012; Piya et al., 2013).

A study (Ali & Erenstein, 2017) using a multivariate probit model to understand various factors shows that household demographics play an important role in the adoption of climate change practices in Pakistan. The study highlighted that out of many demographics used in the study, the size of the household and the type of household (i.e., if it is a joint family or nuclear) was seen to impact adaptation positively whereas the age of the household head is seen to negatively impact adaptation practices. This study’s findings indicate that the younger population are more inclined to adaptation when compared to relatively older farmers.

A study by Kabir et al. (2021) on determinants of climate change adaptation strategies in coastal Bangladesh also shows that socioeconomic factors play an important role on farmer’s choice of adaptation. In their study, they found different socio-economic attributes impact differently for adoption of different adaptation practices. For example, the age of the household head was seen to impact adoption of highland plantation. Farming experience was found to impact adoption of new crops to saline conditions, shortening growing seasons, and homestead gardening. Similarly, educational status was seen to impact adoption of other climate change adaptation practices such as change in planting and harvesting dates. Additionally, other socio-economic parameters such as their primary occupation and secondary occupation were also seen to impact the adoption of homestead gardening and new crops that adapt to saline conditions, respectively.

Another study in developing nations (Khanal, Wilson, Hoang, et al., 2018b) shows that, along with other factors, socio-demographic characteristics are also very important. The study in

Nepal shows that education is found to be influential in the adoption of climate change practices. Education for these farmers is the source of new information and this information enhances understanding of the importance of adaptation to climate change (Feinstein & Mach, 2020).

Similarly, a study was conducted using a multivariate probit model in the Wolaita Zone, Ethiopia by Bedeke et al. (2019a) also focused on understanding various factors influencing climate change adaptation. The study analyzed the different forms of capital (e.g., natural capital, human capital, physical capital, financial capital) and local institutions' impact on the adoption of drought-resistant maize, mineral fertilizers, conservation tillage, maize-legume crop rotation, and soil water conservation[3] practices. The study also found that human capital (e.g., education levels, gender, and family size) influences the adoption of technology positively and age impacts adoption negatively.

A study by (Aryal et al., 2021) in understanding factors impacting the adoption of adaptation practices in climate-vulnerable regions like South Asia and East Africa also found household characteristics such as the gender of the household to influence adoption. Male-headed households have a greater chance of adopting practices than female-headed households. The study also emphasized that farm characteristics such as livestock ownership also influence adaptation practices. Livestock has more liquidity as compared to other assets such as land and can be sold readily in a time of need. Thus, having livestock reduces the financial risk, hence increasing resilience.

Overall, many factors influence the adoption of technology and climate change adaptation practices. Adoption of a technology is not influenced by a single parameter. Out of many factors, demographic characteristics of the household are crucial factors. Size of the household, education level of the household, type of family, age, and gender are numerous factors that are seen to impact the adoption of climate change adaptation practices. These household demographic characteristics impact the understanding of the importance of technologies on adoption and help influence the adaptation decision for better results. For example, education brings social awareness of the use of technology to minimize risk and thus help influence adaptation. Meanwhile, other socio-economic factors such as having a secondary

[3] Practices that make use of terraces, ditches, and soil bunds as biological measures

occupation and rearing livestock help to spread risk and minimize financial risk. For example, having a secondary source of income helps farmers invest in the adoption of technologies by reducing their financial burden. Hence, all these socio-economic factors impact the adoption of climate change adaptation practices. As a result, information of these parameters is necessary to understand the adoption of climate change practices by farmers.

CHAPTER THREE
MATERIALS AND METHODS

This section describes the conceptual framework, comprehensive account of the study area, and the size of the sample for the study. It also includes a detailed description of the survey design, data collection and entry procedures, as well as the empirical model used for the analysis.

3.1. Conceptual framework

The adoption of climate change adaptation practices or any other technology by an individual might be influenced by a number of factors. Farmers act to minimize risk and maximize production. To minimize the risk, farmers adopt different adaptation practices. Producers/Farmers are willing to adopt an adaptation strategy if there is a benefit of adoption over non-adoption.

As demonstrated by Figure 3.1, the loss of overseas jobs has forced migrant laborers to return to their household in home countries. These laborers who have returned to the country are relatively younger, better educated, and more technology-friendly than their counterparts at home. They are more likely to adopt newer, advanced technologies and practices. These laborers who have returned are involved in farming and the day-to-day activities of the household. They are also involved in the decision-making of different farm and household activities including technology adoption and the adoption of climate change adaptation practices. During the post-pandemic situation these workers are expected to return overseas for job purposes, these gaps created by the labor return during post-pandemics can be overcome by institutional factors.

3.2. Description of the Study area and Sample size

This section provides an overview of the study area, sample size, and data collection methods in Nepal. Nepal is a landlocked country between India to the east and south and China to the north. All the regions of Nepal fall in the Hindu-Kush Himalaya region. The Hindu Kush Himalaya region is presented in Figure 3.2 indicated by a dark blue line. The area of Nepal is 147,181 square kilometers (36.37 million acres). A map of Nepal is also shown in Figure 3.2.

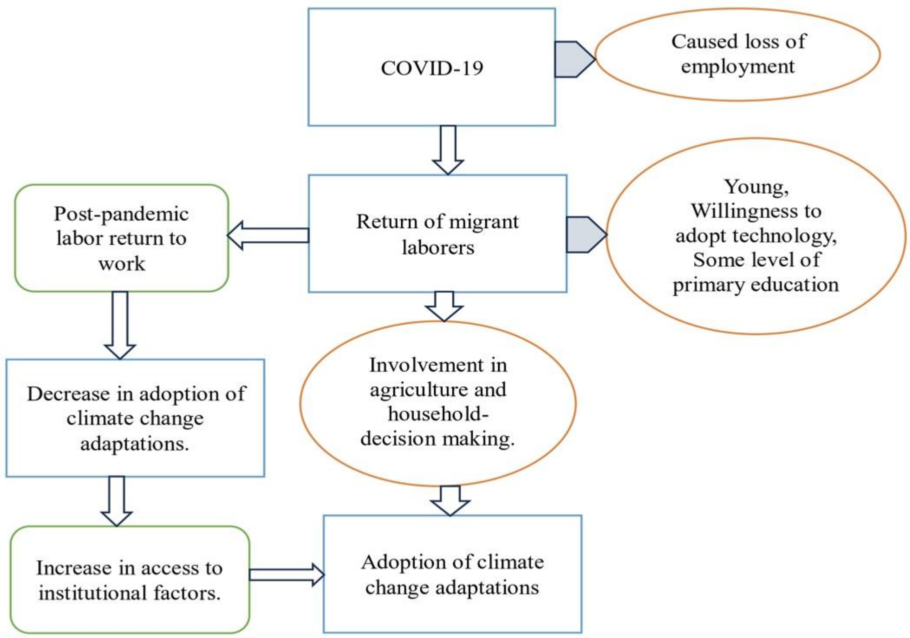

Figure 3.1 Conceptual framework for adoption of climate change adaptation

Geographically, Nepal has three distinct regions - mountains, hills, and plains/*terai* region. The mountain region's altitude ranges from 3,000 to 8,848 meters above sea level, is characterized by Rocky Mountains, and has an average temperature of around 3^0C (37.4^0F) to 10^0C (50^0F) with an average annual precipitation in the range of 5.905-7.874 inches (150-200 mm) (DHM, 2018). Areas in the mountain regions are suitable for agriculture using terraces. The hilly region (Mid-hills) has an altitude range of 300 to 3,000 meters above sea level and is characterized by hills with small valleys with a sub-tropical to temperate climate. The flat land ranging from 60-300 meters above sea level is the plains/*terai* region. The plains/*terai* region is commonly known as the food basket of Nepal, where agriculture is the primary occupation. The climate in this region is tropical and ranges from around 7.22^0C (45^0F) in winter to as high as 35^0C (95^0F) in summer (Regmi, 2020). The plains/*terai* region receives mean annual rainfall between 43.3(1099.82mm) and 118.1(2999.74mm) inches. Rice is one of the major cereal crops grown in the *terai* region.

The study area for this research is *Sunsari* District, located in the eastern *terai* region of Nepal (Figure 3.2). *Sunsari* district is selected deliberately for this study because of its high labor migration rate and open border with India (Nepal, 2007) that facilitates labor transition. According to MoLESS (2020), *Sunsari* district is one of the top ten districts which has received labor migration approval for foreign employment. The study area also lies in the Koshi river basin of the Hindu Kush Himalayan region making it a suitable place for our study.

Sunsari district is a significant rice-producing district in Nepal, with 53,350 hectares of land used to cultivate rice (MoALD, 2020). Along with significant agricultural production, this district has an open border with India, making it more prone to seasonal labor migration. This makes it a suitable site for the study as COVID-19 has impacted all of Nepal. According to one study on Nepal migration, 37.6% of absentee labor migrated to India (IOM, 2019). The primary crops grown in the *Sunsari* district are rice (53,350 hectares), wheat (12,959 hectares), and maize/corn (8,949 hectares). The mean annual temperature of Nepal is 15 ^{0}C (59 ^{0}F). In Nepal, the minimum temperature varies between -5 ^{0}C (23^0F) and 20^0C (68^0F) in a year, and the maximum temperature varies between 5^0C (41^0F) and 30^0C (86^0F) (DHM, 2017). Nepal's annual maximum and minimum temperatures have increased by 0.056 ^{0}C (0.1008^{0}F) per year and 0.002^{0}C (0.0036^{0}F) per year, respectively (2017).

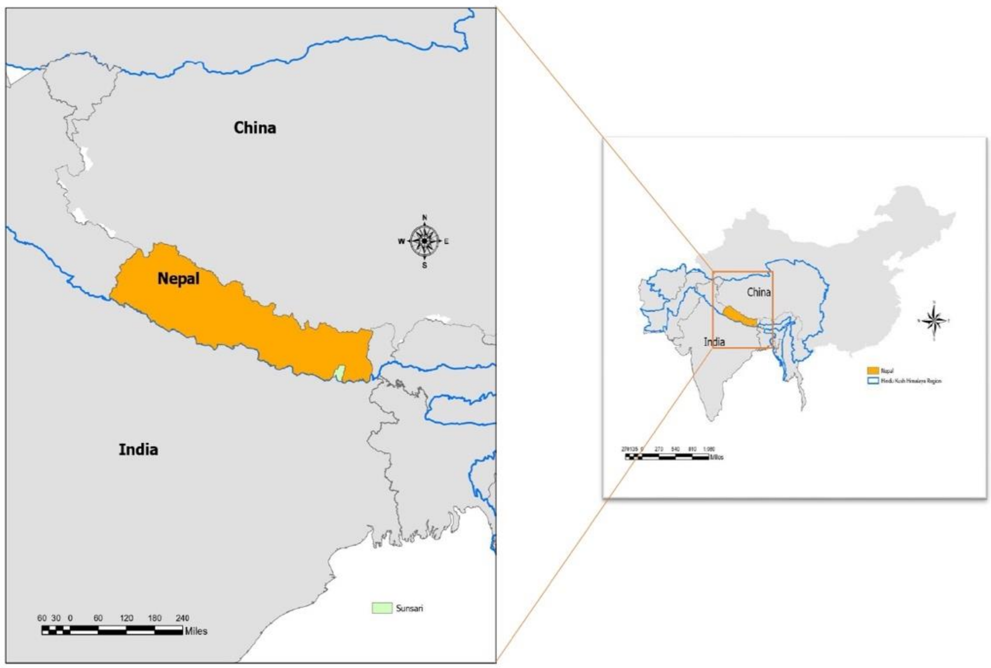

Figure 3.2 Hindu Kush Himalaya region showing Nepal and study area.

The average yearly precipitation is 70 inches (1,800 millimeters) (DHM, 2017). The mean annual precipitation of the *Sunsari* district measured by the *Chatara* station from 1981-2010 is 83.91 inches (2,131.35 mm). The average yearly mean rainfall from 1971-2014 is 70.64 inches (1,794.3mm) (DHM 2017). The minimum annual temperature of *Sunsari* district is 18.60^{0}C (65.48^{0}F) and the yearly maximum temperature is 30.1^0 C (86.18^{0}F). According to DHM (2018), the average maximum temperature of the *Sunsari* district is 30.35^{0}C (86.63^{0}F) and the average minimum temperature of the *Sunsari* district is 17.51^{0}C (63.518^{0}F).

Sample Size

For the sample to be representative of the population, Krejcie and Morgan's (1970) method was used:

Sample size $== \frac{\chi^2 NP(1-P)}{d^2(N-1)+\chi^2 P(1-P)} --------- (1)$

Where,

χ^2 = chi-squared tabulated value at a desired confidence level (95%)

N = total population size

P = population proportion (0.5 to provide the maximum sample size)

D = degree of accuracy (5%)

The total population of *Sunsari* District is 934,461, with a male population of 454,075 and a female population of 480,386 (CBS, 2021). Following the Krejcie and Morgan , the total sample size for a representative sample was estimated to be 384. We were able to collect data from 443 farmers, while 40 respondents declined to participate in the survey. Data enumerators traveled to households in Sunsari district according to their convenience and means of transportation available to them. *Sunsari* district consists of 12 municipalities as shown in Figure B-1. Table 3.1 portrays the demographic statistics for the *Sunsari* district of all municipalities. The column total family members represent the total number of families residing in each municipality.

Table 3.1 Local Population data for Sunsari district

Name of Municipality	Total number of families	Total number of households	Total population	Total Male	Total Female
Barahchhetra Municipality	21,961	20,781	91,891	43,178	48,713
Barju Rural Municipality	8,034	6,867	36,533	18,571	17,962
Bhokraha Nursing Rural Municipality	9,299	8,155	49,371	24,501	24,870
Dewanganj Rural Municipality	7,814	6,526	39,367	19,710	19,657
Dharan Sub-Metropolitian City	43,815	34,834	173,096	82,683	90,413
Duhabi Municipality	15,415	12,410	67,051	33,448	33,603
Gadhi Rural Municipality	8,751	7,664	39,478	19,426	20,052
Harinagar Rural Municipality	8,765	7,630	49,501	24,459	25,042
Inaruwa Municipality	16,931	15,044	75,920	37,273	38,647
Itahari Sub-Metropolitian City	50,743	40,207	198,098	94,308	103,790
Koshi Rural Municipality	9,377	7,634	48,768	24,550	24,218
Ramdhuni Municipality	15,969	14,025	63,378	29,980	33,398

3.3. Description of the questionnaire and Procedure of Data collection

The survey questionnaire was designed based on a literature review, collaboration with government officials working in the study area, the Agriculture Knowledge Centre, and experts working in the study area.

The survey consisted of eight sections (Appendix A) from A to H. In Section A, we collected household, farm, and general information. Data regarding gender, age, ethnicity, education, livestock, group membership, and irrigation were collected in this section. Group membership indicated if the farmers were a member of any private farmers co-operative or any other governmental organizations such as agricultural pocket, blocks, or zone. Similarly, livestock was a variable to assess if the farmers reared goats, pigs, poultry, cattle, buffalo, or ducks.

In Section B, we collected information about the labor migration status of the household. Information regarding the number of migrants, gender, education level, country of migration, remittance received by household per month, and share of the remittance on different household activities were collected. Households which were impacted during the COVID-19 were also identified in this section. Household impacted during COVID-19 were asked if there were any members returning to the household during the COVID-19 pandemic from foreign employment.

In Section C, we collected information about farm production and income. Agricultural production, yield of crops and sales of different crops throughout the year before and after COVID-19 were collected in this section. The cost of production inputs before and during the COVID-19 pandemic was also collected in this section.

In Section D, data regarding farmers' perceptions of climate change and its impact on agriculture were collected. The respondents were asked if they experienced any changes in local weather patterns in the last 10 years or any changes in precipitation or temperature.

In Section E, we collected information regarding climate change adaptation practices. The type of adaptation practices adopted by the household and probable reasons for not adopting are collected in this section. Climate change adaptation practices adopted by the farmers include varietal management, agronomic practices, land use/diversification, changing the dosage/frequency of chemicals, direct-seeded rice, system of rice intensification, use of alternative energy options and flood control measures.

Section F focused on institutional factors. Agricultural subsidy was one of the information collected in this section. Agricultural subsidies were typically used by farmers to purchase essential equipment such as pesticide sprayers, tractors, seeds, fertilizer, and other items necessary for land preparation. Information regarding Extension services was also collected in this same section. Farmers had the option of visiting the Extension office to receive guidance and support, or they could access Extension services through other means. Similarly, Section F collected information on access to the internet. Other information's on agricultural training, information, household confidence on weather forecast were also collected from this section.

Finally, in Section G, we collected data on the adoption of technology and investment in technology. Technologies adopted by the farmers include farm machinery, irrigation facilities, smart-phones, and hybrid varieties. Data regarding type of technology, investment in technology, and reasons for not adopting were collected in this section.

