Economic and Social Impacts of Extreme Weather Events on the Agricultural Sector in the Lowlands of Nepal

A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

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Declaration

I hereby declare that the work herein, now submitted as a thesis for the degree of Doctor of Philosophy of the Charles Darwin University, is the result of my own investigations, and all references to ideas and work of other researchers have been specifically acknowledged. I hereby certify that the work embodied in this thesis has not already been accepted in substance for any degree and is not currently submitted in candidature for any other degree.

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Abstract

Climate change and extreme weather events (EWE) destabilise food systems and threaten global food security. They particulaily affect people in low income countries, which have a high dependence on natural resource livelihoods, as well as limited human, institutional, and financial capacities to adapt. This thesis aims to investigate the socio-economic impacts of multiple EWEs (floods, heat waves and cold spells) on farming in the Terai lowlands of Nepal, by conducting structured interviews with 350 randomly selected farmers of the Bardiya and Banke districts. It explores a) farmers' knowledge of and risk perceptions toward the three EWEs; b) how farmers' livelihoods are affected, and c) how they choose to adapt.

The health and labour productivity of farmers' had been compromised during heatwaves and cold spells. Farmers' perceived cold spells as more threatening to their livelihoods than heatwaves, potentially due to prior experience of heatwaves.

Farmer's perceive climate-related environmental risk as the most severe agriculture risk. Using the Protection Motivation Theory, it was found that farmers' coping and threat appraisals significantly influenced their EWE risk perception. Structural Equation Model results show that education, flood damage experience and response costs, and concern about future flooding had a significant positive impact on intention to prepare, while existing government adaptation strategies had a significant negative impact. However, reciprocal factors had limited effect on farmers' preparedness against slow onset hazards – heatwaves and cold spells.

Crop insurance was most preferred adapation strategy for all EWEs, though off-farm employment was also widely implemented in response to floods. Despite generous premium subsidies offered by the Nepalese Government, however, crop insurance uptake remains low. As farmers' were willing to pay higher premiums, this low uptake is likely

due to poor understanding of crop insurance, cash constraints, or an arduous administrative process.

This thesis emphasises the diverse climate change impact and the need for hazard-specific adaptation. By understanding the differences between EWEs, the Nepalese Government may design suitable adaptation strategies, for integration into the community-based education essential for expanding farmers' coping mechanisms, and which will allow them to adapt effectively to climate change related weather extremes and to mitigate their impact.

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Table of Contents

DECLARATION I

ABSTRACT II

ACKNOWLEDGEMENTS IV

PUBLICATIONS VI

Other Publications During Candidature viii

Conference Presentations viii

Table of Contents ix

List of Figures xv

List of Tables xvi

List of Appendicies xviii

List of Abbreviations xx

Chapter 1 Introduction 1

1.1 NEPAL'S CHANGING CLIMATE 3

1.2 EXTREME WEATHER EVENTS 5

1.3 NEPAL'S AGRICULTURAL SECTOR 10

1.4 SOCIO-ECONOMIC AND HEALTH IMPACTS OF EXTREME WEATHER EVENTS 11

1.5 DISASTER RISK PERCEPTION AND ADAPTATION 14

1.5.1 Relationship between environmental hazard, risk perceptions, impacts, and adaptation.... 15

1.5.2 Insurance as an adaptation. 19

1.6 RESEARCH OBJECTIVES 20

1.7 SIGNIFICANCE OF THIS STUDY 20

1.8 METHODOLOGY 21

1.8.1 Framework. 21

1.8.2 Sampling and primary data collection. 24

1.8.3 Study area. 28

1.8.4 *Data analysis.* 30

1.9 REFERENCES 31

Chapter 2 Socio-Economic Impact of and Adaptation to Extreme Heat and Cold of Farmers in the Food Bowl of Nepal 50

2.1 PREFACE 50

2.2 ABSTRACT 50

2.3 INTRODUCTION 51

2.4 MATERIALS AND METHODS 56

2.4.1 *Study Area.* 56

2.4.2 *Sampling.* 58

2.4.3 *Questionnaire and Variables.* 59

2.4.4 *Potential Determinants of Stress and Productivity Loss during Heat Waves and Cold Spells.* 61

2.4.5 *Data Analysis.* 68

2.5 RESULTS 71

2.5.1 *Sample Description.* 71

2.5.2 *Heat- and Cold-Related Illnesses and Injuries.* 74

2.5.3 *Determinants of Farmers Perceived Heat and Cold Stress.* 75

2.5.4 *Labour Productivity Loss during Heat Waves and Cold Spells.* 77

2.5.5 *Adaptation and Relief Strategies to Cope with Heat and Cold Stress.* 80

2.6 DISCUSSION 82

2.6.1 *Health Impact of Heat Waves and Cold Spells on the Farming Community.* 82

2.6.2 *Determinants of Self-Reported Heat and Cold Stress.* 83

2.6.3 *Impact of Heat Waves and Cold Spells on Labour Productivity.* 85

2.6.4 *Adaptation Measures against Heat Waves and Cold Spells.* 87

2.6.5 *Limitation of the Study.* 88

2.7 CONCLUSIONS 90

2.8 ACKNOWLEDGMENTS 91

2.9 REFERENCES **92**

Chapter 3 Assessing farmers' preparedness to cope with the impacts of multiple climate change-related hazards in the Terai lowlands of Nepal **108**

3.1 PREFACE **108**

3.2 ABSTRACT **108**

3.3 INTRODUCTION **110**

3.4 RISK PERCEPTION AND PROTECTION MOTIVATION THEORY **114**

3.5 METHODS **119**

3.5.1 Study area. *119*

3.5.2 Sampling and data collection. *121*

3.5.3 Data analysis. *122*

3.6 RESULTS **125**

3.6.1 Descriptive statistics. *125*

3.6.2 Perceived agricultural risk and current adaptation strategies. *128*

3.6.3 Preparedness to adapt. *129*

3.6.4 Structural equation model fit statistics. *131*

3.6.5 Direct and indirect impacts on risk perceptions. *132*

3.6.6 Direct and indirect impacts on intended adaptation strategies. *134*

3.7 DISCUSSION **137**

3.7.1 Perceived agricultural risk and current adaptation strategies. *137*

3.7.2 Determinants of risk perception. *138*

3.7.3 Determinants of farmers' adaptation behaviour. *141*

3.7.4 Mediation effect of risk perception. *143*

3.7.5 Policy implications. *145*

3.8 CONCLUSION **146**

3.9 ACKNOWLEDGEMENTS **148**

3.10 REFERENCES **149**

Chapter 4 Heat, Cold, and Floods: Exploring Farmers' Motivations to Adapt to Extreme Weather Events in the Terai Region of Nepal 160