Nine enumerators who were undergraduate students at the Agriculture and Forestry University of Nepal were hired for data collection. The data enumerators were provided with detailed instructions regarding the questions to be used for data collection and were trained in proper data collection procedures. They were specifically instructed not to coerce respondents into answering the survey questions. We then got the approval from the Institutional Review Board for data collection (UTK IRB-22-06980-XM). After approval, data collection in Sunsari Nepal was conducted. Data were collected from the 11th through the 18th of June 2022. On average, the enumerators were able to collect 8-10 surveys per day. Farmers were recruited from several municipalities of the *Sunsari* district with the help of government officials and in collaboration with the Agriculture Knowledge Centers. The enumerators travelled to different households in Sunsari district based upon the convenience of farmers and using personal vehicles (motorcycles). Response from farmers was voluntary since they had the option to decline participating in the survey if they choose. Every enumerator collected survey responses on a paper-based questionnaire. The survey was in English; however, the enumerators could translate the questions to Nepali (local) language to better collect data from each respondent. The enumerators were paid Nepali Rupees NRs 3,000 ($22.70) per day to compensate for their time and transportation costs.

We also conducted a focus group discussion that was attended by 35 participants including rice producers, Extension agents, and students on topics such as labor migration, technology adoption, climate change adaptation, and access to institutional factors. The qualitative responses were noted to validate the survey responses.

3.4. Empirical model

The climate change adaptation strategies used by the rice farmers are varietal management, agronomics practices, land use/diversification, change in the frequency of the chemicals, Direct Seeded Rice (DSR), System of Rice Intensification (SRI), use of alternative energy sources, and flood control measures. The farmers were willing to adopt a strategy if the utility derived from adopting the strategy is greater than the utility derived by not adopting (i.e., $U_j > U_0$, where U_j is the utility derived from adopting the j^{th} strategy and U_0 is the utility derived from not adopting the climate change adaptation strategy). Also, $U_{j+1} > U_i$ indicates that the utility derived from adaptation of an additional i^{th} strategy is more than the adaptation of a j^{th} strategy. We extended this basic framework of deriving greater utility by adopting more adaptation strategies to understand the relationship between the independent variables and the ordinal dependent variable.

We apply the ordered logit model to hypothesize that climate-vulnerable farmers' adoption of climate change adaptation practices is influenced by the external shock of returned laborers due to COVID-19 and by the controllable factor of access to institutional resources. The ordered logit model is chosen since the number of climate change adaptation practices adopted by farmers is observed in the ordered categories of different intensities of adoption. Although the adoption process is an observed ordered variable, there is an unmeasured continuous latent variable whose value determines the observed value of the observed variable. Thus the ordered logit model is adopted over other possible models such as count data ones because ordered logit regression follows the utility maximization framework and a latent regression method (Greene & Hensher, 2010). In addition, ordered logit regression is more likely to provide better estimates because the threshold parameters have the flexibility to enable alignment of predicted and actual frequencies (Winkelmann, 2008).

Following Greene (2012), the ordered logit model is built around a latent regression model:

$$Y_i^* = X_i\beta + \varepsilon_i, \qquad \varepsilon_i \sim N(0,1), \;\; \forall i = 1, \ldots. N. \tag{1}$$

where X_i is a 1*k vector of explanatory variables, β is a 1*k vector of unknown parameters, ε_i is a disturbance term with standard normal distribution, and Y_i^* is the latent continuous variable. We do not observe Y_i^*, but observe only Y_i, which is the number of climate change adaptation practices adopted by a farmer i. The relationship between the Y_i^* and Y_i can be defined as:

$$Y_i = \begin{cases} 0, \text{if } Y_i^* \leq 0 \\ 1, \text{if } 0 < Y_i^* \leq \alpha_1 \\ \text{j, if } \alpha_{j-1} < Y_i^* < \infty \end{cases} \tag{2}$$

where $j = 0, \ldots, 7$ is the number of climate change adaptation practices adopted by each farmer i, α is the parameter that is estimated with β, and is also known as cut points or thresholds. Our interest primarily lies in probability. As a result, the probability of each category of climate change adaptation is calculated as:

$$P(Y_i = 0) = F(-X_i\beta),$$

$$P(Y_i = 1) = F(\alpha_1 - X_i\beta) - F(-X_i\beta),$$

.

.

.

$$P(Y_i = j) = F(\alpha_j - X_i\beta) - F(\alpha_{j-1} - X_i\beta) \tag{3}$$

where $F(.) = \frac{exp(.)}{1+exp(.)}$ is a cumulative logistic distribution function. The coefficient from equation (1) only gives us the direction of the impact of the explanatory variable on climate change adaptation. To get the magnitude, we need to calculate the marginal effect. Marginal effects give a change in output caused by relaxing one unit of input. The marginal effect of relaxing regressor X_i, on the probability of selecting the alternative j by the farmer i, can be calculated by taking the derivative of equation (3) with respect to explanatory variable X_i

$$\frac{dP(Y_i=j)}{dX_i} = \begin{cases} -\beta F(X_i\beta) & if\ j = 0 \\ \beta(F\left(\alpha_j - \mathrm{Xi}\beta\right) - F\left(\alpha_{j-1} - X_i\beta\right)) & if\ 1 < j < J \\ \beta F\left(\alpha_{j-1} - X_i\beta\right) & if\ j = J \end{cases} \qquad (4)$$

where J is the maximum value of climate change practices available (7 in our data). These predicted probabilities and marginal effects are estimated using the *oglmx* package in R software (Regensburg, 2020).

3.5. Estimation of dependent variable across the change in the explanatory variable of interest

To understand how the dependent variable is affected when the explanatory variable is changed, the parameter for each explanatory variable is estimated from equation 1 ($\hat{\beta_i}$). One of the independent binary variables of interest in the model is changed from one to zero randomly or zero to one depending on the interest of objectives. If the binary variable is changed from 0 to 1, a simulation is conducted randomly until all the variables have converged to the value of 1. It is also kept in consideration that the index first changed to one from zero was not changed in the second simulation. The simulation was done continuously until all the values were converged to one. Then the simulated value were then used in the earlier predicted model from equation 1 to get the new predicted probabilities for each outcome. The predicted probabilities for each outcome are predicted using the *predict()* function using R. Then, the new dependent variable is calculated as:

$$\hat{Y_i} = X_{i-1}^{i}\hat{\beta}_{i-1} + X_N^i\hat{\beta}_N \qquad (5)$$

Here, $\hat{Y_i}$ *is* the new estimated values for each household, $\hat{\beta}_N$ is the estimated parameter from equation 1 for the new value of an explanatory variable X_N^i. Equation 5 helps us to get new predicted probabilities of the outcomes using the function *predict ()* from R. The new estimated values can be calculated for each household *j* as:

$$Y_i' = \sum E_a * P_a^j \qquad (6)$$

Where, Y_i' is the new predicted dependent variable (i.e., climate change adaptation for each household *i*) and E_a is the event value of each outcome, and P_a^j is the probability of each outcome for each household *i*.

(A) Selection of Dependent Variables

The selection of the dependent variables is based on literature review and the National Adaptation Programme of Action (NAPA) (MoE, 2010). NAPA works mainly in adoption to climate change in sectors such as forestry, agriculture, water resources, and health in Nepal. Vulnerability to climate change is primarily due to temperature and precipitation-related issues (Gentle & Maraseni, 2012). The major adaptation strategies practiced by farmers include crop and farm diversification, water management, income diversification, varietal adjustments, fertilizer management, DSR, SRI, and flood control measures (Devkota et al., 2014; Dhungana et al., 2020; Karki et al., 2020; Regmi et al., 2022). Based on an in-depth literature review, ongoing adaptation policy set by NAPA (MoE, 2010), and discussion with agricultural officers from the study area, we selected the climate change adaptation practices used for the analysis. The climate change adaptation practices used in the study are varietal management, agronomic practices, land use/diversification, fertilizer use management, DSR, SRI, use of alternative energy options, and flood control measures. Depending on responses, practices were categorized into different degrees of adoption with the data ranging from zero level of adoption to a maximum where all adaptation practices were adopted.

(B) Selection of Independent variables

Independent variables were selected based on literature review and variables of interest to our study. Explanatory variables with expected signs are presented in Table 3.2. Details on the selection of each independent variable are presented below.

Households impacted by the COVID-19 pandemic that had migrant labor that returned home is a variable of concern since we are interested in the impact of COVID-19 on household climate change adaptation as demonstrated through this variable. Another group of variables that is of interest involves institutional factors: Extension, subsidy, internet, and membership status of farmer's groups or co-operatives. Various studies show that these institutional factors are instrumental in the adoption of climate change adaptation practices (Deressa et al., 2009a; Tazeze & Haji, 2012;Alauddin & Sarker, 2014; Ndamani & Watanabe, 2016; Regmi et al., 2022). Another group of variables (group c in Table 3.2) used in the modeling was household and socio-economic characteristics of the household (e.g., gender, size of the household, average age (migrant), farming experience, and off-farm income). The gender of the household head is seen to impact the adoption of climate change practices by the household (Marie et al., 2020) as shown by the literature, and we also expect the gender of the household to have a positive influence on the adoption of climate change adaptation practices. The size of the household is also an important variable which can play a role in the adoption of climate change practices (Bryan et al., 2009; Deressa et al., 2011). In a region where labor shortage is a factor reducing adaptation, household size would likely affect the adoption process, and we expect it to impact positively. Experience and off-farm income are also factors that impact the adoption of climate change practices (Obayelu et al., 2014; Regmi et al., 2022). Labor migration and the resulting change in demography is also considered a strategy for adoption to climate change in many areas (Mortreux & Barnett, 2009; Scheffran et al. ,2011; Afifiet al., 2016). As a result, migrant age is also considered as an independent variable.

Model estimation issues: Multicollinearity, Proportional Odds assumption, and endogeneity

In estimating the ordered logistic model, multicollinearity of the explanatory variables is tested by using variance inflation factors (VIF), which estimate how the variance of a regression coefficient is inflated by the existence of correlation among the explanatory variables (Mansfield & Helms, 1982a). Multicollinearity is a situation where the explanatory variables are highly correlated (Alin, 2010; Daoud, 2017). The high correlation between the variables results in a biased estimation (Wooldridge, 2015). The multicollinearity of the model was checked with the calculation of the variance inflation factors (VIFs) (Mansfield & Helms, 1982b) in R using the package *car* (Fox, J et al., 2012). Multicollinearity in the model is detected if the VIF is found to be greater than six (>6) for any of the explanatory variables used in the model. In our test, we did not find VIF values greater than 6 (Table C-1). As a result, multicollinearity was determined to not be a concern.

The proportional odds assumption in the ordered logit model assumes that the relationship between each pair of outcome groups is the same. The coefficient (β_i) that describes the relationship between the lower and higher categories must be the same as the coefficient that describes the relationship between the next lowest category and higher categories (Brant, 1990; Williams, 2006). The Brant test is used to check for the proportionality odds assumption of the model. Our model was checked for the proportionality odds assumption and the assumptions were not violated (Table C-2).

Similarly, another estimation issue that may arise while modeling is endogeneity. Endogeneity is the condition when the explanatory variables are correlated with the error term in the model (i.e., Cov (X_i^j, ε) ≠ 0) (Wooldridge, 2015). The problem of endogeneity results in a biased estimation of the parameter. We tested for endogeneity of the potential endogenous binary institutional factors. We also tested the endogeneity of the four variables representing access to institutional resources since they are decision variables that are potentially endogenous to the farmer's decision to adopt climate change adaptation practices. We used the Durbin–Wu–Hausman test with presence of farm machinery and education of household head as instrumental variables (IVs), respectively, for the test of endogeneity of access to agricultural government subsidy and internet. Also, number of the migrants in the family and education level of the migrant are used as IVs for the test of endogeneity of access to Extension service, and education of household head is used as an IV for the test of endogeneity of membership to farmers' organizations.

The validity of the IVs is tested by under-, weak- and over-identification tests. The under identification test evaluates if the instrument is not correlated with the potential endogenous regressor using the canonical correlation test (Anderson, 1951). The weak identification test evaluates if the instrument is weakly correlated with the potential endogenous regressor using the Stock and Yogo's weak identification statistics (Stock & Yogo, 2002). Sargen-Hansen's over-identification test evaluates if overidentifying restrictions are valid (Sargan, 1958). The result from the tests is presented in the appendix (Table C-3)

Another variable, livestock, which represents if the household has diversified their faming to rear livestock or not is also considered since it has been found to influence adaptation (Obayelu et al., 2014). Similarly, information regarding climate change is an important attribute for the adoption of climate change adaptation practices (Deressa et al., 2009b; Khanal, Wilson, Hoang, et al., 2018b; Regmi et al., 2022). However, it is important to understand people's confidence in this weather forecast information. As a result, we have selected the categorical variable household confidence in weather as an explanatory variable.

Table 3.2 Description of the variables used in the ordered logit model.

Variable	Description	Exp. Sign
A. Dependent variable		
Climate change adaptation	Ordered variable ranging from 0-7, 0 without any adaptation and 7 with maximum adoption	
B. Explanatory variables		
a. Institutional resource variable		
Subsidy	1, if the producer has received any form of agricultural Subsidy in the past two years, 0 otherwise	+
Extension	1, if the producer visited or contacted Extension agents in the past two years, 0 otherwise	+
Internet	1, if the producer has access to the internet, 0 otherwise	+
Membership status	1, if any household individual is a member of any farmer's organization (farmer's group or organization), 0 otherwise	+
b. Covid impact variable		
COVID impact	1 if the household has a COVID-19-triggered return of labor, 0 otherwise	+/-
c. Household demographic variable		
Off-farm income	1, if the household head has income from another source except for farm, 0 otherwise	+
Size of Household	Total number of the household members	+
Average Age	The average age in years of the migrant members of households	+/-
Farming Experience	Producer's years of farming experience	+
Gender	1, if the head of the household is male, 0 otherwise	+/-
d. Farm Characteristics variable		
Livestock	1, if the household has livestock, 0 otherwise	+/-
e. Others		
Household confidence on weather	The belief of household head on weather forecast information, 1 if low belief, 2 if medium and 3 if high	+

3.6 Descriptive Statistics from Survey

Table 3.3 presents the descriptive statistics for the producer's household, socio-demographic, farm characteristics, access to institutional factors, and other related explanatory variables.

A. Institutional resource variables

Subsidy

Among the survey respondents, agricultural subsidies were available to only 16% of the population. The rest of the respondents did not receive any form of an agricultural subsidy. The agricultural subsidies offered to farmers are for pesticide sprayers, tractors, seeds, fertilizer, irrigation, post-harvest facilities (cold storage, grain storage bins) and other land preparation equipment (spades, crow bars). The rest of the respondents did not receive any form of an agricultural subsidy. 41% of the respondent farmers preferred fertilizer if a subsidy was provided. For smallholder farmers with limited adaptive capacities, having access to subsidies helps reduce their financial burden. This would help farmers increase their resilience against climate change by better adapting to it.

Extension

Among the survey respondents, access to Extension was also found to be incredibly low. Only 22.51% of producers had any sort of access to an Extension service. It was evident that producers who lived within proximity to an Extension office had availed themselves of their services when compared to producers who lived farther from the Extension office. Extension is a dynamic concept. An Extension service is a way of providing informal education to the rural population or farmers, solving their problems, and increasing the efficiency of farmers. The objective of Extension is to provide insight regarding problems facing farmers and to provide solutions to overcome these problems.

Internet

Access to internet improves access to information. The internet can provide information related to climate and technologies of interest to farmers. With the availability of smart devices, the internet has reached many farmers. Among the respondents, 58.87% had access to the internet for information. While internet accessibility is good, many producers used the internet to connect with family and friends as well as for entertainment purposes. Very few farmers used the internet to track weather, prices of inputs, market for outputs or newer technologies or advanced practices. Using the internet also requires basic literacy and digital literacy, i.e., knowledge of the basics of the device (telephone, smartphone) as well as an understanding of the content to search for and where to look on the internet. Additional training on basic literacy and digital literacy can enhance internet use to improve farming practices and adaptation to climate change.

Membership status

An important institutional factor for the adoption of climate change adaptation is being a member of a farmer's group or co-operative. Being a member of a group helps the farmers in several ways such as receiving financial help, information, networking opportunities with other farmers to learn from each other and understand newer technology and upcoming innovative practices. 44.15% of the respondents surveyed were found to be a member of a farming co-operative or group.

B. Covid impact variable

COVID Impact

Household impacted by COVID-19 is defined as a dummy variable with the value of 0 and 1 with 0 representing households which do not have any migrant members returning to the household during COVID-19 pandemic and 1 representing households with at least one family migrant returning to the household during the COVID-19 pandemic. Among the respondents, 27.27 % of households were found to be impacted by COVID-19. Due to COVID-19, these households had a migrant member return to the household.

C. Household demographic variables

Off-farm income

Off-farm income provides households with financial flexibility. If the household head has off-farm income, then he has a greater probability of climate change adaptation. On average, 23% of household heads in the survey area had off-farm income.

Size of the household

The size of the household in the survey area ranged from 2 to 24 members. The family type was found to be nuclear or joint. The average household size in the survey area was found to be 6.24. The size of the household acts as a source of labor supply in agriculture. The larger the size of the household, the higher the availability of labor. Household size is seen to influence the adoption of climate change adaptation practices by households.

Average Age

Labor migration and the resulting change in demography of the household is an adaptation strategy to cope with climate change. Most of the people involved in labor migration for foreign contract work are on average 22 years old. Young people of age 17.5 years to elderly people of age 56 years were involved in foreign migration for work.

Farming Experience

Experience is a key factor that impacts the adoption of climate change strategies by smallholder producers. With greater experience, farmers have more information and knowledge. The experience of farmers in the survey area ranged from no experience to experience of up to 60 years. The average experience of respondents was found to be 28.69 years.

Gender

Literature shows that, in developing countries, the gender of the household head plays a key role in any household decision-making. Around 65% of the household respondents had a male as a household head. This shows that male-dominated households were predominant in the area.

D. Farm characteristic variable

Livestock

Possessing livestock is seen as diversifying the household's source of income. Diversification is seen as a strategy to cope with climate change. Among the respondents in the survey area, 83% had livestock on their farms.

E. Others

Household confidence on weather

Information on the climate is a principal factor to have for producers to adapt to climate change. In addition, the degree of trust the farmers have in climate change information and weather forecasts is important. In the survey area, the confidence of farmers in weather forecasts is 1.84 which is slightly below medium on a 1 to 3 scale.

Table 3.3 Summary statistics of respondent's explanatory variables (n=231)

Variable	Minimum	Maximum	Mean	Standard Deviation
a. Institutional resource variable				
Subsidy	0	1	0.16	0.37
Extension	0	1	0.23	0.42
Internet	0	1	0.59	0.49
Membership status	0	1	0.44	0.50
b. Covid impact variable				
COVID Impact	0	1	0.27	0.45
c. Household demographic variable				
Off-farm income	0	1	0.23	0.42
Size of Household	2	24	6.24	2.93
Average Age	17.5	56	34.22	8.77
Farming Experience	0	60	28.69	15.37
Gender	0	1	0.65	0.48
d. Farm Characteristic variable				
Livestock	0	1	0.83	0.38
e. Others				
Household confidence on weather	1	3	1.84	0.74

CHAPTER FOUR
RESULTS AND DISCUSSION

This section describes the results of the analysis. The results and discussion section includes descriptive statistics from the survey and parameter estimates (along with associated marginal effects) of explanatory variables impacting climate change adaptation of farmers from an ordered logistic regression model. Marginal effects help us to understand how relaxing one unit of an explanatory variable used in the model changes the climate change adaptation of farmers. This section also includes how changes in the accessibility of institutional factors (e.g., Extension, subsidy) to farmers and a post-pandemic labor scenario impact the climate change adaptation of farmers from the current baseline position.

4.1. Adoption to climate change adaptation in the study area

The farmers in the study area adopted various practices to cope with the changing climate. The adaptation practices adopted by the farmers in these areas are listed below:

a. Varietal Management

The farmers in this region were found to use different varieties to adapt to climate change adaptation practices. Farmers were found to grow drought-tolerant varieties, short-duration varieties, diseases resistance varieties, and hardy varieties. Major varieties of rice grown by farmers are *Ranjit, Basmati, Sabitri, Masino, Ramdhan, Kanchi,* and *Thulo Musli.* The farmers also grow hybrid varieties such as *Radha-12, Kanchi HYV,* and *Radha-11.*

b. Agronomic practices

Smallholder farmers also managed their agronomic practices to cope with climate change. Farmers were found to harvest later and adapted to rotate crops. Some farmers who adopted crop rotation were found to plant rice-maize-wheat in the first year and then replace wheat or maize with beans or mustard the following year. Depending upon the monsoon, they also adjusted their planting time. If the monsoon was late the previous year, then they would plant late the following year. Additionally, farmers also adopted the technique of zero tillage to conserve soil.

c. Land use diversification

Another adaptation practice adopted by farmers was land use diversification. Here, the farmers were found to diversify their land to diversify their source of income. The farmers diversified their land and used it for growing fruit crops from normal cereal crops and used it also for rearing livestock such as goats, pigs, poultry, and for fisheries.

d. Integrated Pest Management

Integrated Pest Management (IPM) is an environmentally friendly technique to control pests and diseases using the combination of different plant and animal products. The Nepal Government accepted IPM as a plant protection program in 1990 (Kafle et al., 2014). In the study area, only 4.61% of farmers adopted IPM to control disease and pests. Major reasons for not adopting this were lack of knowledge of existing IPM techniques and farmers who knew about the practice but lacked technical knowledge to implement it.

e. Changing the dosage of chemicals

To cope with the impacts of climate change, farmers in our study area changed their dose of chemical fertilizers used. In the study area, 298 of 434 farmers have adopted the technique of increasing the dosage of chemical fertilizers, and 30 of them have adopted the technique of decreasing the number of chemical fertilizers used. The remaining 106 farmers neither increased nor decreased the dose of chemical fertilizers. Many farmers in various regions of the world have used chemical fertilizers as a way to adapt to climate change (Fadina & Barjolle, 2018; Kurgat et al., 2020).

f. Change in pesticide use

Along with the change in the dosage of the chemical fertilizers, farmers in our study were found to change the use of pesticides. 309 out of 434 farmers from our survey were found to increase the usage of pesticides, 27 were found to decrease the usage of pesticides, and 98 of them did not change their dose of pesticide used. Farmers in the study regions and other regions of the world have adopted change in pesticide use as a way to mitigate the impacts of climate change (Atube et al., 2021; Fadina & Barjolle, 2018). Climate change is thought to impact the interaction between pathogens and crops. This interaction increases the frequency and intensity of different diseases (Topolovec-Pintaric, 2020). Thus, change in pesticide use is a technique or adaptation practice to tackle climate change.

g. Direct-seeded rice (DSR)

With DSR, the rice seed is sowed directly in the field without transplanting form a nursery (E. Joshi et al., 2013). Direct-seeded rice is adapted mainly in low irrigation areas to mitigate the impacts of climate change (E. Joshi et al., 2013; Regmi et al., 2022). In the study area, only 12 of 434 farmers adopted the technique of direct-seeded rice. Most of the farmers surveyed did not have knowledge of DSR techniques, and those who knew had not adopted the practice.

h. System of Rice Intensification (SRI)

SRI is a modern technique for increasing the yield of rice where the rice seedlings are planted singly rather than in clumps in a certain scientific spacing (Dobermann, 2004). Farmers in the Hindu-Kush Himalaya region have used SRI as a technique to adapt to climate change. However, adoption is extremely low because smallholder farmers do not have awareness of this technique, and those who knew lack the technical knowledge to implement it. Only 3% of farmers in this region were found to have used SRI in their fields.

i. Alternative source of energy

Farmers in the study area practically did not use any alternative energy sources. The primary alternative source of energy used by farmers in this region was solar energy. They did not use any other source such as wind energy. Only 3% of farmers utilized solar energy. The alternative source of energy was used by farmers for irrigation as well as the day-to-day activities of the household. The major reason for not adopting alternative sources of energy was the excessive cost associated with it.

j. Flood control measures

In our study area, flooding was one of the fundamental issues faced by farmers during monsoon season. Being near the Koshi river basin made farmers more prone to flooding. Even though it was a major issue, only 12.44% of farmers were found to have adopted flood control measures. The low rate of adoption of flood control measures was due to prohibitive costs. Also, it was found that farmers who experienced floods in the past felt that the losses due to flooding is extremely high. As a result, farmers preferred not to adopt.

4.2 Factors affecting the intensity of climate change adaptation practices.

The producers in the study area adopted multiple adaptation practices. However, adoption intensity varied among farmers. To understand intensity of adoption, we used ordered logit regression. The results of the ordered logit model are presented in Table 4.1. The table presents parameter coefficients and marginal effects. The values for the marginal effect and threshold parameters for farmers who adopted six climate change adaptation practices are not available. This is because none of the farmers chose six climate change adaptation practices. The distribution of adoption of climate change adaptation strategies is presented in Figure B-2. The Likelihood ratio chi-squared statistic for the model was found to be 71.55 with a probability less than 0.001 indicating that the model has an overall good fit.

Out of the 12 explanatory variables used in the model, seven variables were found to significantly impact the intensity of climate change adaptation practices by farmers. Household members returning to the household during the COVID-19 pandemic was found to impact the adoption of climate change adaptation practices positively and significantly at a 1 % level of significance. The positive impact of COVID-19 on the household is a result of additional labor supply for the household. Laborers who returned during the pandemic have relatively higher education levels as compared to the average dependent household member (Kharel et al., 2022). Additionally, laborers working in Gulf countries work in a diverse group of semi-skilled to unskilled jobs and are more accustomed to technologies.

Access to subsidy and Extension were seen to impact positively and significantly at a 1% level of significance the climate change adaptation practices of farmers. There are similar studies that found Extension has a positive and significant impact on the adoption of climate change practices (Bedeke et al., 2019b; Ojo & Baiyegunhi, 2020; Regmi et al., 2022). Extension services are the main source of information for farmers in these areas. Any innovation, modern technology, hybrid seeds, and other information is known to farmers primarily through Extension services. In addition to information, informal training, or use of instruments/technologies by farmers are learned through Extension agents. Furthermore, even if the farmers are aware of climate change and its impact, most smallholder farmers in developing countries do not have the financial support to adapt and mitigate. As a result, a subsidy is required by farmers to better adapt (Chandio et al., 2021). Similarly, another institutional factor, access to the internet, was found to impact positively and significantly at a 5% level of significance. The Internet also acts as a source of information for farmers. Having access to the internet helps smallholder farmers get proper information and knowledge related to modern technologies. Membership in farmer's groups, co-operatives, or any other organization did not impact the farmers' adoption of climate change adaptation practices.

The coefficient of the parameter only explains the direction of impact, positive and negative, but not the magnitude of impact. As a result, to calculate the magnitude of impact, we calculated marginal effects. With other variables remaining constant, a unit increase in access to subsidy decreases the likelihood of low intensity adoption (one and two) of climate change adaptation practices significantly by 17.4% and 11% respectively and increases the likelihood of high intensity adoption (three, four, and five practices) by 14%, 12.7% and 2.4% respectively. Similarly, having access to one additional unit of Extension services significantly decreases the likelihood of low intensity adoption (one and two practices) by 20.5% and 13.1% respectively. On the other hand, Extension significantly increases the likelihood of high intensity adoption (three, four, and five practices) by 16.5%, 15%, and 2.9% respectively. Additionally, increasing access to the internet by one more unit significantly decreases the likelihood of low intensity adoption (one and two practices) by 7.5% and 4.8% respectively. However, a one unit increase in access to the internet significantly increases the likelihood of high intensity adoption (three, four, and five practices) by 6%, 5.4%, and 1% respectively. As the likelihood of one category increases the likelihood of adoption of other categories decreases and the total marginal effect of all the categories sum up to zero.

Out of five socio-demographic variables used, only off-farm income and gender were found to be significant. Both off-farm income and gender were found to be positively significant at a 10% level of significance. Most of the families in the study area are patriarchal and decisions of the household are mostly made by males. Similar findings of male household head impacting positively climate change adaptation were found by Legesse et al. (2013) and Deressa et al.

(2011) in their study in Ethiopia. Off-farm income is a source of additional income for the family. Having an additional source of income reduces the financial pressure placed on the household. The availability of extra funds then can be used in the adoption of climate change adaptation practices. Khanal & Wilson's (2019) research also found similar findings of off-farm income positively impacting climate change adaptation. Other variables such as size of the household, experience, and average age were not found to be significant at any level.

Households that had livestock had a positive and significant impact on the adoption of climate change adaptation practices. Livestock such as cattle, buffalo, pigs, poultry, and duck were reared by farmers in the study area. The farmers had diversified themselves to livestock rearing by cutting their land use from agriculture to livestock. Another variable, confidence of the household in weather forecast information, was not found to be significant.

Another variable of interest, household impacted by COVID-19, was found to impact climate change adaptation significantly. With other variables remaining constant, if a household has labor return triggered by COVID-19, then the household is less likely to adopt low-intensity climate change adaptation (one and two practices) by 8.3% and 5.2% respectively. If the household has labor return triggered by COVID-19, then the household is more likely to adopt high-intensity climate change adaptation (three, four, and five practices) by 6.6%, 6.0%, and 1.2% respectively, ceteris paribus.

If a household has off-farm income, then the household is less likely to adopt the low-intensity category of one and two practices by 7.6%, and 4.8% respectively. On the other hand, the household is more likely to adopt the high-intensity category of three and four practices by 6.1% and 5.5% respectively. If the household head is male, then the likelihood of adopting one practice decreases by 7.1%. Conversely, other variables remaining constant, if the household head is male, then the adoption of three and four practices increases by 5.7%, and 5.2% respectively.

Similarly, keeping other variables constant, if the household rears livestock, then the likelihood of adopting the low category of one and two practices decreases by 9.8% and 6.2% respectively. On the other hand, the likelihood of adoption increases by 7.9%, 7.2%, and 1.4% respectively for three, four, and five practices, respectively, if the household rears livestock.

4.3 Predicted estimation of climate change adaptation over a change in Extension, Subsidy, and Household impacted by COVID-19

The age of migrant laborers ranged from 17.5 years to 56 years. All the returned laborers are predominantly of the working class and could return to temporary contract work if they could. The households impacted by COVID-19 is a temporary phenomenon. Once the COVID-19 situation stabilizes, the labor force may be able to resume their overseas work activities. If the labor force resumes their work, then the current baseline of climate change adaptation practices would decrease as the household is impacted by COVID-19. Access to the current Extension and subsidy can increase the climate change adaptation of smallholder farmers. Access to these institutional factors can be increased to complement the gap that will be created if the returning household labor returns to work.

Table 4.3 explains the change in the climate change adaptation practices of the household with increase in the accessibility to Extension during assumed post-pandemic labor situation. In Figure 4.1, the Y-axis represents the additional increase in access to Extension, the X-axis represents the number of returning migrants going back to work, and the color gradient graph represents the predicted value of climate change adaptation practices. The value of the color gradient graph increases from green to red and ranges from 2.353 to 3.043. At the baseline, the climate change practice value is 2.435. If all the households who had returned during COVID-19 got back to work, then the climate change adaptation practices would reduce to 2.353, *ceteris paribus*. If no migrant returns to work and all the households surveyed had access to Extension, then climate change adaptation increases to 3.043. The highest value of climate change adaptation (3.043) would be in a situation where none of the returning migrants return to work and all households have access to Extension services.

Table 4.1 Parameter estimates and marginal effects of ordered logit model

			Marginal effect						
Explanatory variables	Coef.	St. Err	Prob (Y=0|X)	Prob (Y=1|X)	Prob (Y=2|X)	Prob (Y=3|X)	Prob (Y=4|X)	Prob (Y=5|X)	Prob (Y=7|X)
Institutional resource variable									
Subsidy	1.195**	0.383	-0.010	-0.174**	-0.110*	0.140**	0.127**	0.024*	0.002
Extension	1.413**	0.344	-0.011	-0.205**	-0.131**	0.165**	0.150**	0.029*	0.003
Internet	0.515*	0.257	-0.004	-0.075*	-0.048	0.060	0.054	0.010	0.001
Membership status	0.239	0.262	-0.002	-0.035	-0.022	0.028	0.025	0.005	0.000
Covid impact variable									
COVID impact	0.568*	0.283	-0.005	-0.083*	-0.052	0.066	0.060	0.012	0.001
Household demographic variable									
Off-farm income	0.521	0.291	-0.004	-0.076	-0.048	0.061	0.055	0.011	0.001
Size of household	0.057	0.041	0.000	-0.008	-0.005	0.006	0.006	0.001	0.000
Average Age	-0.010	0.015	0.000	0.002	0.000	-0.001	-0.001	0.000	0.000
Farming Experience	-0.002	0.008	0.000	0.000	0.000	-0.000	-0.000	0.000	0.000
Gender	0.488	0.280	-0.004	-0.071	-0.045	0.057	0.052	0.010	0.001
Farm characteristics variable									
Livestock	0.673*	0.341	-0.005	-0.098	-0.062	0.079	0.072	0.014	0.001
Others									
Household confidence on weather	-0.091	0.179	0.001	0.013	0.008	-0.010	-0.010	-0.002	0.000
Threshold/cut points									
0|1	-2.969*	0.965							
1|2	0.383	0.800							
2|3	2.101*	0.810							
3|4	3.560**	0.834							
4|5	5.598**	0.913							
5|7	8.102**	1.329							

LR chi2(12): 71.55 **Prob > chi2 : 0.000.** **BIC: 734.19** **AIC: 672.23**
Log-Likelihood: -318.11 **Deviance: 636.23** **Num. obs.: 231**

** and * refers to significance at 1%, and 5% levels, respectively

Note: We do not have results for Prob(Y=6|X) because we did not have farmers adoption 6 climate change adaptation practices.