4.1 PREFACE 160

4.2 ABSTRACT 160

4.3 INTRODUCTION 161

4.4 THE CONCEPTUAL FRAMEWORK OF PROTECTION MOTIVATION THEORY.. 164

4.5 DATA AND METHOD 168

4.5.1 Study area. 168

4.5.2 Sampling. 170

4.5.3 Questionnaire and variables. 170

4.5.4 Data analysis. 171

4.6 RESULTS 173

4.6.1 Sample description. 173

4.6.2 Implemented and intended adaptation strategies. 174

4.6.3 Number of intended adaptation strategies (adaptation intensity). 177

4.6.4 Determinants of farmers' choices of adaptation strategies. 180

4.7 DISCUSSION 186

4.7.1 Adaptation intensity. 186

4.7.2 Farmers' intended adaptation strategies. 191

4.8 STUDY LIMITATIONS 195

4.9 CONCLUSION 196

4.10 ACKNOWLEDGEMENTS 198

4.11 REFERENCES 199

Chapter 5 Farmers' Interest and Willingness-to-Pay for Index-Based Crop Insurance in the Lowlands of Nepal 209

5.1 PREFACE 209

5.2 ABSTRACT 209

5.3 INTRODUCTION 210
5.4 METHODS 214
5.4.1 Study area. *214*
5.4.2 Sampling method. *215*
5.4.3 An overview of crop insurance in Nepal. *216*
5.4.4 Questionnaire design. *217*
5.4.5 Contingent valuation design. *218*
5.4.6 Designing of bids. *220*
5.4.7 Analysis. *222*
5.4.8 Variables. *225*
5.5 RESULTS 227
5.5.1 Sample description. *227*
5.5.2 General interest for crop insurance and reasons for not participating. *228*
5.5.3 Preferred premium payment options. *229*
5.5.4 Farmers' Willingness to Pay for area-based yield insurance. *229*
5.5.5 Factors affecting farmers' Willingness to Pay. *231*
5.5.6 Other risk management strategies. *233*
5.6 DISCUSSION 234
5.6.1 WTP for rice and wheat insurance. *234*
5.6.2 Factors affecting the uptake of crop insurance. *235*
5.6.3 Reasons for not purchasing crop insurance. *237*
5.6.4 Impacts of premium subsidy on the government's budget. *238*
5.7 CONCLUSION, POLICY IMPLICATION, AND RECOMMENDATIONS 239
5.8 ACKNOWLEDGEMENTS 242
5.9 REFERENCES 243
Chapter 6 Conclusion 254
6.1 CONCLUDING REMARKS 254
6.1.1 Socio-economic impact of and adaptation to extreme heat and cold of farmers. *255*

6.1.2 Assessing farmers' preparedness to cope with the impacts of multiple climate change-related hazards in the Terai lowlands of Nepal. *257*

6.1.3 Farmers' motivations to adapt to extreme weather events. *260*

6.1.4 Farmers' Interest for Index-Based Crop Insurances in the Lowlands of Nepal. *261*

6.2 OVERALL CONCLUSION – LINKING PAPER 1, 2 3 AND 4. .... **262**

6.3 POLICY IMPLICATIONS **264**

6.4 STUDY LIMITATION AND FURTHER RESEARCH **271**

6.5 REFERENCES **274**

Appendices **279**

APPENDIX A: FIGURES **279**

APPENDIX B: TABLES **281**

APPENDIX C: SUPPORTING DOCUMENTS **308**

List of Figures

Figure 1.1: Conceptual Framework 24

Figure 1.2: Sampling framework. HH: Household's head; KII: Key Informants Interview. 27

Figure 1.3: Study areas……………………………………………………………29

Figure 2.1: Study areas. 59

Figure 2.2: Analytical framework. 70

Figure 2.3: Heat wave and cold spell induced health problems. 75

Figure 3.1: Map of the study area. 120

Figure 3.2: Types of risks perceived by farmers (in %; N = 350). 128

Figure 3.3: Current risk management strategies in response to three natural disasters (cold, heat and floods). 129

Figure 3.4: Multilevel structural equation model paths for the preparedness analysis for floods...133

Figure 3.5: Multilevel structural equation model paths for the preparedness analysis for heat waves. 133

Figure 3.6: Multilevel structural equation model paths for the preparedness analysis for cold spells..134

Figure 4.1: An extended framework of Protection Motivation Theory 168

Figure 4.2: Study area. 169

Figure 5.1: Study area. 215

List of Tables

Table 1.1: Composition of Climate change-related Disaster Impact in Nepal (1970-2013). Source: DESINVENTAR (Disaster Information Management System) of UNISDR (United Nations International Strategy for Disaster Reduction)..9

Table 1.2: Sample Design……………………………………………………………...26

Table 2.1: Summary of factors determining the heat and cold stress and related productivity loss. 63

Table 2.2: Sample description (N = 350)..72

Table 2.3: Results of ordered logit model with the dependent variables being the level of heat stress and cold stress (from 1 very low to 3 very high)...76

Table 2.4: Determinants of self-reported labour productivity loss...................................79

Table 3.1: Sample description (N = 350)...125

Table 3.2: Description Of Variables Used In The Model..126

Table 3.3: Most preferred intended adaptation strategies by farmers in the Terai region of Nepal (frequencies in %; N =350). 130

Table 3.4: Results of structural equation model with bootstrapping (n = 1000) for three natural hazards with the dependent variables. 136