Table 4.2 Change in Climate change adaptation practices of farmers due to change in post pandemic labor scenario and accessibility to Extension services.

		Post-pandemic labor scenario (number of farmers with their household members returned from foreign employments)							
		0	**10**	**20**	**30**	**40**	**50**	**60**	**63**
Increase in accessibility to Extension	**20**	2.50	2.49	2.48	2.46	2.45	2.44	2.42	2.42
	40	2.57	2.56	2.54	2.53	2.52	2.50	2.49	2.49
	60	2.64	2.62	2.61	2.60	2.59	2.57	2.56	2.55
	80	2.71	2.69	2.68	2.67	2.65	2.64	2.62	2.62
	100	2.77	2.76	2.75	2.73	2.72	2.71	2.69	2.69
	120	2.84	2.83	2.82	2.80	2.79	2.78	2.76	2.76
	140	2.91	2.90	2.88	2.87	2.86	2.84	2.83	2.82
	160	2.98	2.96	2.95	2.94	2.92	2.91	2.89	2.89
	179	3.04	3.03	3.02	3.00	2.99	2.97	2.96	2.95

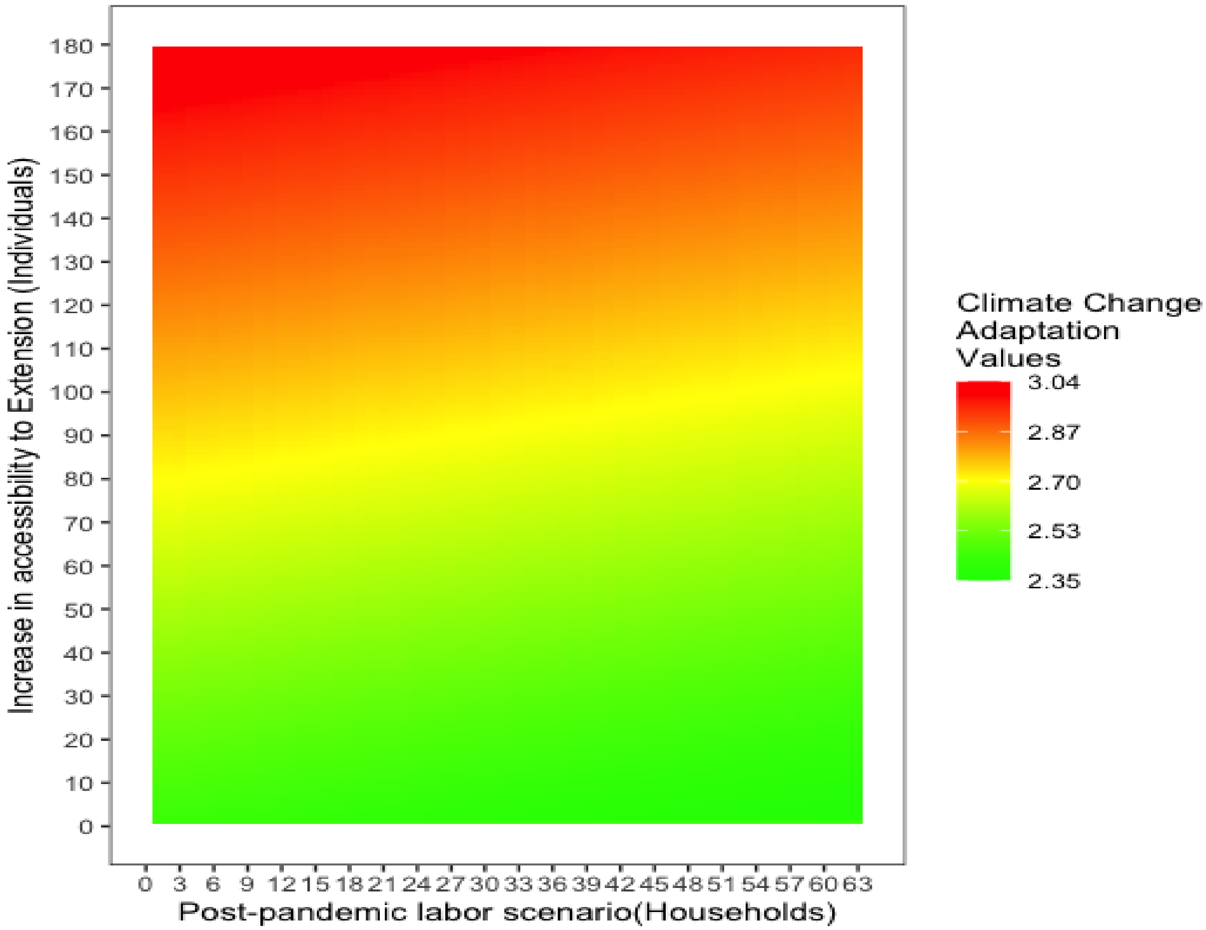

Figure 4.1 Climate change adaptation due to change in access to Extension and Household Impacted

Table 4.3 Change in Climate change adaptation practices of farmers due to change in post-pandemic labor scenario and accessibility to agricultural subsidy.

		Post-pandemic labor scenario (number of farmers with their household members returned from foreign employments)							
		0	**10**	**20**	**30**	**40**	**50**	**60**	**63**
Increase in accessibility to agricultural government subsidy	**20**	2.49	2.48	2.47	2.45	2.44	2.43	2.41	2.41
	40	2.55	2.54	2.53	2.51	2.50	2.48	2.47	2.46
	60	2.61	2.59	2.58	2.57	2.55	2.54	2.53	2.52
	80	2.66	2.65	2.64	2.63	2.61	2.60	2.58	2.58
	100	2.72	2.71	2.68	2.68	2.67	2.65	2.64	2.64
	120	2.78	2.76	2.75	2.74	2.73	2.71	2.70	2.69
	140	2.84	2.82	2.81	2.80	2.78	2.77	2.76	2.75
	160	2.89	2.88	2.87	2.85	2.84	2.83	2.81	2.81
	180	2.95	2.94	2.92	2.91	2.90	2.88	2.87	2.86
	194	2.99	2.98	2.96	2.95	2.94	2.92	2.91	2.90

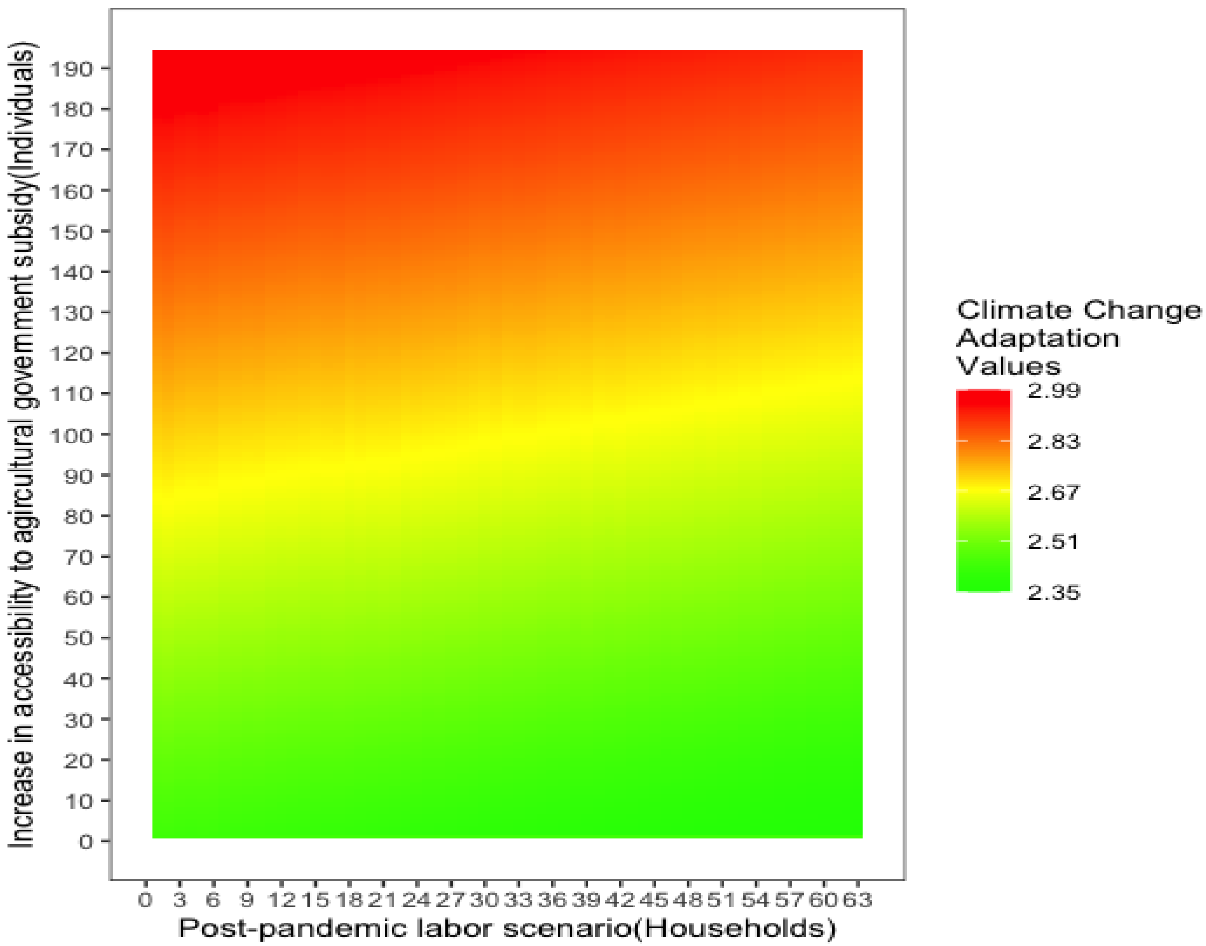

Figure 4.2 Climate change adaptation due to change in access to Subsidy and Household Impacted

In Figure 4.2, the Y-axis represents the additional increase in access to agricultural subsidy, the X-axis represents the number of returning migrants returning to work, and the color gradient graph represents the predicted value of climate change adaptation practices. The value of the color gradient graph increases from green to red and ranges from 2.352 to 2.99. At the baseline, the climate change practice value is 2.435. If all the households who had returned during COVID-19 got back to work, then climate change adaptation practices would be reduced to 2.352, *ceteris paribus*. If no migrants return to work and all households surveyed had access to a subsidy, then climate change adaptation would increase to 2.99. The highest value of climate change adaptation (2.99) would be in a situation where none of the returning migrants get back to work and all the households have access to a subsidy. Table 4.4 also provides details on the change in climate change adaptation of farmers due to an increase in accessibility to agricultural government subsidy during assumed post pandemic labor scenarios.

Overall, climate change adaptation would likely decrease if the returning migrants returned to work overseas, and adaptation would increase if and only if access to Extension and a subsidy is increased. The adaptation value is highest when there is complete access to Extension and a subsidy with no migrants returning to work. The lowest value is when there is no increase in access to Extension and a subsidy for all the people who returned during COVID returning to work. However, the impact of Extension on climate change adaptation is greater compared to access to subsidies.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

This chapter describes a summary of the conclusions, recommendations, policy implications, limitations of the study, and potential future research areas. This study revealed that the household that had labor return triggered by COVID-19 led to the adoption of climate change adaptation practices. Similarly, institutional factors were also instrumental in the adoption of climate change adaptation practices. In the post-pandemic labor scenario if the laborers return to their job overseas, a decrease in climate change adaptation practices is expected, and this decrease in the adaptation could be mitigated by increasing access to Extension services and agricultural subsidies.

(A) Summary and Conclusions

COVID-19 has impacted many sectors. Agriculture and the labor market are a few of the many sectors that are impacted by COVID-19. Loss of jobs and reduced working hours have forced Nepalese migrants to return to their homeland from foreign countries. This return has caused a temporary increase in the labor supply of the market. Additionally, these returning laborers are relatively young, better educated, and used to technology as compared to general households. This influx of labor has impacted the climate change adaptation of smallholder farmers.

By testing the impact of households affected by COVID-19 on climate change adaptation practices, we found that households with labor returning during the COVID-19 pandemic positively and significantly impacted the climate change adaptation of households. Climate change adaptation of the household is also positively and significantly impacted by institutional factors (e.g., access to Extension, agricultural subsidy, and the internet). Additionally, variables such as off-farm income, gender, and livestock ownership were also found to affect the adoption of climate change measures positively and significantly. Furthermore, after a certain time, the impact of COVID-19 is assumed to be diminished and migrant workers will likely be able to return to work overseas. The analysis also shows that climate change adaptation would decrease if the workers began returning to their foreign jobs. To offset this, greater access to institutional factors (e.g., Extension and subsidies) can be used to increase adoption of adaptation practices. The impact of the adoption of climate change adaptation practices is higher for Extension as compared to the agricultural subsidy. If there is one unit increase in the accessibility of Extension services, it is associated with 20.5% and 13.1% less likelihood to be adopting one or two climate change adaptation practices. However, the one-unit increase is associated with 16.5%, 15% and 2.9% higher likelihood to be adopting three, four and five climate change adaptation practices, respectively. On the other hand, one unit increase in subsidy is associated with 17.4% and 11% less likelihood to be adopting one and two climate change adaptation practices, respectively but 14%, 12.7% and 2.4% more likely to be in category three, four and five climate change adaptation practices, respectively.

(B) Policy Implications

Based on findings from the study, the following policy implications are suggested.

a. Institutional factors improve climate change adaptation practices. Since there is extremely low access to Extension (23%) and subsidies (37%) as shown in the study area, increasing additional access to Extension and subsidies would improve adaptation. Effective Extension and subsidy programs that almost all farmers are aware and informed about could increase access to Extension and subsidies, thus improving climate change adaptation.
b. Those farmers who are in better financial conditions have a higher likelihood of adopting climate change adaptation practices. Those farmers who are poor and have no diverse source of income are more vulnerable to climate change. Policy relevant to diversifying the source of income other than farm income can help these vulnerable farmers better adopt climate change adaptations.
c. The impact of access to Extension on adoption is greater than the impact of access to subsidies. As a result, priority should be given to Extension over subsidies. For example, if an institute has limited funds and is deciding between investing in Extension services or subsidies, then priority should be given to increasing access to Extension. Extension services such as delivering information on new agricultural technologies, also not only

modern technologies but an information on scientific ways of farming would be a lot of help.

d. Extension and agricultural subsidies both are important. If priority is to be given to the implementation of subsidies, it requires a substantial investment. Coordination between international and national organizations would be beneficial to improve access to subsidies. This study emphasized how important subsidies are for the adoption of climate change adaptation. So, identifying and prioritizing agricultural subsidies such as fertilizers, rice varieties, irrigation, and farm machineries could help better adaptation.

e. As households impacted by COVID-19 have greater adoption, it can be inferred that the resulting additional increase in labor improves adaptation. As a result, government policy to make labor more easily available will improve adaptation. For example, making the laborers in the area aware of the high labor demand during the cropping season, so that the laborers do not migrate to other places for work during the cropping season. Also, bringing laborers from the less intensive agricultural neighboring district during the cropping season would be beneficial.

(C) Limitations of the study and Future Research Areas

The study was limited by various constraints. Following time and budget constraints, we were able to collect data from only the municipalities of *Sunsari* district which falls in the *Terai* geographical region of Nepal. We were not able to cover other geographical regions of Nepal and other HKH regions. Other relevant variables to our model such as remittance are not included in the model because of the respondent's unwillingness to share such sensitive information. Also, there is possible motivational bias in the study. Households potentially assumed that if they answered negatively on some questions, then they may not receive subsidies in the future. For example, if they responded they had not received any training, then the producer perceived they could potentially receive training after the survey.

Future research should focus on encompassing more districts in Nepal. Also, we found very few households had received subsidies, Extension, and training. Examining the factors that impact access to institutional factors may be a key area of research in the future. For example, studies examining factors impacting access to a subsidy for small farmers with variables of interest of household approach to government office, household members in the government office, and distance to government officials could get significant results to improve institutional factors. Furthermore, there are many climate change adaptation strategies adopted by smallholder farmers, but they are not able to use them efficiently. As a result, a study focusing on geography-based priority climate change adaptation to smallholder farmers can help producers better adapt to climate change on limited financial resources. Additionally, we did not take into consideration the legacy effect. The farmers might continue to adopt adaptation practices even after the post-pandemic scenario if they see benefit. So, following up the study with panel data in future could also help understand the legacy of adoption as well.

LIST OF REFERENCES

Afifi, T., Milan, A., Etzold, B., Schraven, B., Rademacher-Schulz, C., Sakdapolrak, P., Reif, A., van der Geest, K., & Warner, K. (2016). Human mobility in response to rainfall variability: Opportunities for migration as a successful adaptation strategy in eight case studies. *Migration and Development*, *5*(2), 254–274. https://doi.org/10.1080/21632324.2015.1022974

Alamgir, M., Mohsenipour, M., Homsi, R., Wang, X., Shahid, S., Shiru, M., Alias, N., & Yuzir, A. (2019). Parametric Assessment of Seasonal Drought Risk to Crop Production in Bangladesh. *Sustainability*, *11*(5), 1442. https://doi.org/10.3390/su11051442

Alauddin, M., & Sarker, M. A. R. (2014). Climate change and farm-level adaptation decisions and strategies in drought-prone and groundwater-depleted areas of Bangladesh: An empirical investigation. *Ecological Economics*, *106*, 204–213. https://doi.org/10.1016/j.ecolecon.2014.07.025

Ali, A., & Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management*, *16*, 183–194. https://doi.org/10.1016/j.crm.2016.12.001

Alin, A. (2010). Multicollinearity. *WIREs Computational Statistics*, *2*(3), 370–374. https://doi.org/10.1002/wics.84

Anderson, T. W. (1951). Estimating linear restrictions on regression coefficients for multivariate normal distributions. *The Annals of Mathematical Statistics*, 327–351.

Aryal, J. P., Sapkota, T. B., Rahut, D. B., Marenya, P., & Stirling, C. M. (2021). Climate risks and adaptation strategies of farmers in East Africa and South Asia. *Scientific Reports*, *11*(1), Article 1. https://doi.org/10.1038/s41598-021-89391-1

Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Alarakol, S. P., & Okello-Uma, I. (2021). Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agriculture & Food Security*, *10*(1), 6. https://doi.org/10.1186/s40066-020-00279-1

Bajracharya, S. R., Shrestha, B. R., International Centre for Integrated Mountain Development, & Sweden (Eds.). (2011). *The status of glaciers in the Hindu Kush-Himalayan region*. International Centre for Integrated Mountain Development.

Barnett, J., & Adger, W. N. (2018). Mobile worlds: choice at the intersection of demographic and environmental change. *Annual Review of Environment and Resources*, *43*, 245-265.

Bedeke, S., Vanhove, W., Gezahegn, M., Natarajan, K., & Van Damme, P. (2019). Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. *NJAS - Wageningen Journal of Life Sciences*, *88*, 96–104. https://doi.org/10.1016/j.njas.2018.09.001

Borrelli, P., Robinson, D. A., Panagos, P., Lugato, E., Yang, J. E., Alewell, C., Wuepper, D., Montanarella, L., & Ballabio, C. (2020). Land use and climate change impacts on global soil erosion by water (2015-2070). *Proceedings of the National Academy of Sciences*, *117*(36), 21994–22001. https://doi.org/10.1073/pnas.2001403117

Bossavie, L., & Denisova, A. (2018). *Youth Labor Migration in Nepal* [Working Paper]. World Bank. https://doi.org/10.1596/29682

Brant, R. (1990). Assessing Proportionality in the Proportional Odds Model for Ordinal Logistic Regression. *Biometrics*, *46*(4), 1171–1178. https://doi.org/10.2307/2532457

Bryan, E., Deressa, T. T., Gbetibouo, G. A., & Ringler, C. (2009). Adaptation to climate change in Ethiopia and South Africa: Options and constraints. *Environmental Science & Policy*, *12*(4), 413–426. https://doi.org/10.1016/j.envsci.2008.11.002

Central Bureau of Statistics. (2014). "National Population and Housing Census 2011". Government of Nepal.

Central Bureau of Statistics. (2021). "National Census 2021 Preliminary Results". Kathmandu: Government of Nepal.

Chandio, A. A., Jiang, Y., Ahmad, F., Adhikari, S., & Ain, Q. U. (2021). Assessing the impacts of climatic and technological factors on rice production: Empirical evidence from Nepal. *Technology in Society*, *66*, 101607. https://doi.org/10.1016/j.techsoc.2021.101607

Chaudhry, Q. U. Z. (2017). *Climate Change Profile of Pakistan*. Asian Development Bank.

Daoud, J. I. (2017). Multicollinearity and Regression Analysis. *Journal of Physics: Conference Series*, *949*(1), 012009. https://doi.org/10.1088/1742-6596/949/1/012009

Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science*, *149*(1), 23–31. https://doi.org/10.1017/S0021859610000687

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, *19*(2), 248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002

Devkota, R. P., Cockfield, G., & Maraseni, T. N. (2014). Perceived community-based flood adaptation strategies under climate change in Nepal. *International Journal of Global Warming*, *6*(1), 113–124. https://doi.org/10.1504/IJGW.2014.058758

Dhakal, B. N., & Khanal, N. R. (2018). Causes and Consequences of Fragmentation of Agricultural Land: A Case of Nawalparasi District, Nepal. *Geographical Journal of Nepal*, *11*, 95–112. https://doi.org/10.3126/gjn.v11i0.19551

Department of Hydrology and Meteorology (DHM), Kathmandu, Nepal (2017). Observed Climate Trend Analysis in the Districts and Physiographic Regions of Nepal (1971-2014).

Department of Hydrology and Meteorology (DHM), Kathmandu, Nepal (2018). Annual Weather Summary of 2014

Dhungana, N., Silwal, N., Upadhaya, S., Khadka, C., Regmi, S. K., Joshi, D., & Adhikari, S. (2020). Rural coping and adaptation strategies for climate change by Himalayan communities in Nepal. *Journal of Mountain Science*, *17*(6), 1462–1474. https://doi.org/10.1007/s11629-019-5616-3

Dobermann, A. (2004). A critical assessment of the system of rice intensification (SRI). *Agricultural Systems*, *79*(3), 261–281. https://doi.org/10.1016/S0308-521X(03)00087-8

Draper, J. (2022). Labor Migration and Climate Change Adaptation. *American Political Science Review*, *116*(3), 1012–1024. https://doi.org/10.1017/S0003055421001313

Fadina, A. M. R., & Barjolle, D. (2018). Farmers' Adaptation Strategies to Climate Change and Their Implications in the Zou Department of South Benin. *Environments*, *5*(1), Article 1. https://doi.org/10.3390/environments5010015

Feinstein, N. W., & Mach, K. J. (2020). Three roles for education in climate change adaptation. *Climate Policy*, *20*(3), 317–322. https://doi.org/10.1080/14693062.2019.1701975

Fox, J, Weisberg, S, Adler, D, Bates, D, & Baud-Bovy, G., Ellison, S., ... & Monette, G. (2012). *Package 'car.' 16*, 16.

García de Jalón, S., Iglesias, A., & Neumann, M. B. (2018). Responses of sub-Saharan smallholders to climate change: Strategies and drivers of adaptation. *Environmental Science & Policy*, *90*, 38–45. https://doi.org/10.1016/j.envsci.2018.09.013

Gebremariam, G., & Tesfaye, W. (2018). The heterogeneous effect of shocks on agricultural innovations adoption: Microeconometric evidence from rural Ethiopia. *Food Policy*, *74*, 154–161. https://doi.org/10.1016/j.foodpol.2017.12.010

Gentle, P., & Maraseni, T. N. (2012). Climate change, poverty, and livelihoods: Adaptation practices by rural mountain communities in Nepal. *Environmental Science & Policy*, *21*, 24–34. https://doi.org/10.1016/j.envsci.2012.03.007

Gerlitz, J.-Y., Macchi, M., Brooks, N., Pandey, R., Banerjee, S., & Jha, S. K. (2017). The Multidimensional Livelihood Vulnerability Index – an instrument to measure livelihood vulnerability to change in the Hindu Kush Himalayas. *Climate and Development*, *9*(2), 124–140. https://doi.org/10.1080/17565529.2016.1145099

Greene W, Hensher D (2010) Modeling ordered choices, a primer. Cambridge University Press, Cambridge

Greene, W. (2012) Econometric Analysis. 7th Edition, Prentice Hall, Upper Saddle River.

Hamid, M., Khuroo, A. A., Charles, B., Ahmad, R., Singh, C. P., & Aravind, N. A. (2019). Impact of climate change on the distribution range and niche dynamics of Himalayan birch, a typical treeline species in Himalayas. *Biodiversity and Conservation*, *28*(8), 2345–2370. https://doi.org/10.1007/s10531-018-1641-8

Hassan, C. N., and R. (2007). *Micro-Level Analysis of Farmers Adaption to climate change in Southern Africa*. Intl Food Policy Res Inst.

Holden, S. T., & Quiggin, J. (2017). Climate risk and state-contingent technology adoption: shocks, drought tolerance and preferences. *European Review of Agricultural Economics, 44*(2), 285-308.

ILO. (2020). *Impact of COVDI-19 on Nepali Migrant workers during the health and Economic Crisis*. International Labor Organization. https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---ilo-kathmandu/documents/briefingnote/wcms_748917.pdf

IOM. (2019). *Migration in Nepal: A COUNTRY PROFILE 2019*. https://publications.iom.int/books/migration-nepal-country-profile-2019

IPCC, 2022: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

J. Schmidhuber, J. P. & B. Q. (2020). *COVID-19: Channels of transmission to food and agriculture*. FAO. https://doi.org/10.4060/ca8430en

Joshi, E., Kumar, D., Lal, B., Nepalia, V., Gautam, P., & Vyas, A. K. (2013). Management of direct seeded rice for enhanced resource—Use efficiency. *Plant Knowledge Journal*, *2*(3), 119–134. https://doi.org/10.3316/informit.766917019565468

Joshi, S., Simkhada, P., & Prescott, G. J. (2011). Health problems of Nepalese migrants working in three Gulf countries. *BMC International Health and Human Rights*, *11*(1), 3. https://doi.org/10.1186/1472-698X-11-3

Kabir, A., Amin, M. N., Roy, K., & Hossain, M. S. (2021). Determinants of climate change adaptation strategies in the coastal zone of Bangladesh: Implications for adaptation to climate change in developing countries. *Mitigation and Adaptation Strategies for Global Change*, *26*(7), 30. https://doi.org/10.1007/s11027-021-09968-z

Kafle, L., Gc, Y., Yang, J.-T., Bhattarai, S., Tiwari, S., & Katuwal, M. (2014). *Integrated Pest Management in Nepal*. https://doi.org/10.13140/2.1.2563.2324

Karki, S., Burton, P., & Mackey, B. (2020). Climate change adaptation by subsistence and smallholder farmers: Insights from three agro-ecological regions of Nepal. *Cogent Social Sciences*, *6*(1), 1720555. https://doi.org/10.1080/23311886.2020.1720555

Kassie, M., Yesuf, M., & Köhlin, G. (2009). The role of production risk in sustainable land-management technology adoption in the Ethiopian Highlands. *rapport nr.: Working Papers in Economics 407*.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological forecasting and social change*, *80*(3), 525-540.

Khamis, M., Prinz, D., Newhouse, D., Palacios-Lopez, A., Pape, U., & Weber, M. (2021). *The Early Labor Market Impacts of COVID-19 in Developing Countries: Evidence from High-Frequency Phone Surveys* [Working Paper]. World Bank. https://openknowledge.worldbank.org/handle/10986/35044

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

Khanal, U., Wilson, C., Hoang, V.-N., & Lee, B. (2018). Farmers' Adaptation to Climate Change, Its Determinants, and Impacts on Rice Yield in Nepal. *Ecological Economics*, *144*, 139–147. https://doi.org/10.1016/j.ecolecon.2017.08.006

Khanal, U., Wilson, C., Lee, B., & Hoang, V.-N. (2018). Do climate change adaptation practices improve technical efficiency of smallholder farmers? Evidence from Nepal. *Climatic Change*, *147*(3), 507–521. https://doi.org/10.1007/s10584-018-2168-4

Kharel, A., Bhattarai, S., Tumsa, D., Gupta, S., & Sen, P. (2022). *Province 1 of Nepal Migration Profile*. Centre for the Study of Labour and Mobility.

Khatri, D., Marquardt, K., Fischer, H., Khatri, S., Singh, D., & Poudel, D. P. Why is farming important for rural livelihood security in the Global South? COVID-19 and changing rural livelihoods in Nepal's mid-hills. *Frontiers in Human Dynamics*, *5*, 8.

Krejcie, R. V., & Morgan, D. W. (1970). Determining Sample Size for Research Activities. *Educational and Psychological Measurement*, *30*(3), 607–610. https://doi.org/10.1177/001316447003000308

Kumar, P., Singh, S. S., Pandey, A. K., Singh, R. K., Srivastava, P. K., Kumar, M., Dubey, S. K., Sah, U., Nandan, R., Singh, S. K., Agrawal, P., Kushwaha, A., Rani, M., Biswas, J. K., & Drews, M. (2021). Multi-level impacts of the COVID-19 lockdown on agricultural systems in India: The case of Uttar Pradesh. *Agricultural Systems*, *187*, 103027. https://doi.org/10.1016/j.agsy.2020.103027

Kumasi, T. C., Antwi-Agyei, P., & Obiri-Danso, K. (2019). Small-holder farmers' climate change adaptation practices in the Upper East Region of Ghana. *Environment, Development and Sustainability*, *21*(2), 745–762. https://doi.org/10.1007/s10668-017-0062-2

Kurgat, B. K., Lamanna, C., Kimaro, A., Namoi, N., Manda, L., & Rosenstock, T. S. (2020). Adoption of Climate-Smart Agriculture Technologies in Tanzania. *Frontiers in Sustainable Food Systems*, *4*. https://www.frontiersin.org/articles/10.3389/fsufs.2020.00055

Legesse, B., Ayele, Y., & Bewket, W. (2013). Smallholder Farmers' Perceptions and Adaptation to Climate Variability and Climate Change in Doba District, West Hararghe, Ethiopia. *Asian Journal of Empirical Research*, *3*(3), Article 3.

Lybbert, T. J., & Sumner, D. A. (2012). Agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion. *Food Policy*, *37*(1), 114–123. https://doi.org/10.1016/j.foodpol.2011.11.001

Maharjan, A., Tuladhar, S., Hussain, A., Mishra, A., Bhadwal, S., Ishaq, S., Saeed, B. A., Sachdeva, I., Ahmad, B., Ferdous, J., & Hassan, S. M. T. (2021). Can labour migration help households adapt to climate change? Evidence from four river basins in South Asia. *Climate and Development*, *13*(10), 879–894. https://doi.org/10.1080/17565529.2020.1867044

Malla, B., & Rosenbaum, M. S. (2017). Understanding Nepalese Labor Migration to Gulf Countries. *Journal of Poverty*, *21*(5), 411–433. https://doi.org/10.1080/10875549.2016.1217578

Manandhar, S., Vogt, D. S., Perret, S. R., & Kazama, F. (2011). Adapting cropping systems to climate change in Nepal: A cross-regional study of farmers' perception and practices. *Regional Environmental Change*, *11*(2), 335–348. https://doi.org/10.1007/s10113-010-0137-1

Mandlekar, D. K. C. (2020). *Impact of Covid-19 on Indian Agriculture Sector: A Study*. https://www.semanticscholar.org/paper/Impact-of-Covid-19-on-Indian-Agriculture-Sector%3A-A-Mandlekar/aa6a873e2410e02d06ae539777d887167c4a80b6

Mansfield, E. R., & Helms, B. P. (1982). Detecting Multicollinearity. *The American Statistician*, *36*(3a), 158–160. https://doi.org/10.1080/00031305.1982.10482818

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

Matata, A. C. (2018). *Causes of climate change and its impact in the multi sectoral areas in Africa-Need for enhenced adaptation policies*. https://repo.umma.ac.ke/handle/123456789/31

McLeman, R. (2010). Impacts of population change on vulnerability and the capacity to adapt to climate change and variability: a typology based on lessons from "a hard country". *Population and Environment*, *31*, 286-316.

McMichael, C. (2015). Climate change-related migration and infectious disease. *Virulence*, *6*(6), 548–553. https://doi.org/10.1080/21505594.2015.1021539

Mendelsohn, R. (2009). The Impact of Climate Change on Agriculture in Developing Countries. *Journal of Natural Resources Policy Research*, *1*(1), 5–19. https://doi.org/10.1080/19390450802495882

Mishra, A., Appadurai, A. N., Choudhury, D., Regmi, B. R., Kelkar, U., Alam, M., Chaudhary, P., Mu, S. S., Ahmed, A. U., Lotia, H., Fu, C., Namgyel, T., & Sharma, U. (2019). Adaptation to Climate Change in the Hindu Kush Himalaya: Stronger Action Urgently

Needed. In P. Wester, A. Mishra, A. Mukherji, & A. B. Shrestha (Eds.), *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People* (pp. 457–490). Springer International Publishing. https://doi.org/10.1007/978-3-319-92288-1_13

MoALD. (2020). Statistical Information on Nepalese Agriculture 2076/77 (2019/20). kathmandu: Government of Nepal.