Table 4.1: Most preferred intended household and farm level adaptation strategies of EWE based on various characteristics (Frequencies in %; N =350).......................................176

Table 4.2: Results from the Poisson regression model with the number of intended adaptation strategies as dependent variable..179

Table 4.3: Results of the multinomial logit models to explain farmers' intentions to adopt different adaptation strategies in response to flood, heat wave and cold spells. 183

Table 5.1: Bid structure used for paddy rice and wheat against extreme weather events221

Table 5.2: Joint frequencies of the discrete response of WTP questions for Paddy rice and Wheat. 230

Table 5.3: Determinants of Willingness to Pay for Paddy rice and wheat crops by using interval regression..230

Table 5.4: Willingness to Pay for paddy rice and wheat farmers' using DBDC model (in NPR per Kattha per cropping season) (1 ha = 29.58 Kattha). 231

Table 5.5: Implemented risk management strategies for coping with the impacts of EWEs in the study areas (% of respondents). 233

List of Appendicies

APPENDIX A: FIGURES 241

Appendix A.1: Hypothesized model of risk perception of and adaptation intention to natural hazards. 279

Appendix A.2: General mediation model. 280

Appendix A 3: Three most severe perceived risks (% of farmers'). 280

APPENDIX B: TABLES 243

Appendix B.1: Questions on perceived stress from heat and cold and associated productivity loss and health effects.. 281

Appendix B.2: Results of ordered logit model with the dependent variables being the level of heat stress and cold stress (from 1: very low - 3: very high), by district..................... 282

Appendix B.3: Determinants of self-reported labour productivity loss, by district......... 283

Appendix B.4: Correlation matrix of determinants of the perceived level of heat stress (N=350)... 285

Appendix B.5: Correlation matrix of determinants of the perceived level of cold Stress (N=350)... 286

Appendix B.6: Correlations matrix of determinants of perceived labour productivity loss from heat waves (N=350). 287

Appendix B.7: Correlations matrix of determinants of perceived labour productivity loss from cold stress (N=350). 288

Appendix B.8: Impacts of the level of income and level of heat and cold stress on different coping strategies related to heat and cold by bivariate analysis(N=350)......................... 289

Appendix B.9: Definitions and coding of key variables used in structural equation model. 291

Appendix B.10: Sampling Design--292

Appendix B.11: Goodness of fit statistics, Amos SEM outputs. 292

Appendix B.12: Validity of measurement model……………………………………293

Appendix B.13: Definitions of key explanatory variables and their coding used for Poisson and Multinomial regression models of three extreme weather events (heatwaves, cold spells, floods) intended adaptation strategies...295

Appendix B.14: Socio-economics characteristics..296

Appendix B.15: Poisson regression of intended adaptation to the impacts of future floods, heat waves and cold spells. 297

Appendix B.16: Relative Risk Ratio of multinomial Flood, Heat waves and Cold spells adaptation model. 299

Appendix B.17: Questions. 303

Appendix B.18: Single-bound model result..305

Appendix B.19: Descriptive Statistics (n=350). 306

Appendix B.20: Farmers' WTP based on different households characteristics (in NPR). 307

APPENDIX C: SUPPORTING DOCUMENTS 266

Appendix C.1: Consent Form for Key Informants Interview. 308

Appendix C.2: Household Survey Questionnaires. 313

List of Abbreviations

ABC	Atmospheric Brown Cloud
AMOS	Analysis Moment Structures
ASL	Above Sea Level
CBS	Central Bureau of Statistics
CCRPM	Climate Change Risk Perception Model
CFI	Comparative Fit Index
CRI	Climate Risk Index
CV	Contingent Valuation
CVD	Cardiovascular Diseases
DBDC	Double Bounded Dichotomous Choice
DDRC	District Disaster Relief Committee
DHM	Department of Hydrology and Meteorology
DESINVENTAR	Disaster Information Management System
EWES	Extreme Weather Events
GDP	Gross Domestic Product
GHGs	Green House Gas Emissions
GoN	Government of Nepal
HHs	Household's Head
HDI	Human Development Index
IIA	Independence of Irrelevant Alternatives
IPCC	International Panel on Climate Change
IRR	Incidence Rate Ratio
MNL	Multinomial Logit Model
MoAD	Ministry of Agricultural Development
MoF	Ministry of Finance

MoHA	Ministry of Home Affairs
MSP	Minimum Support Price
NGO	Non-Governmental Organization
NPR	Nepalese Rupees
NRB	Nepal Rastra Bank
PMT	Protection Motivation Theory
RCP	Representative Concentration Pathways
NCVST	Nepal Climate Vulnerability Study Team
RMSEA	The Root Mean Squared Error of Approximation
RRR	Relative Risk Ratio
SBDC	Single Bounded Dichotomous Choice
SD	Standard Deviation
SEM	Structural Equation Modeling
SoVI	Social Vulnerability Index
SRMR	Standardized Root Mean Square Residual
STATA	Software for Statistics and Data Science
TLI	Tucker Lewis Index
UCLA	University of California Los Angeles
UNISDR	United Nations Office for Disaster Risk Reduction
USD	United States of America Dollar
VIF	Variance of Inflator Factor
WBGT	Wet Bulb Globe Temperature
WRI	Water Resources Institute
WTP	Willingness to Pay

Chapter 1 Introduction

A changing climate leads to changes in the intensity, frequency, duration and timing of extreme weather and climatic events, which in turn is more likely to increase unprecedented extreme weather and climatic events (IPCC, 2012; Stott, 2016). Extreme events lead to disaster risks after interaction with human and enviornmental factors (IPCC, 2014).