MoE. (2010). *National Adaptation Programme of Action to Climate chnage*. Ministry of Environment.

MOEF. (2005). *National Adaptation Programme of Action (NAPA)*. Ministry of Environment and Forest Government of People's Republic of Bangladesh.

MoLE. (2018). *Labour Migration for Employment A Status Report for Nepal: 2015/2016 – 2016/2017*. Government of Nepal.

MoLESS. (2020). *Nepal Labour Migration Report 2020*. Government of Nepal.

Mortreux, C., & Barnett, J. (2009). Climate change, migration and adaptation in Funafuti, Tuvalu. Global Environmental Change, 19(1), 105-112.

Mueller, V., Gray, C., & Hopping, D. (2020). Climate-Induced migration and unemployment in middle-income Africa. *Global Environmental Change*, *65*, 102183. https://doi.org/10.1016/j.gloenvcha.2020.102183

Mulwa, C., Marenya, P., Rahut, D. B., & Kassie, M. (2017). Response to climate risks among smallholder farmers in Malawi: A multivariate probit assessment of the role of information, household demographics, and farm characteristics. *Climate Risk Management*, *16*, 208–221. https://doi.org/10.1016/j.crm.2017.01.002

Murray, U., Gebremedhin, Z., Brychkova, G., & Spillane, C. (2016). Smallholder Farmers and Climate Smart Agriculture: Technology and Labor-productivity Constraints amongst Women Smallholders in Malawi. *Gender, Technology and Development*, *20*(2), 117–148. https://doi.org/10.1177/0971852416640639

Nabikolo, D., Bashaasha, B., Mangheni, M. N., & Majaliwa, J. G. M. (2012). Determinants of climate change adaptation among male and female headed farm households in eastern Uganda. *African Crop Science Journal*, *20*, 203–212. https://doi.org/10.4314/acsj.v20i2

Ndamani, F., & Watanabe, T. (2016). Determinants of farmers' adaptation to climate change: A micro level analysis in Ghana. *Scientia Agricola*, *73*, 201–208. https://doi.org/10.1590/0103-9016-2015-0163

Obayelu, O. A., Adepoju, A. O., & Idowu, T. (2014). Factors influencing farmers' choices of adaptation to climate change in Ekiti State, Nigeria. *Journal of Agriculture and Environment for International Development (JAEID)*, *108*(1), Article 1. https://doi.org/10.12895/jaeid.20141.140

Ojo, T. O., & Baiyegunhi, L. J. S. (2020). Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in south-west Nigeria. *Land Use Policy*, *95*, 103946. https://doi.org/10.1016/j.landusepol.2019.04.007

Omerkhil, N., Kumar, P., Mallick, M., Meru, L. B., Chand, T., Rawat, P. S., & Pandey, R. (2020). Micro-level adaptation strategies by smallholders to adapt climate change in the least developed countries (LDCs): Insights from Afghanistan. *Ecological Indicators*, *118*, 106781. https://doi.org/10.1016/j.ecolind.2020.106781

Pandey, R., Aretano, R., Gupta, A. K., Meena, D., Kumar, B., & Alatalo, J. M. (2017). Agroecology as a Climate Change Adaptation Strategy for Smallholders of Tehri-Garhwal in the Indian Himalayan Region. *Small-Scale Forestry*, *16*(1), 53–63. https://doi.org/10.1007/s11842-016-9342-1

Pandve, H. T. (2009). India's National Action Plan on Climate Change. *Indian Journal of Occupational and Environmental Medicine*, *13*(1), 17–19. https://doi.org/10.4103/0019-5278.50718

Sharma, P., T. P., Zhang, J., Koju, U. A., Zhang, S., Bai, Y., & Suwal, M. K. (2019). Review of flood disaster studies in Nepal: A remote sensing perspective. *International Journal of Disaster Risk Reduction*, *34*, 18–27. https://doi.org/10.1016/j.ijdrr.2018.11.022

Parry, M. L. (2019). *Climate Change and World Agriculture*. Routledge.

Paudel, B., Wang, Z., Zhang, Y., Rai, M. K., & Paul, P. K. (2021). Climate Change and Its Impacts on Farmer's Livelihood in Different Physiographic Regions of the Trans-Boundary Koshi River Basin, Central Himalayas. *International Journal of Environmental Research and Public Health*, *18*(13), Article 13. https://doi.org/10.3390/ijerph18137142

Piya, L., Maharjan, K. L., & Joshi, N. P. (Eds.). (2012). *Vulnerability of rural households to climate change and extremes: Analysis of Chepang households in the Mid-Hills of Nepal*. https://doi.org/10.22004/ag.econ.126191

Piya, L., Maharjan, K. L., & Joshi, N. P. (2013). Determinants of adaptation practices to climate change by Chepang households in the rural Mid-Hills of Nepal. *Regional Environmental Change*, *13*(2), 437–447. https://doi.org/10.1007/s10113-012-0359-5

Pokhrel, S., & Chhetri, R. (2021). A Literature Review on Impact of COVID-19 Pandemic on Teaching and Learning. *Higher Education for the Future*, *8*(1), 133–141. https://doi.org/10.1177/2347631120983481

Rasul, G. (2010). The Role of the Himalayan Mountain Systems in Food Security and Agricultural Sustainability in South Asia. *International Journal of Rural Management*, *6*(1), 95–116. https://doi.org/10.1177/097300521100600105

Regensburg, N. C. U. (2020). *oglmx: A Package for Estimation of Ordered Generalized Linear Models.*

Regmi, H.P. (2020) Climate Change and Variability: Producers' Perceptions and Determinants of Adaptation Strategies in Rice Farming in Chitwan, Nepal [Master's Dissertation, University of Tennessee, Knoxville]

Regmi, H. P., Upendram, S., Cho, S.-H., & Clark, C. D. (2022). Examining complementary relationships among climate change adaptation practices of rice producers in Chitwan, Nepal. *Climate and Development*, *0*(0), 1–21. https://doi.org/10.1080/17565529.2022.2107980

Roka, H. (2017). The status of smallholder farmers in Nepal's agricultural development strategy (2015–2035). *Agrarian South: Journal of Political Economy*, *6*(3), 354-372.

Sargan, J. D. (1958). The Estimation of Economic Relationships using Instrumental Variables. *Econometrica*, *26*(3), 393–415. https://doi.org/10.2307/1907619

Scheffran, J., Marmer, E., & Sow, P. (2012). Migration as a contribution to resilience and innovation in climate adaptation: Social networks and co-development in Northwest Africa. *Applied Geography*, *33*, 119–127. https://doi.org/10.1016/j.apgeog.2011.10.002

Seddon, D., Adhikari, J., & Gurung, G. (2002). Foreign Labor Migration and the Remittance Economy of Nepal. *Critical Asian Studies*, *34*(1), 19–40. https://doi.org/10.1080/146727102760166581

Shukla, R., Agarwal, A., Sachdeva, K., Kurths, J., & Joshi, P. K. (2019). Climate change perception: An analysis of climate change and risk perceptions among farmer types of Indian Western Himalayas. *Climatic Change*, *152*(1), 103–119. https://doi.org/10.1007/s10584-018-2314-z

Si, R., Aziz, N., Liu, M., & Lu, Q. (2021). Natural disaster shock, risk aversion and corn farmers' adoption of degradable mulch film: Evidence from Zhangye, China. *International Journal of Climate Change Strategies and Management*, *13*(1), 60–77. https://doi.org/10.1108/IJCCSM-08-2020-0090

Siche, R. (2020). What is the impact of COVID-19 disease on agriculture? *Scientia Agropecuaria*, *11*(1), 3–6. https://doi.org/10.17268/sci.agropecu.2020.01.00

Sintayehu, D. W. (2018). Impact of climate change on biodiversity and associated key ecosystem services in Africa: A systematic review. *Ecosystem Health and Sustainability*, *4*(9), 225–239. https://doi.org/10.1080/20964129.2018.1530054

Sorte, C. J., Williams, S. L., and Zerebecki, R. A. (2010). Ocean warming increases threat of invasive species in a marine fouling community. *Ecol. Soc. Am.* 91, 2198–2204. doi: 10.1890/10-0238.1

Stock, J. H., & Yogo, M. (2002). *Testing for weak instruments in linear IV regression*. National Bureau of Economic Research Cambridge, Mass., USA.

Tacoli, C. (2009). Crisis or adaptation? Migration and climate change in a context of high mobility. *Environment and urbanization*, *21*(2), 513-525.

Tan, Y., Sarkar, A., Rahman, A., Qian, L., Hussain Memon, W., & Magzhan, Z. (2021). Does External Shock Influence Farmer's Adoption of Modern Irrigation Technology?—A Case of Gansu Province, China. *Land*, *10*(8), Article 8. https://doi.org/10.3390/land10080882

Tazeze, A., & Haji, J. (2012). *Climate Change Adaptation Strategies of Smallholder Farmers: The Case of Babilie District, East Harerghe Zone of Oromia Regional State of Ethiopia*. 14.

Thieme, S., & Wyss, S. (2005). Migration Patterns and Remittance Transfer in Nepal: A Case Study of Sainik Basti in Western Nepal. *International Migration*, *43*(5), 59–98. https://doi.org/10.1111/j.1468-2435.2005.00342.x

Tiwari, P. C., & Joshi, B. (2012). Natural and socio-economic factors affecting food security in the Himalayas. *Food Security*, *4*(2), 195–207. https://doi.org/10.1007/s12571-012-0178-z

Topolovec-Pintaric, S. (2020). *Plant Diseases: Current Threats and Management Trends*. BoD – Books on Demand.

Uddin, M. N., Bokelmann, W., & Entsminger, J. S. (2014). Factors Affecting Farmers' Adaptation Strategies to Environmental Degradation and Climate Change Effects: A Farm Level Study in Bangladesh. *Climate*, *2*(4), Article 4. https://doi.org/10.3390/cli2040223

UNDP. (2022). Human Development Report 2021-22. In *Human Development Reports*. United Nations. https://hdr.undp.org/content/human-development-report-2021-22

Verma, A. K., & Prakash, S. (2020). *Impact of COVID-19 on Environment and Society* (SSRN Scholarly Paper No. 3644567). https://papers.ssrn.com/abstract=3644567

Williams, R. (2006). Generalized Ordered Logit/Partial Proportional Odds Models for Ordinal Dependent Variables. *The Stata Journal*, *6*(1), 58–82Winkelmann R (2008) Econometric analysis of count data, 5th edn. Springer, Berlin. https://doi.org/10.1177/1536867X0600600104

Wooldridge, J. M. (2015). *Introductory Econometrics: A Modern Approach*. Cengage Learning.

Xue, C., Qiao, D., & Aziz, N. (2022). Influence of Natural Disaster Shock and Collective Action on Farmland Transferees' No-Tillage Technology Adoption in China. *Land*, *11*(9), 1511.

Yang, L., Liu, S., Liu, J., Zhang, Z., Wan, X., Huang, B., Chen, Y., & Zhang, Y. (2020). COVID-19: Immunopathogenesis and Immunotherapeutics. *Signal Transduction and Targeted Therapy*, *5*(1), Article 1. https://doi.org/10.1038/s41392-020-00243-2

APPENDIX

APPENDIX A:QUESTIONNAIRE USED FOR THE COLLECTION OF DATA.

Nepal: Survey of farmers on agricultural production, climate change and adaptation, and labor immigration

Namaste! My name is __________ I am working on a research project for University of Tennessee, US. I will ask you questions about farming practices. This is a voluntary survey, and your responses will be kept confidential. Information you provide will help inform how labor participation affects production & climate change adaptation. Would you take 15 minutes to participate in this study?

YES: Continue **No:** Thank you and have a great day **Interview No:** ☐ **Location:** ________

Name: _________________ Age: ___ Gender: M F Ethnicity: ☐ Brahmin/Chettri ☐ Janjati ☐ Dalit

Section A: Household (HH), Farm and General Information

1	Head of Household	M	F	**7**	No. of rice plots (parcels)			**13**	Sources of irrigation: a. Kulo/Canal water			
2	No. of total household members			**8**	Irrigated (low land) ....Unit				b. Canal+ Ground water pumping (both)			
	a. No. of members-16 to 60 years				Unirrigated(upland)...............Unit			**14**	a. Member of farmer group/cooperative	Y	N	
3	No. of literate family members			**9**	Crop area in last year.............Unit				b. Are you involve in group/cooperative farming through Pocket/Blocks/Zone?	Y	N	
4	No of members migrated abroad			**10**	Crop harvest last year............Unit			**15**	Distance of frequently/mostly visited market for agricultural input/output (KM)			
5	Education years of household head			**11**	Crop quantity sold last year ....Unit							
6	Household head years of farming			**12**	Do you rear livestock	Y	N	**16**	Is farming profitable to you?	Y	N	

Section B: Labor migration

17. Is there any household members who lives away from house at least 2 months a year? Y N (If yes, continue this section)

18	Number of migrant labors?					
19	Gender of the migrant labor?	Male ( )			Female ( )	
20	Age of the migrant labor (years)		If more than one member →			
21	Education level of the migrant labor		If more than one members			
22	Has anybody returned to the family during the pandemic?	Y (if Yes ask i,ii,iii)			N	
	i) How many migrant labor have returned to the family?					
	ii) Has he/she/they been involved in agriculture?	Y	N	If yes, No. of labor- ________	No ( )	
	iii) Where did he/she return from?	Within Nepal from the cities:		B. Specify Country:		
23	Average Income of the person who was away from home?	__________________(NRs/person/year)				
24	Remittance/off-farm income received by household from migrant?	__________________(NRs/person/year) Foreign Country				
25	Income received by household (NRs/person/year) from other city?	__________________(NRs/person/year) (Within country)				
26	Share of remittance/off-farm income consumed in: (amount)	**Share % (Total 100%)**				
	(i) Agriculture (machinery, technology, equipment)					
	(ii) Food					
	(iii) Household Goods (TV, Fridge, Motorcycle)					
	(iv) Education					
	(v) Other					
27	I am ______ that he/she has returned home	A(Highly Satisfied)	B(Slightly satisfied)	C(Neither)	D(Slightly dissatisfied)	E(Strongly dissatisfied)
28	I ________ that labor immigration has negative impact on agricultural production	A(Strongly believe)	B(Slightly believe)	C(Neither)	D(Slightly disbelieve)	E(strongly disbelieve)
29	He/She/They may stay at home if the income is __ % of what they earn away from home	25%	50%	75%	90%	100%

Section C: Farm production and Income										
30	Income sources	Particulars	Before COVID (Before Jan 2020)				During COVID (After March 24, 2020)			
			Production		Sales		Production		Sales	
			Quantity	Price (NRs)	Quantity	Price (NRs)	Quantity	Price (NRs)	Quantity	Price (NRs)
	i)Agriculture	Rice								
		Wheat								
		Maize								
		Mango								
		Other fruits								
	ii) Livestock	Dairy products								
		Meat								
	iii) Employment									

31	Variable cost of the Commodity	Amount (NRs)		Variable cost of the Commodity	Amount (NRs)	
		Before COVID	During COVID		Before COVID	During COVID
	(i) Cost of seed /grafted plant			(ii) Cost of harvesting, threshing		
	(iii) Cost of fertilizer			(iv) Cost of machinery and bullock		
	(v) Cost of land			(vi) Total labor cost		
	(vii) Cost of pesticides			(viii) Hired labor (number)	( )	( )
	(ix) Total cost of transportation			(x) Family labor (number)	( )	( )
	(xi) Cost of weeding			(xii) Cost for livestock		
	(xiii) Total variable cost					

SECTION D: Farmers perception on climate change /variability and impact on agriculture

32. Have you noticed any changes in local weather patterns in past 10 years? (Circle one) **Y** **N** If yes, ask 33

33. In average, over the last 3 years, due to weather changes, please indicate:

a. Approx. % of agricultural area affected	<25%	☐	25-50%	☐	>50%	☐
b. Approx. % of agricultural yield decline	<25%	☐	25-50%	☐	>50%	☐
c. Approx. % loss of net income from climate change	<25%	☐	25-50%	☐	>50%	☐

SECTION E: Adaptation to Climate change							
34. Have you adopted these practices in crop practice since March 24,2020 (During COVID-19)?			**35**. If not, why have you not adopted the practices (Select that all apply)				
			Lack of Information	Finance	Lack of technical information	Climate change is not a big issue	No change in production
(A)Varietal Management							
Growing drought tolerance varieties	Y	N	☐	☐	☐	☐	☐
Growing short duration varieties	Y	N	☐	☐	☐	☐	☐
Growing disease resistance varieties	Y	N	☐	☐	☐	☐	☐
Short maturing and hardy crops	Y	N	☐	☐	☐	☐	☐
(B) Agronomic Practices							
Late harvest ______	Y	N	☐	☐	☐	☐	☐
Crop rotation /cropping pattern	Y	N	☐	☐	☐	☐	☐
Change in sowing /planting dates	Y	N	☐	☐	☐	☐	☐
Minimum/zero tillage	Y	N	☐	☐	☐	☐	☐
(C) **Land use /Diversification**							
Change in land use from crops/fruit/livestock	Y	N	☐	☐	☐	☐	☐
Change in agricultural land for other purposes	Y	N	☐	☐	☐	☐	☐
Change in ag land for livestock	Y	N	☐	☐	☐	☐	☐

(D)Changing the dose / frequency of chemicals							
IPM (Integrated Pest Management)	Y	N	☐	☐	☐	☐	☐
Increase in use of Chemical fertilizer	Y	N	☐	☐	☐	☐	☐
Decrease in use of the chemical fertilizer	Y	N	☐	☐	☐	☐	☐
Increase in use of pesticide	Y	N	☐	☐	☐	☐	☐
Decrease in use of pesticide	Y	N	☐	☐	☐	☐	☐
(E) Using Direct seeded Rice (DSR)	Y	N	☐	☐	☐	☐	☐
(F) Use of SRI (System of Rice Intensification)	Y	N	☐	☐	☐	☐	☐
(G) Use of alternative energy options	Y	N	☐	☐	☐	☐	☐
(H) Flood control measures	Y	N	☐	☐	☐	☐	☐
36. Are there any other climate change strategies you have adopted				____			

SECTION G: Access to Extension services, Credit, Subsidy, and Information				
Insurance	**37. a.** Do you know/aware about crop insurance?	**Y**	**N**	
	b. Do you have crop insurance within last 3 years?	**Y**	**N**	if not, why not ( ) High cost ( ) unaware about benefit/cost ( ) no use ( ) not nearby ( ) burdensome process
Extension	**38.a** Do you visit extension office or extension agent?	**Y**	**N**	**b** Extension visits: Before March 2020(2 years) ☐ After March 2020 ☐
Training	**39.a.** Have you received any training related to:	**Y**	N	**b.**Training received **:**
	(i) Commercial agriculture	**Y**	**N**	Before March 2020(2 years) ☐ After March 2020
	(ii) Use of pesticide and fertilizer (IPM)	**Y**	**N**	
	(iii) Irrigation	**Y**	**N**	
	(iv) Climate change adaptation	**Y**	**N**	
Credit	**40.**a Did you take a loan for farming?	**Y**	**N**	**b**. If yes, how much? _______________
	c. if not why not? ( ) high interest rate ( ) time consuming process ( ) no need			If yes, Sources ( )bank ( ) microlenders/Co-operatives ( ) relatives/friends ( ) money lenders
Subsidy	**41a**. Do you have access to any subsidy in rice/mango farming?	**Y**	**N**	**b**. Please indicateyour preference of subsidy to build resilience against climatic variability (Select top 3) ( ) variety (drought tolerance/short duration/disease/ pest) ( ) Irrigation canal/solar/electricity ( ) Farm machinery/tools ( ) Fertilizers and pesticides (both chemical/organic)
Information	**42a** Do you have access to the internet?	**Y**	**N**	**b**. Do you get weather information in TV/Radio? **Y** **N**
	c. Do you look at weather information?	**Y**	**N**	**d.** Do you receive weather message on mobile Y N
	e. Do you plan agricultural activities based on weather forecast?			Y N
	f. What is the reliability of the weather forecast information?			Low ☐ Medium ☐ High ☐
	g. Do you use such information in farming decision?	**Y**	**N**	
	h. Do you produce value-added agricultural products?	**Y**	**N**	

i. Please indicate your level of agreement on : I have adequate access to:	Strongly Agree	Slightly Agree	Neutral	Slightly Disagree	Strongly disagree
i. Information on past weather trends	☐	☐	☐	☐	☐
ii. Information on weather forecasers	☐	☐	☐	☐	☐
iii. Information on climate smart farming pracitce	☐	☐	☐	☐	☐
iv. Varietal information	☐	☐	☐	☐	☐
v. Price and Marketing information	☐	☐	☐	☐	☐

SECTION H: ADOPTION OF TECHNOLOGY AND INVESTMENT ON TECHNOLOGY												
43	**Have you used any technology and equipment on the farm since the COVID-19 pandemic (After March 24, 2020)?**			**44. a. If yes, what is the value of:**			**45. If not, why have you not adopted the technology? (Select all that apply)**					
				Investment	**Loan**	**Subsidy**	**Finance**	**Lack of technical information**	**No use**	**No change in production**	**Others**	
i	**Machinery/Equipment: Do you have:**											
	a. Tractor	Y	N				☐	☐	☐	☐	☐	
	b.Land preparation equipment	Y	N				☐	☐	☐	☐	☐	
	c.Pesticide sprayer	Y	N				☐	☐	☐	☐	☐	
	d. Harvester	Y	N				☐	☐	☐	☐	☐	
	e.Post-harvest facility	Y	N				☐	☐	☐	☐	☐	
	f. Others__________	Y	N				☐	☐	☐	☐	☐	
ii	**Power/Irrigation: Do you:**											
	a. Have irrigation?	Y	N				☐	☐	☐	☐	☐	
	b. Electricity?	Y	N				☐	☐	☐	☐	☐	
	d. Use solar power?	Y	N				☐	☐	☐	☐	☐	
iii	**Varieties: Do you:**											
	a. Plant hybrid varieties?	Y	N				☐	☐	☐	☐	☐	
iv	**ICT: Do you have**											
	a. Smart Phone	Y	N				☐	☐	☐	☐	☐	
v.	What is your source of investment in techology, power/irrigation/varieties: (Select All that apply):											
	a. Remittance ☐			b. Job/Employment ☐			c. Farm income ☐		☐ d. Other Sources_______			

THANK YOU!!!!!!!!!

All information collected here is part of a University of Tennessee research project and is completely voluntary. All information will be kept strictly confidential. If you have questions about this survey, please contact Sreedhar Upendram at (865)-974-7410 or UTK IRB staff at (865)-974-7697.

Questionnaire translated into the Nepali language.

नेपाल: कृषि उत्पादन, जलवायु परिबर्तन र अनुकुलन, र श्रम आप्रवासनमा किसानहरुकको सर्वेक्षण

नमस्ते ! मेरो नाम अमृत श्रेष्ठ हो र म अमेरिकाको टेनेसी विश्वविद्यालयको अनुसन्धान परियोजनामा काम गर्दैछु । म तपाईंहरूलाई खेतीपातीसम्बन्धी केही प्रश्नहरू सोध्न चाहन्छु । यो स्वैच्छिक सर्वेक्षण हो र तपाईंको प्रतिक्रिया गोप्य राखिनेछ। श्रम सङ्ख्यामा आएको परिवर्तनले नेपालमा उत्पादन, जलवायु परिवर्तन अनुकूलनमा कस्तो परिवर्तन आएको छ भन्ने जानकारी दिन तपाईले उपलब्ध गराउनुभएको जानकारीले सहयोग पुग्नेछ । के तपाईं यस अध्ययनमा भाग लिन हामिलाई १५ मिनेट दिन चाहनुहुन्छ ?

हुन्छ: जारी राख्नुहोस् हुदैन: धन्यवाद र एक महान दिन रहोस अन्तर्वार्ता ☐ ठेगाना: ______

नाम: ______________ उमेर (वर्ष): __ लिङ्ग: महिला पुरूष जातियता: ब्राह्मण/क्षेत्री ☐ जनजाति ☐ दलित ☐

खण्ड क: घरपरिवार(HH), फार्म र सामान्य जानकारी

१	घरको प्रमुख	पु	म	७	धानको प्लटको संख्या (पार्सल)			१३	सिँचाइको स्रोत: क. कुलो/नहरको पानी		
२	कुल घरपरिवार सदस्य संख्या			८	सिँचाइ गरिएको (तराई) .... एकाइ				ख. नहर + जमिनको पानी पम्पिङ (दुवै)		
	क. १६ देखि ६० वर्षसम्मका सदस्य संख्या				सिँचाइरहित (उच्च भूमि) .... एकाइ			१४	क. किसान समूह/सहकारी सदस्य	छ	छैन
३	साक्षर परिवार सदस्य संख्या			९	गत वर्षको बाली क्षेत्र .... एकाइ				ख. के तपाई पकेट/ब्लक/जोन मार्फत सामूहिक/सहकारी खेतीमा संलग्न हुनुहुन्छ?	छ	छैन
४	बिदेशीएका सदस्यको संख्या			१०	गत वर्ष बाली फसल .... एकाइ			१५	कृषि इनपुट/आउटपुट को लागि बारम्बार / प्राय: भ्रमण गरिएको बजारको दूरी (कि.मि)		
५	घरपरिवार प्रमुखको शैक्षिक वर्ष			११	गत वर्ष बिक्री भएको बालीको मात्रा ....एकाइ						
६	घर प्रमुखको खेती वर्ष			१२	गाईवस्तु पाल्नु हुन्छ?	छ	छैन	१६	के तपाईलाई खेती लाभदायक छ?	छ	छैन

खण्ड ख: श्रम माइग्रेसन

१७. वर्षको कम्तिमा २ महिना घरबाट टाढा बस्ने कुनै घरपरिवार सदस्य छन्? छ छैन (यदि हो भने, यो खण्ड जारी राख्नुहोस्)

१८	आप्रवासीहरुको संख्या ?				
१९	आप्रवासीहरूको लिंग?	पुरूष ( )		महिला( )	
२०	आप्रवासीहरूको उमेर (वर्ष)		एक भन्दा बढी सदस्य भएमा →		
२१	प्रवासी सदस्यहरूको शिक्षा स्तर		एक भन्दा बढी सदस्यहरु भएमा ----		
२२	के कोही महामारीको समयमा परिवारमा फर्केका छन्?	छ		छैन	
	i) कति आप्रवासी परिवारमा फर्किए?				
	ii) उहाँ/उनी/उनीहरूलाई कृषिमा संलग्न गराउनुभएको छ?	छ	छैन	यदि हो भने, श्रम संख्या- _______	छैन( )
	iii) उहाँ कहाँबाट फर्कनुभयो?	क. नेपाल भित्रका सहरहरुबाट	ख. कुन देश?		
२३	घरबाट टाढा भएको व्यक्तिको औसत आय?	________________(रु/व्यक्ति/वर्ष)			
२४	आप्रवासीबाट घरपरिवारले प्राप्त गरेको रेमिटेन्स/फार्म-बाहिरको आय?	________________(रु/व्यक्ति/वर्ष) विदेशी मुलुक			
२५	अन्य सहरबाट घरपरिवारबाट प्राप्त आय (रु/व्यक्ति/वर्ष)?	________________(रु/व्यक्ति/वर्ष) (देश भित्र)			
२६	रेमिटेन्स/फार्म-बाहिरको आम्दानीमा खपत भएको अंश: (रकम)	**शेयर % (कुल 100%)**			
	(i) कृषि (मेसिनरी, प्रविधि, उपकरण)				
	(ii) खाना				
	(iii) घरायसी सामान (टिभी, फ्रिज, मोटरसाइकल)				
	(iv) शिक्षा				
	(v) अन्य				

२७	उहाँ/उनी घर फर्किनुभएकोमा म............................ छु	क (एकदमै सन्तुष्ट)	ख (अलिकति सन्तुष्ट)	ग (न त)	घ (अलिकति असन्तुष्ट)	ङ (कडा रूपमा असन्तुष्ट)
२८	श्रम अध्यागमनले कृषि उत्पादनमा नकारात्मक असर पार्छ भन्ने मेरो...............	क (दृढ विश्वास छ)	ख (अलिकति विश्वास छ)	ग (न त)	घ (अलिकति अविश्वास)	ङ (कडा अविश्वास)
२९	यदि उनीहरूले घरबाट बाहिर रहेर कमाएको आम्दानीको __________कमाई भएमा ऊ/उनी/उनीहरू रहनेछन्	२५%	५०%	७५%	९०%	१००%

खण्ड ग: कृषि उत्पादन र आय										
३०	**आय स्रोत**	**विशेष**	**कोभिड अघि (जनवरी २०२० अघि)**				**कोभिड को समयमा (मार्च २४, २०२० पछि)**			
			उत्पादन		बिक्री		उत्पादन		बिक्री	
			मात्रा	मूल्य (रु)	मात्रा	मूल्य (रु)	मात्रा	मूल्य (रु)	मात्रा	मूल्य (रु)
	i) कृषि	धान								
		गहुँ								
		मकै								
		आँप								
		अन्य फलहरू								
	ii) पशुधन	दुग्ध - उत्पादन								
		मासु								
	iii) रोजगारी									

३१	**परिवर्तनशील लागत**	**रकम (रु)**		**परिवर्तनशील लागत**	**रकम (रु)**	
		कोभिड अघि	**कोभिड को समयमा**		**कोभिड अघि**	**कोभिड को समयमा**
	बीउ/कलमी बिरुवाको लागत			फसल काट्ने, थ्रेसिङको लागत		
	मलको लागत			मेसिनरी र हलोको लागत		
	जग्गाको लागत			कुल श्रम लागत		
	कीटनाशक लागत			भाडामा लिएको श्रम (संख्या)	( )	( )
	यातायात को कुल लागत			पारिवारिक श्रम (संख्या)	( )	( )
	झारपात ब्यबस्थापनको लागत			कुल परिवर्तनीय लागत		

खण्ड घ: जलवायु परिवर्तन / परिवर्तनशीलता र कृषिमा प्रभाव बारे किसानहरूको धारणा

३२. के तपाईंले विगत १० वर्षमा स्थानीय मौसमको ढाँचामा कुनै परिवर्तन देख्नुभएको छ? (कुनै एकमा गोलो लगाउनुस) छ छैन

यदि छ भने, ३३ सोध्नुहोस्

३३. औसतमा, पछिल्लो 3 वर्षमा, मौसम परिवर्तनको कारण, कृपया संकेत गर्नुहोस्:

क. लगभग.......................% कृषि क्षेत्र प्रभावित	<२५%	☐	२५-५०%	☐	>५०%	☐
ख. लगभग.......................% कृषि उपज घट्यो	<२५%	☐	२५-५०%	☐	>५०%	☐
ग. लगभग........................%जलवायु परिवर्तनबाट शुद्ध आम्दानीको % घाटा	<२५%	☐	२५-५०%	☐	>५०%	☐

खण्ड ङ : जलवायु परिवर्तनको लागि अनुकूलन							
३४. के तपाईंले मार्च २४,२०२० (COVID-19 को अवधिमा) देखि बाली अभ्यासमा यी अभ्यासहरू अपनाउनुभएको छ?			**३५. यदि होइन भने, तपाईंले किन अभ्यासहरू अपनाउनुभएको छैन (सबै लागू हुने छनौट गर्नुहोस्)**				
			सूचनाको अभाव	**वित्त**	**प्राविधिक जानकारीको अभाव**	**जलवायु परिवर्तन ठूलो समस्या होइन**	**उत्पादनमा कुनै परिवर्तन छैन**
(क) प्रजातिहरुको व्यवस्थापन							
खडेरी सहनशीलता प्रजातिहरूको उत्पादन	छ	छैन	☐	☐	☐	☐	☐

छोटो अवधिको प्रजातिहरू उत्पादन	छ	छेन					
रोग प्रतिरोधी प्रजातिहरूको उत्पादन	छ	छेन					
छोटो परिपक्व र कडा बाली	छ	छेन					
(ख) कृषि अभ्यासहरू							
प्रारम्भिक फसल _____	छ	छेन					
बाली चक्र/ खेतीको ढाँचा	छ	छेन					
बीउ/बिरुवा रोप्ने मितिमा परिवर्तन	छ	छेन					
न्यूनतम / शून्य खेती	छ	छेन					
(ग) भूमि प्रयोग / विविधीकरण							
बाली/फलफूल/पशुधनबाट भूमि प्रयोगमा परिवर्तन	छ	छेन					
अन्य उद्देश्यका लागि कृषि भूमिमा परिवर्तन	छ	छेन					
पशुपालनका लागि कृषि भूमिमा परिवर्तन	छ	छेन					
(घ) रसायनको खुराक / आवृत्ति परिवर्तन गर्दै;							
आईपीएम (एकीकृत कीट व्यवस्थापन)	छ	छेन					
रासायनिक मलको प्रयोगमा बृद्धि	छ	छेन					
रासायनिक मलको प्रयोगमा कमी	छ	छेन					
विषादीको प्रयोगमा वृद्धि	छ	छेन					
विषादीको प्रयोगमा कमी	छ	छेन					
(ङ) प्रत्यक्ष बीउयुक्त धान (DSR) को प्रयोग	छ	छेन'					
(च) SRI को प्रयोग (धानको तीव्रता प्रणाली)	छ	छेन					
(छ) वैकल्पिक ऊर्जा विकल्पहरूको प्रयोग	छ	छेन					
(ज) बाढी नियन्त्रण उपायहरू	छ	छेन					
३६. तपाईंले अपनाउनुभएको कुनै अन्य जलवायु परिवर्तन रणनीतिहरू छन्?				______________________			