Climate change and its effects are accelerating across the globe (Linton et al., 2019), with the effects of climate change-related extreme weather events threatening severe and disproportionate impacts on people living in low-income countries, compared to high-income countries (De Silva & Kawasaki, 2018; Diffenbaugh & Burke, 2019). A disaster is a defined as a hazardous event, which presents actual significant economic impacts to the society, while a hazard represents potential threat to the people and community due to humans and their activities being exposed to the natural events (Montz, Tobin, & Hagelman, 2017). The various factors attributed to the disproportionate impacts on these countries consist of adverse geographical conditions, excessive dependence on the climate-sensitive agriculture sector, and limited human, institutional, and financial capacities to anticipate and respond to the direct and indirect effects of climate change (Adger, 2006; Brooks, Adger, & Kelly, 2005; Morton, 2007; Hallegatte, Fay, & Barbier, 2018; De Silva & Kawasaki, 2018; Diffenbaugh & Burke, 2019). Moreover, most of the people in low-income countries reside in tropical and volatile climatic regions, where additional warming has adverse impacts on health and productivity (Hsiang et al., 2017; Zorn, 2018; Duffy et al., 2019). Vulnerability is highest in the least developed countries with the fewest resources, which are likely to bear the greatest burden of climate change (Thomas et al., 2019). Due to the persistent adaptation gap, current climate change imposes a significant social and economic burden to a country's population, and the changing climate is increasingly likely to have additional future impact in the low-income countries (Carleton & Hsiang, 2016). Another problem is that nearly two-thirds of low-income countries that contribute a tiny fraction of world carbon emissions are acutely vulnerable to the effects of carbon emissions, while more than half of the highest emitting countries are ranked among the least vulnerable to climate change (Althor, Watson, & Fuller, 2016; Diffenbaugh & Burke, 2019).

Human activities have caused global warming of approximately 1 °C, and without climate change mitigation, it is estimated to increase by 1.5°C between 2030 and 2052 (IPCC, 2018). The climate has also become more volatile, with more frequent extreme weather events (EWE) and more extreme temperatures (Stott, 2016; Yin et al., 2018). Nearly a billion people have faced high exposure to climate change effects (Institute for Economics & Peace, 2019), which have had significant social and economic impacts on both people and nations. During the past two decades (1998-2017), around half a million people have died as direct results of approximately 11,500 EWEs. The economic damage of EWEs has been estimated at USD 3.47 trillion (Eckstein, Hutfils, & Winges, 2018).

The agricultural sector is the most sensitive to climate change because it is highly weather dependent, and thus more prone to be adversely affected by natural hazards arising from extreme events (Lesk, Rowhani, & Ramankutty, 2016; Pachauri et al., 2014). It is also the sector upon which most people in low-income countries rely (Handmer et al., 2012), with nearly one-third of the total losses and damages in agriculture in low-income countries being caused by EWEs (FAO, 2015). Climate change is expected to lead to more EWEs, such as droughts and floods (Watts et al., 2018) and particularly extreme heatwaves and drought, which were found to have reduced cereal production by 9-10% across the globe from 1947 to 2007 (Lesk et al., 2016). Global maize and wheat production have declined by 3.8% and 5.5% respectively since 1980 (Lobell, Schlenker, & Costa-Roberts, 2011). Rice, wheat, and maize production in the temperate and tropical regions are more likely to be negatively affected by the temperature increases to 2°C or above in the late twentieth centuries (Pachauri et al., 2014). Further, Pachauri et al. (2014) stated that declining major cereal crop production would destabilise the food system and jeopardise local and global food security.

1.1 Nepal's Changing Climate

South Asia is one of the poorest regions on Earth after sub-Saharan Africa (Thirtle, Lin, & Piesse, 2003). By 2050, an additional 2.4 billion people will be living in low-income countries predominantly in South Asia and sub-Saharan Africa, where, on average, 20% of the total population of these regions currently has an insecure food situation (Wheeler & von Braun, 2013). South Asia is a highly vulnerable region on the climate risk index (CRI)[1]. Based on the magnitude, frequency, and severity of flooding events, the South Asian region is more likely to be adversely affected in the coming

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[1] Calculating from three indices consist of fatalities per thousands of inhabitants, total damages and losses (USD million), and losses as percentages of GDP as a result of extreme events as prepared by Eckstein et al. (2018).

years, which will cause significant damages to property, infrastructure, and agricultural products and lives (Mirza, 2011; Christensen et al., 2013; Bell et al., 2016).

Nepal is the fourth most vulnerable country to climate-induced natural hazards due to the unique topography and ecological diversity (Maplecroft, 2010; Shrestha & Aryal, 2011; Karki et al., 2018). It is ranked as the eleventh most affected country over the last two decades (1997-2017) and the fourth most affected country in 2017, based on the CRI (Eckstein et al., 2018). It has also been ranked sixth in flood vulnerability (Christenson, Elliott, Banerjee, Hamrick, & Bartram, 2014). Though Nepal's population accounts for only 0.04% of the global population and contributes to only 0.025% of the global Greenhouse Gas emissions, it is disproportionately affected by climate change compared to other nations (GoN, 2011).

The average temperature in Nepal is rising at a higher rate than the global average, with a 1.8 °C increase between 1975 and 2006 (Shrestha, Wake, Mayewski, & Dibb, 1999; Malla, 2009). Between 1977 and 1994 the average warming was 0.06 °C per year (Shrestha & Aryal, 2012). On average, the minimum and maximum annual temperature in Nepal has increased by 0.41 °C and 1.5 °C, respectively, between 1980 and 2014 (Budhathoki & Zander, 2019a), and annual average maximum temperature has been predicted to increase by 0.82 °C, 1.35 °C, and 2.29 °C by 2090 under the Representative Concentration Pathways (RCP) 2.6, RCP 4.5, and RCP 8.5 scenarios, respectively (Khadka & Pathak, 2016). Similarly, the annual average minimum temperature has been predicted to rise by 0.87 °C, 1.44 °C and 2.43 °C by 2090 for the RCP 2.6, RCP 4.5, and RCP 8.5 scenarios, respectively. A rise in temperature and precipitations could have both beneficial and harmful impacts on crop yields based on crop varieties and altitudes (Poudel & Kotani, 2013). The average temperature has been predicted to rise significantly by 0.5 to 2.0 °C by 2030 (NCVST, 2009), 1.3 to 3.8 °C by 2060, and by 1.8

to 5.8 °C by 2090 (McSweeney, Lizcano, New, & Lu, 2010). Based on the baseline average (1961-1990), the projected warming is 1.2 °C for 2030, 1.7 °C for 2070 and 3.0 °C for 2100 (Shrestha & Aryal, 2011). However, the mean annual precipitation for Nepal does not show a clear trend with reference to both increases and decreases: -34% to +22% by the 2030s; -36% to +67% by the 2060s; and -43% to +80% by the 2090s (NCVST, 2009).