खण्ड च: विस्तार सेवाहरूमा पहुँच, क्रेडिट, सब्सिडी, र जानकारी				
बीमा	**३७.क.के तपाईलाई बाली बिमा बारे थाहा छ ?**	**छ**	**छैन**	
	ख. विगत ३ वर्ष भित्रको बाली बिमा छ ?	**छ**	**छैन**	यदि छैन भने, किन छैन ( ) उच्च लागत ( ) लाभ / लागत बारे अनजान ( ) कुनै उपयोग छैन ( ) नजिकै छैन ( ) बोझिलो प्रक्रिया
प्रसार	**३८. क. के तपाई एक्स्टेन्सन अफिस वा एक्स्टेन्सन एजेन्टमा जानुहुन्छ?**	**छ**	**छैन**	प्रसार भ्रमणहरू: मार्च २०२० अघि (२ वर्ष) मार्च २०२० पछि
तालिम	३९.a के तपाईंले यससँग सम्बन्धित कुनै तालिम प्राप्त गर्नुभएको छ:	**छ**	छेन	ख. तालिम प्राप्त:
	(i) व्यावसायिक कृषि	**छ**	**छैन**	मार्च २०२० अघि (२ वर्ष) मार्च २०२० पछि
	(ii) विषादी र रासायनिक मलको प्रयोग (IPM)	**छ**	**छैन**	
	(iii) सिँचाइ	**छ**	**छैन**	
	(iv) जलवायु परिवर्तन अनुकूलन	**छ**	**छैन**	
ऋण	**४०. क.** कृषिका लागि ऋण लिनुहुन्छ ?	**छ**	**छैन**	**ख. यदि हो भने, कति?** ____________
	ग. होइन भने किन ? - उच्च ब्याज दर ( ) - कुनै आवश्यकता छैन ( ) - समय खपत र बोझ प्रक्रिया ( )			**घ. यदि हो भने** - बैंकबाट ( ) - आफन्त/साथीहरूबाट ( ) - माइक्रो फाइनान्स ( ) - पैसा ऋणदाता ( )
अनुदान	**४१. क** . के तपाइँसँग धान/आँप खेतीमा कुनै अनुदानमा पहुँच छ?	**छ**	**छैन**	**ख**. कृपया जलवायु परिवर्तन विरुद्ध लचिलोपन निर्माण गर्न सब्सिडी को आफ्नो प्राथमिकता संकेत गर्नुहोस् (शीर्ष 3 चयन गर्नुहोस्)

				( ) जात (खडेरी सहिष्णुता / छोटो अवधि / रोग / कीट) ( ) सिंचाई नहर/सौर/बिजुली ( ) फार्म मेसिनरी/औजारहरू ( ) उर्वरक र कीटनाशक (दुवै रासायनिक/अर्गानिक)		
जानकारी	**४२. क. के तपाईसँग इन्टरनेटको पहुँच छ?**	**छ**	**छैन**	**ख**. के तपाइँ टिभी/रेडियो मा मौसम जानकारी प्राप्त गर्नुहुन्छ?	**छ**	**छैन**
	ग . के तपाइँ मौसम जानकारी हेर्नुहुन्छ?	**छ**	**छैन**	**घ. के तपाई मोबाइलमा मौसमको सन्देश प्राप्त गर्नुहुन्छ**	छ	छैन
	ङ. के तपाइँ मौसम पूर्वानुमानमा आधारित कृषि गतिविधिहरूको योजना बनाउनुहुन्छ?				छ	छैन
	च. मौसम पूर्वानुमान जानकारीको विश्वसनीयता के हो?			कम ☐ मध्यम ☐ उच्च ☐		
	छ. के तपाइँ यस्तो जानकारी खेती निर्णय मा प्रयोग गर्नुहुन्छ?	**छ**	**छैन**			
	ज. के तपाइँ मूल्य अभिवृद्धि कृषि सामग्री उत्पादन गर्नुहुन्छ?	**छ**	**छैन**			

कृपया तपाईंको सम्झौताको स्तर संकेत गर्नुहोस्: मसँग पर्याप्त पहुँच छ:	दृढतापूर्वक सहमत	अलिकति सहमत	तटस्थ	अलिकति असहमत	कडा रूपमा असहमत
	☐	☐	☐	☐	☐
i. मौसम पूर्वानुमानकर्ताहरूको बारेमा जानकारी	☐	☐	☐	☐	☐
ii. जलवायु स्मार्ट खेती अभ्यास बारे जानकारी	☐	☐	☐	☐	☐
iii. विविधता जानकारी	☐	☐	☐	☐	☐
iv. मूल्य र मार्केटिङ जानकारी	☐	☐	☐	☐	☐

खण्ड छ: प्रविधि अपनाउने र प्रविधिमा लगानी

४३	**के तपाईंले COVID-19 महामारी (मार्च २४, २०२० पछि) फार्ममा कुनै प्रविधि र उपकरण प्रयोग गर्नुभएको छ?**			**४४. यदि हो भने, यसको मूल्य के हो:**			**४५. होइन भने प्रविधि किन अपनाएनन् ? (लागू हुने सबै चयन गर्नुहोस्)**				
				लगानी	**ऋण**	**अनुदान**	**वित्त**	**प्राविधिक जानकारीको अभाव**	**उपयोग छैन**	**उत्पादनमा कुनै परिवर्तन छैन**	**अरू**
i	**मेसिनरी/उपकरण: के तपाईसँग छ:**										
	क. ट्र्याक्टर	**छ**	**छैन**				☐	☐	☐	☐	☐
	ख. भूमि तयारी उपकरणहरू (अर्थात् कोदाल, हलो इत्यादि।)	**छ**	**छैन**				☐	☐	☐	☐	☐
	ग. बिषादी स्प्रेयर	**छ**	**छैन**				☐	☐	☐	☐	☐
	घ. फसल काट्ने	**छ**	**छैन**				☐	☐	☐	☐	☐
	ङ. फसल पछि सुविधा	**छ**	**छैन**				☐	☐	☐	☐	☐
	च. अरू _______	**छ**	**छैन**				☐	☐	☐	☐	☐
ii	**पावर/सिंचाई: के तपाईसंग :**										
	क. सिँचाइ छ?	**छ**	**छैन**				☐	☐	☐	☐	☐
	ख . बिजुली?	**छ**	**छैन**				☐	☐	☐	☐	☐
	ग . सौर्य ऊर्जा प्रयोग गर्नुहुन्छ?	**छ**	**छैन**				☐	☐	☐	☐	☐
iii	**बिरुवाको जातहरु : के तपाइँ:**										
	क . हाइब्रिड प्रजातिहरू रोप्नुहुन्छ?	**छ**	**छैन**				☐	☐	☐	☐	☐
iv	**ICT: तपाईंसँग छ:**										
	क . स्मार्ट फोन	**छ**	**छैन**				☐	☐	☐	☐	☐
v.	टेक्नोलोजी, पावर/सिंचाई/विविधहरूमा तपाईंको लगानीको स्रोत के हो: (लागू हुने सबै चयन गर्नुहोस्):										
	क. रेमिट्यान्स ☐			ख. जागिर/रोजगार ☐			ग. कृषि आम्दानी ☐		☐ घ. अन्य स्रोतहरू ______		

धन्यवाद!!!!!!!!!

यहाँ संकलन गरिएका सबै जानकारी टेनेसी विश्वविद्यालयको अनुसन्धान परियोजनाको अंश हो र पूर्णतया स्वैच्छिक हो। सबै जानकारी सख्त रूपमा गोप्य राखिनेछ। यदि तपाइँसँग यस सर्वेक्षणको बारेमा प्रश्नहरू छन् भने, कृपया (८६५)-९७४-७४१० मा श्रीधर उपेन्द्रमलाई वा (८६५)-९७४-७६९७ मा UTK IRB कर्मचारीलाई सम्पर्क गर्नुहोस्।

APPENDIX B :

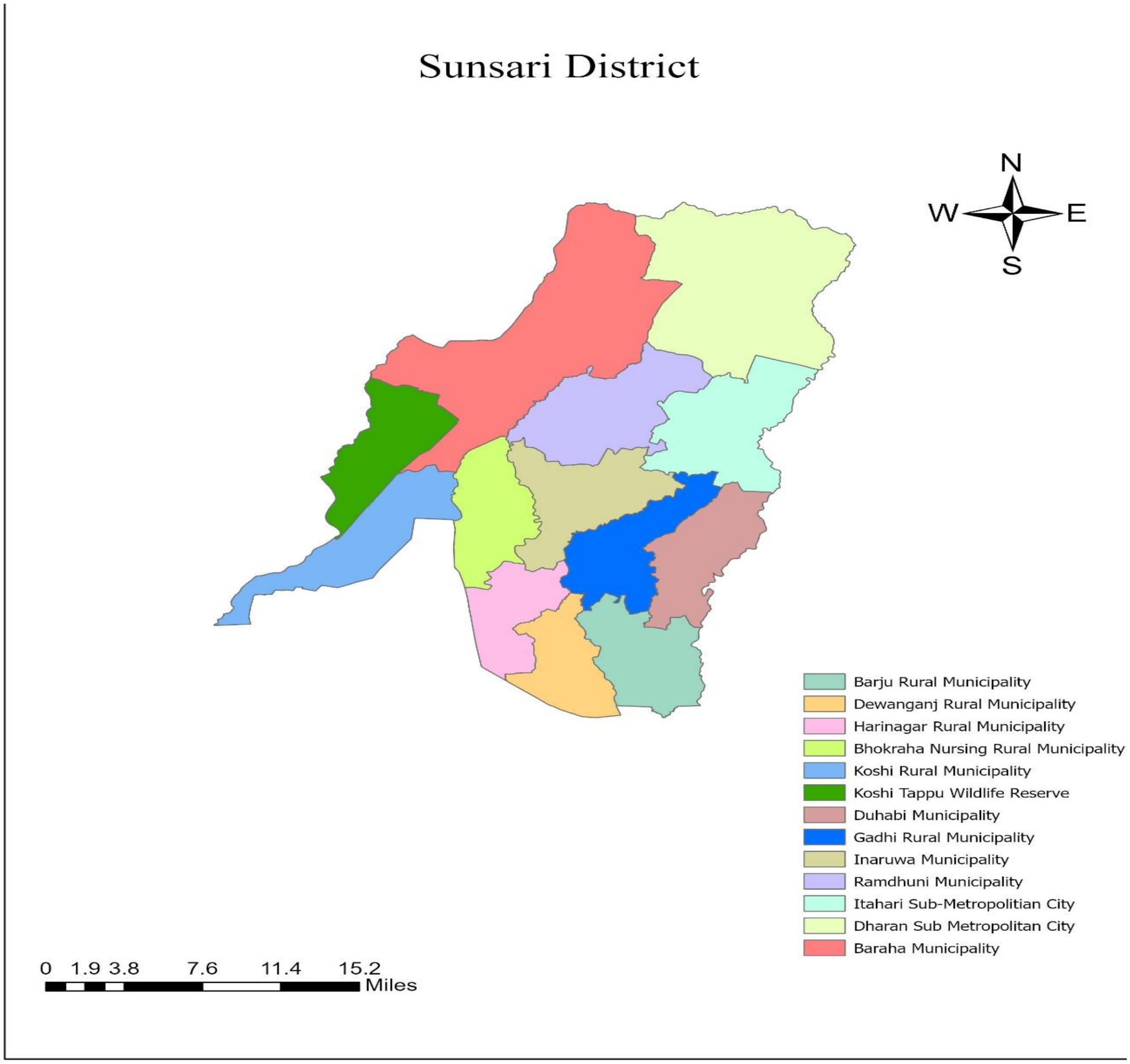

Figure B-1: Map of Sunsari district with local levels

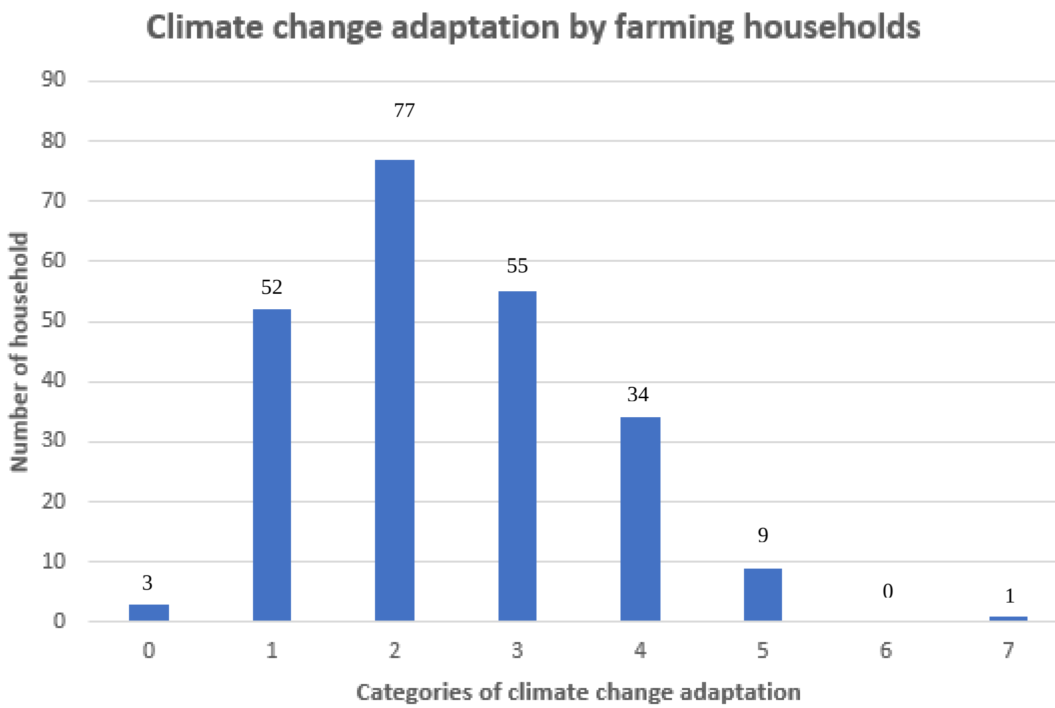

Figure B-2 Distribution of adoption of climate change adaptation strategies by a farming

APPENDIX C

Table C-1 Variance inflation factor values for explanatory variables

Variable	Variance Inflation Factors
Subsidy	1.185390
Extension	1.225260
Internet	1.067971
Membership Status	1.160465
COVID impact	1.072671
Off-farm income	1.051691
Size of household	1.129882
Average Age	1.174690
Farming Experience	1.173141
Gender	1.201699
Livestock	1.075818
Household confidence on weather	1.190310

Table C-2 Brant test of ordered logistic model used for study.

Test	χ^2 value	df	p-value
Omnibus	42.41	60	0.96
Subsidy	4.48	5	0.48
Extension	2.77	5	0.74
Internet	2.76	5	0.74
Membership Status	6.94	5	0.23
COVID impact	0.56	5	0.99
Off-farm income	0.73	5	0.98
Size of household	0.81	5	0.98
Average Age	4.5	5	0.48
Farming Experience	5.42	5	0.37
Gender	1.61	5	0.9
Livestock	0.01	5	1
Household confidence on weather	2.07	5	0.84

Table C-3 Test for the validity of the instrument and Endogeneity test

	IVs	Under-identification		Weak identification		Over-identification		Durbin Wu-Hausman test	
Institutional resource variable		LM stat.	p-value	F-stat	p-value	Sargan stat.	p-value	F-stat	p-value
Subsidy	1	8.603	0.003	7.653	0.006	-		0.071	0.789
Extension	3,4	6.828	0.033	5.072	0.007	0.000	0.995	0.532	0.466
Internet	2	8.469	0.003	5.585	0.019	-		1.429	0.233
Membership status	2	5.880	0.015	9.948	-0.002	-		1.429	0.233

Note: 1= Farm machinery, 2=Education of the household head, 3=education of migrant, 4=Number of migrants

VITA

Amrit Shrestha is from a hilly district of Gorkha, Nepal. He completed his Bachelor in Agricultural Science from Agriculture and Forestry University, Nepal in 2020. He joined the Department of Agricultural and Resource Economics at the University of Tennessee, Knoxville in the fall of 2021 and will graduate in the summer of 2023.