Several different types of EWEs have been reported in Nepal since 1970, causing significant physical damage and deaths (UNISDR, 2013). This study further identified landslides, floods, cold spells, thunderstorms, and heatwaves as the most common and most severe EWEs in the region. In my research area in the Terai lowlands, floods, cold spells, and heatwaves have been the most severe climate-related events, resulting in considerable damage. Therefore, I focused on these three events in my thesis which I explain in more detail in Section 1.2. Moreover, as climate changes, the occurrences of heatwaves and cold spells have become more frequent in recent years, particularly in the Terai lowlands, and have been predicted to further increase (Gentle, Thwaites, Race, & Alexander, 2014).

1.2 Extreme Weather Events

Cold spells are a relatively new weather phenomenon in Nepal, where the frequency and intensity of this phenomenon have been triggered by climate change, particularly after 1990 (Budhathoki, Lassa, Pun, & Zander, 2019). Although increase in temperature is comparatively low in the lowlands, prolonged fog related cold spells is causing significant threat to the population of the warmest part of the country during winter

(Karki et al., 2020). There are various approaches to define cold spells, which differ from country to country. Hicky (2011) defined cold spells as "*a period consists of 10 consecutive days when the minimum air temperature was 5°C or more below normal*".

In Nepal, cold spells, also known as 'Sitlahar' in the Terai region (Budhathoki & Zander, 2019b), are characterised by a rapid decline in maximum temperature to 10-15 °C during the winter season in the lowlands, where such a trend continues for over 24 hours. During cold spells, most of the Terai region is covered by thick fog and smog lasting for several days, resulting in significant winter cooling due to the increased stability of lower atmosphere during winter and post-monsoon seasons (Karki et al., 2020). Cold spells in Nepal and the foothills of the Himalayan region are also attributed to regional air quality problems - Atmospheric Brown Clouds (ABC). The thick haze and fog formed in Indo-Gangetic Plain in the winter season is a result of industrial pollution in northern India (Saikawa et al., 2019). They further stated that during winter, temperatures over the Indo-Gangetic plains (IGP) are cold. A layer of cool air is trapped near the ground under a layer of warm air. This condition suppresses the normal tendency of pollutants to rise and disperse over a wide area, trapping them instead in a relatively shallow boundary layer and causing winter haze to be optically thick (Tare et al. 2006). The build-up of the haze, which is sometimes referred to as atmospheric brown cloud (ABC), starts in the post-monsoon season when, after the rice harvest, paddy residue is burned across large parts of the region (Saikawa et al., 2019). The resulting anomalous cold conditions are usually referred to as sheet lahar (cold spells) in many parts of the IGP including Nepal.

In between 2001 and 2010, nearly 262 cases of cold spells were reported, about 376 people were killed, and approximately 2,000 people were affected (MoHA, 2018). MoHA (2018) further mentions that, on average, 42 people die because of cold spells each year. In Banke and Bardiya districts, 15 and 4 cases of cold spells were reported respectively between 2000 and 2013, and 4 deaths in Bardiya and 12 deaths in Banke districts were reported in the same period (UNISDR, 2013).

Heatwaves are defined as ‘‘*a periods of unusually hot dry or hot humid weather compared to a threshold value near the upper end of the range of observed values of the variables in the region and lasts for, at least, 2-3 days*” (Smith, Zaitchik, & Gohlke, 2013). The temperature threshold above which a heatwave is defined varies widely across the world; Heatwaves are locally known in the Terai lowlands region of Nepal as ‘loo’, which prevail in the hot summer months, and are identified by the temperatures remaining above 40 °C for at least 2 to 3 days (Budhathoki & Zander, 2019). Increasing mean and extreme temperatures affect the agriculture sector (by crop failure due to drought caused by excessive dryness and high evaporation) and water resources (Karki et al., 2020). Watts et al. (2018) reported that an additional 125 million vulnerable people were exposed to heatwaves between 2000 and 2016, due to temperature increases, which were estimated to have reduced global outdoor labour productivity by approximately 5.6% over the same period.

Floods are defined “*as the overflowing or failing of the normal confines of a river, stream, lake, canal, sea or accumulation of water as a result of heavy precipitation where drains are lacking or their discharge capacity is exceeded”* (Douben & Ratnayake, 2006). It can have indirect impacts, such as compromising water provisioning, ecosystem disruption, infectious diseases outbreak, and long term post-traumatic stress, besides the direct impact of physical damage to crops, infrastructure, or to the population (Bell et al., 2016). In Nepal, 3,953 cases of floods were reported between 1971 and 2013, which caused 3,538 deaths, injured 547 people, destroyed nearly 100,000 houses and damaged another 100,000; and, affected around half-a-million people overall (UNISDR, 2013). Likewise, UNISDR (2013) further reported that more than half a million cattle were lost, and the total property damage cost around USD 6,076 million, while 244 thousand hectares of crop land were destroyed (Table 1.1). It is estimated that additional 200,000 people will be affected annually by 2030 due to river floods in Nepal (WRI, 2015). Based on the district wise disaggregated data, 30 and 40 cases of floods were reported respectively between 2000 and 2013, resulting in 11 deaths, 6,726 families affected, and 372 houses destroyed in Banke, and 10 deaths, 27,472 families affected and 6,745 houses destroyed in Bardiya district over the same period (UNISDR, 2013).

Events	Frequency	Death	Injured	Houses Destroyed	Houses Damaged	Victims	Affected	Relocated	Local Losses (Million USD)	Crop Damage (Ha; 000)	Lost Cattle
Total	11,321	1,0881	6,050	119,854	151,254	216	5,411,776	220,108	12,035	941.8	560,161
Cold spells	647	822	83	0	0	0	2405	0	835	26.9	732
Drought	160	0	0	0	0	0	1625	0	12	412.8	0
Flood	3,953	3,538	547	96,418	103,318	0	4,453,647	178,548	6,076	243.1	538,324
Frost	6	7	0	0	0	0	0	0	457	5	0
Hail storm	763	65	102	208	1,636	0	213,475	0	2,228	132.9	943
Heatwave	49	45	20	0	0	210	381	0	0	0	250
Landslide	3,208	4,658	1,714	18,897	34,126	6	597,334	26,217	1,179	22.6	10,798
Rains	256	96	44	791	2,319	0	69,636	4,687	379	70.6	5,174
Snow storm	194	82	44	102	59	0	13,750	4,700	2	1.9	882
Storm	123	52	283	1022	566	0	2,397	0	25	0.1	358
Strong wind	508	184	497	2,056	8,712	0	46,079	5,739	803	25.9	1,140
Thunderstorm	1,453	1,332	2,716	360	518	0	11,047	108	39	0	1,560

Table 1.1: Composition of Climate change-related Disaster Impact in Nepal (1971-2013). Source: DESINVENTAR (Disaster Information Management System) of UNISDR (United Nations International Strategy for Disaster Reduction).

1.3 Nepal's Agricultural Sector

Approximately 17% of the total area of Nepal is used for agriculture (CBS, 2011). Agricultural land comprises approximately 2.5 million hectares with cropping intensity varying from one to three crops per year, with only 20% of the total agricultural area under irrigation. Agriculture, forestry, and fisheries contribute to almost 35% of Nepal's gross domestic product (MoF, 2018), with approximately 74% of Nepalese workers engaged in the agriculture sector, making it a significant source of employment (CBS, 2009). Despite high dependence on the agricultural sector, Nepal is a net food importer, constantly struggling with food shortages (Pyakuryal, Roy, & Thapa, 2010). Though Gentle & Maraseni (2012) suggest the agriculture sector of Nepal is highly vulnerable to climate change related weather due to higher dependence on the rain-fed weather system, Budhathoki & Bhatta (2016) suggest that these studies may be undermined by socio-economic variables and practices that differ between farms due to levels of farming and their socio-economic characteristics.

As there have been very few studies completed in Nepal, this thesis is important because it focus on how farmers' labour productivity have been compromised in recent years due to the extreme temperature. Increasing cold spells and heatwaves have been shown to result in significant health problems to members of farming households and to cause a huge reduction in labour productivity (Budhathoki & Zander, 2019). Reduction in labour productivity in turn affects agricultural productivity at the household level. Nepalese farmers are highly exposed to threats resulting from climate change (Shrestha & Aryal 2011; Gentle et al., 2014). Variation in both temperature and rainfall has negative impacts on crop production in Nepal, with the severity of the impacts varying across regions and jeopardising farmers' livelihoods (Chalise, Naranpanawa, Bandara, & Sarker, 2017; Budhathoki & Zander, 2020). Karn (2014) found that rice yield is expected to decline by 4.2% relative to current production level by 2100 under a doubled CO_2 scenario. A study by Shrestha & Aryal (2011) further revealed that a 4.0 °C temperature increase combined with a 20% precipitation rise, marginal yield could be increased between 0.1 to 7.5%, but beyond that threshold, yield will decline.

Nepal has three primary agro-ecological regions: Terai lowlands, hills and mountain region. Terai region extends 800 km from east to west and 30-40 km south to north with an elevation range from 100-300 metres above sea level (a.s.l), while the hill region constitutes nearly 68 % of the total land of Nepal with altitudes ranging from 250-1500 m a.s.l. To the north is the mountain region which extends to over 8000 M.a.s.l. It has been predicted that increases in both temperature and CO_2 levels may increase rice production in the hills and mountains of Nepal by more than 16% by 2080 (Ahmed & Suphachalasai, 2014). However, in the Terai lowlands, rice yield may be more likely to decline because the maximum temperature is already above the threshold level of 29 °C, the maximum temperature that rice can tolerate (Karn, 2014). However, a similar study conducted by Joshi, Maharjan, and Piya (2011) revealed that an increase in both summer rain and maximum temperature has contributed positively to rice, but negatively to maize and millet yields.

1.4 Socio-Economic and Health Impacts of Extreme Weather Events

Globally, climate change leads to health issues and disease outbreaks, and its impact is more pronounced on marginally poor and disadvantageous communities (Sherwood, Huber, & Emanuel, 2010; Ung, Luginaah, Chuenpagdee, & Campbell, 2017). The severity and extent of health effects associated with EWEs depends on their physical impacts and timing as well as other social, environmental, and human circumstances (Bell et al., 2016).

Heatwaves results in serious health issues ranging from mild heat stress[2] symptoms, such as headaches and fatigue, to severe heat strokes and fainting (Kovats & Hajat, 2008; Basu, 2009). Old and poor people with illnesses (Basu, 2009; Ng et al., 2014), agricultural workers, and menial labourers will be most profoundly affected by heat stress (Lundgren, Kuklane, Gao, & Holmer, 2013; Subhashis, Moumita, & Kjellstrom, 2013). Heatwaves and increasing temperatures can also cause the occurrence of vector-borne diseases in areas where these diseases have not before occurred (Haines, Kovats, Campbell-Lendrum, & Corvalán, 2006).

Besides the health implications, heatwaves also impact general well-being and labour productivity (Kjellstrom, Kovats, Lloyd, Holt, & Tol, 2009; Lundgren et al., 2013; Kjellstrom, Lemke, Hyatt, & Otto, 2014). High heat exposure caused heat strain and reduced labour productivity of rice harvesters in India by 5% in bundle collection per 1 °C increase in Wet Bulb Globe Temperature (WBGT; Subhashis et al., 2013). Besides a reduction in labour productivity and farmers' income, heatwaves can also lead to higher accident rates due to extreme heat exposure when working outside (Morabito, Cecchi, Crisci, Modesti, & Orlandini, 2006; Tawatsupa et al., 2012).

So far, only one study has taken place in Nepal concerning the response of working people in the Terai region to heatwaves. This occurred when the average temperature reached approximately 39 °C during the hot summer months (Pradhan et al.,

[2] Heat stress is determined by various factors which consist of air temperature, humidity, radiant heat, wind speed, and metabolic heat generated by physical activities and clothing effect which moderates heat exchange between body and environment (Rowlinson, Yunyanjia, Li, & Chuanjingju, 2014).

2013). The study found that men had more exposure to heat stress than women due to the substantial outdoors nature of their work, and that no coping mechanisms had been applied due to the unavailability of adequate facilities and infrastructures (Karki et al., 2020). Heat also reduced work performance in Germany, resulting in an estimated output loss of between 0.1% and 0.5% of the gross domestic product (Hübler, Klepper, & Peterson, 2008).

Likewise, cold spells are considered a severe health threat to the people living in the Terai lowlands. Cold-related diseases, such as viral flu, coughs, colds, diarrhoea, asthma, pneumonia, and other respiratory problems, are common during these events (Goutam, 2014). Cold spells can cause cardiovascular diseases, mortality, and morbidity (Urban, Davídkovová, & Kyselý, 2014). Generally, older and underprivileged rural people, and those who live in the moderate winter temperatures reported being profoundly affected by variations in cold winter temperatures (Conlon, Rajkovich, White-Newsome, Larsen, & O'Neill, 2011).

As with heatwaves, the labour productivity of farmers can be affected by cold spells. While most studies (Kjellstrom et al., 2009; Lundgren et al., 2013; Kjellstrom et al., 2014), focused on the reduction in labour productivity from only heat, a study by Dicpinigaitis, Eccles, Blaiss, & Wingertzahn (2015) revealed that cold-related diseases, such as cold cough, had a pronounced impact on daily activity, productivity, and absenteeism.

Many studies have investigated how people perceive the health risks resulting from climate change, both in developing (Haque, Yamamoto, Malik, & Sauerborn, 2012; Ng et al., 2014; Mishra et al., 2015; Kabir, Alauddin, & Crimp, 2017) and developed countries (Akompab et al., 2013; Bélanger, Gosselin, Valois, & Abdous, 2014; Xiang, Hansen, Pisaniello, & Bi, 2016). These studies found that perception has a substantial impact on health behaviours that ought to be changed and further argued that to protect themselves from such climatic impacts, farmers must first perceive that the climate has changed significantly, and then identify useful adaptation and coping mechanisms to respond to those hazards (Ung et al., 2017). Ung et al. (2017) reported that those farmers who perceived the socio-ecological impacts of climate change did not necessarily protect themselves and their health, but that there were other factors, such as the availability of financial and health services, that played a crucial role as well. Ung et al. (2017) further found that food-insecure households and individuals who perceived more barriers to physical activities were less likely to report good health.

Disaster risk reduction strategies should be introduced to reduce socio-economic vulnerabilities to disasters, as well as other environmental problems and hazards that may trigger vulnerabilities. Implementation of these strategies may help to identify, assess, and reduce the risks associated with natural hazards (De Silva & Kawasaki, 2018).

1.5 Disaster Risk Perception and Adaptation

Farmers' perceptions of climate change related risk have been found to be an important determinant of adaptive decision making (Patt & Schröter, 2008; Mertz, Mbow, Reenberg, & Diouf, 2009; Deressa, Hassan, & Ringler, 2011; Bubeck, Botzen, & Aerts, 2012; Budhathoki & Zander, 2020). Risk perception and awareness of natural hazards are essential for undertaking climate change-related precautionary adaptation measures; people who do not perceive the risk of climate-related hazards are less likely to adopt future disaster preparedness measures (Paton, Smith, & Johnston, 2005; Weber, 2010).

Risk perception and the risk patterns of slow-onset hazards significantly differ from that of sudden-onset hazards (Birkmann & Welle, 2015). Slow-onset hazards have creeping impacts, allowing farmers plenty of time to plan and respond with potentially slower preparedness and adaptation strategies, while rapid or sudden-onset hazards have an immediate impact on the community and the occurrence of these phenomena is generally sudden and unpredictable.

1.5.1 Relationship between environmental hazard, risk perceptions, impacts, and adaptation.

Leiserowitz (2006) found that risk perception is a subjective judgment profoundly affected by mental assessment, such as fears or concern about the occurrence and damage of future extreme events, more than analytical assessment of the likelihood of these phenomena occurring. Other studies assumed that risk perception is driven by psychological, socio-cultural factors, values, and norms, thereby to mitigate the loss of potential damage resulting from extreme events, proper risk communication requires exchanging, sharing, and integrating climate change risks among concerned stakeholders (Lavell et al., 2012; van Der Linden, 2015). Existing exposures and vulnerability also determine risk perception of hazards, such that an individual who has exposure to hazards might not be vulnerable because they have sufficient means to mitigate the potential losses (Cardona et al., 2012). Cardona et al., (2012) further explained that individuals and communities have different exposure and vulnerabilities based on socioeconomic, geographical, health, demographical, institutional, cultural, and environmental factors. Among other determinants of risk perception, prior direct damage experience of natural hazards is the main determinant (Demski, Capstick, Pidgeon, Sposato, & Spence, 2017) that can increase and decrease future adaptive action.

Risk perception is only one predictor of precautionary mitigation behaviours; factors such as socio-economic variables, experience, and knowledge about and concern for hazards can also strongly influence mitigation measures (Bubeck, Botzen, Aerts, Bubeck, & Kreibich, 2012). Based on the Protection Motivation Theorem (PMT), people will protect themselves against the impacts of EWEs if they assume that the threat and coping appraisals are high (Rogers, 1975). In the same line, it is argued that risk perception and perceived adaptive capacity are the two most important determinants of private response to climate change related hazards (Grothmann & Patt, 2005). Differences in the characteristics of natural hazards, for instance, the severity and frequency of EWEs may also lead to differences in the relationship between risk perceptions and precautionary behaviour (Bubeck et al., 2012).

Previous studies have focused on the risk perception of single hazards, including sudden-onset hazards such as floods or typhoons (Grothmann & Reusswig, 2006; Poussin, Botzen, & Aerts, 2014) or slow-onset hazards such as heatwaves and droughts (Gebrehiwot & van der Veen, 2015; Keshavarz & Karami, 2016). Other studies have investigated the risk perceptions of climate change impacts in general (Manandhar, Vogt, Perret, & Kazama, 2011; Bryan et al., 2013; Roco, Engler, Bravo-Ureta, & Jara-Rojas, 2015).

There is a growing number of empirical studies from other parts of the world on the relationship between individual risk perception of EWEs and adaptation behaviour (Grothmann & Reusswig, 2006; Zaalberg, Midden, Meijnders, & McCalley, 2009; Poussin et al., 2014; Richert, Erdlenbruch, & Figuières, 2017). However, there is a dearth of studies on the assessment of farmers' perceptions and their responses to the risk of

EWEs in Nepal. This study, therefore, focuses on understanding multiple hazards, including both sudden- and slow-onset hazards and the associated risks that farmers within the study area have faced, as well as identifying the socio-psychological factors that influence farmers' intended behaviour changes to efficiently implement hazard-specific disaster risk management in the future.

There have been a few studies from Nepal on livelihood vulnerability to climate change in the past decade (Devkota, Maraseni, Cockfield, & Devkota, 2013; McDowell, Ford, Lehner, Berrang-Ford, & Sherpa, 2013; Aryal, Maraseni, & Cockfield, 2014; Panthi et al., 2016; Piya, Joshi, & Maharjan, 2016; Gerlitz et al., 2017). Similarly, there is a lack of studies on the impact of cold spells on farmers' self-reported labour productivity loss, and of studies comparing the impacts of extreme temperatures (heatwaves and cold spells) on labour productivity loss. This thesis will be listed among the few empirical studies to examine the factors that affect farmers' adaptation measures related to multiple EWEs instead of a single event or to climate change in general. In observing the impact of extreme temperature (both heatwaves and cold spells), both on farmers' self-reported labour productivity loss and health problems, and their existing coping mechanism to minimise the loss of cold spells and heatwaves at the farming household level, it becomes possible to gauge and improve the systems in place to prevent such losses.

One gap is that most previous studies were focused on climate change in general or focused on single rapid or slow onset hazards. But this study has attempted to identify the how psychological factors along with other socio-economic factors have affected farmers' behavioral response (preparedness intention) across slow and rapid onset hazards. The importance of this preliminary research into the disaster management strategies of Nepal is to inform understanding of the range of temporal hazard issues that need to be considered and to support the development of disaster management thinking beyond the contemporary concentration of efforts directed to rapid onset hazards such as floods. The inclusion of data on slow onset hazards is also necessary to provide input into the challenges associated with slow onset events. One such issue is the so-called "boiling frog syndrome." This phenomenon describes how, with slow onset events, people will assimilate changes as they tend to be relatively small at each point in time, but when the changes reach a tipping point, it is too late for preventative/ precautionary activity and populations become reactive. This work can inform the development of national adaptive strategies for slow onset events that might otherwise lead to more significant future problems. Moreover, disaster management policy has been targeted for response and recovery, rather than mitigation and preparedness, and ignoring slow onset hazards and preparation for them, despite the plight of locals in the lowland Terai region.

A better understanding of the variables that influence farmers' risk perception the coping mechanisms that would work for their situations would be beneficial for farmers to cope with disaster. Those farmers who were found to be well prepared were less stressed during disasters. Even the smallest advancement could save lives and reduce the negative consequences of disasters, including significantly reducing psychological and physical stress. However, to formulate and implement effective adaptation measures at a local level and to reduce farmers' vulnerability, policy-makers in Nepal need a better understanding of the perceived risks of the main EWEs and should identify the most preferred and feasible adaptation strategies both now and in the future. Governments have limited funds to spend in disaster management and relief after an EWE occurrence; having better information about the economic and social impacts on farmers' and their production systems can guide efficient investment. In addition to governmental sectors, this information could also be useful to NGOs and other donors.

1.5.2 Insurance as an adaptation.

Different disaster risk management approaches, such as risk-sharing, vulnerability reduction, transformation, preparedness, response and recovery, increasing community resilience, and exposure reduction overlap or interlink with each other to reduce the risk of extreme events (Lal, Mitchell, Mechler, & Hoch Rainer-Stigler, 2012). Among these strategies, agricultural insurance is a risk-sharing or transferring tool of disaster risk reduction strategies for the farming community, allowing for loss recovery after disasters (Cutter et al., 2012). Despite substantial financial subsidies on insurance premiums in Nepal, the uptake of agricultural insurance is low (Budhathoki et al., 2019).

The preparedness approach presents an opportunity to anticipate problems and devise protective strategies to be performed prior to disasters. These pre-disaster activities focus on limiting the negative impact of disasters on people, property, and the environment (Mileti, 1999).

Few studies have dealt with farmers' adaptation to floods in Nepal, and no studies, thus far, have investigated the potential of crop insurance, despite the Nepalese government having introduced a crop insurance scheme in recent years. This study is the first to analyse whether crop insurance is an acceptable tool against EWEs in Nepal. It also fills the knowledge gap of understanding farmers' willingness (or reluctance) to participate, as is the case with the newly established crop insurance scheme. The results of this study will help the Nepalese Government set appropriate and fair insurance premiums that will be generally accepted by farmers', thereby helping increase farmers' participation in the insurance market.

1.6 Research Objectives

The overall objective of this thesis is to assess the impact of three extreme weather events – floods, heat waves, and cold spells – on the economic and social wellbeing of farmers' in the Terai lowlands of Nepal and their potential adaptation strategies.

The specific objectives are: to assess the impacts of heat waves and cold spells on farmers' health and labour productivity; to explore how farming households in the Terai lowlands region of Nepal have adapted in the past and intend to adapt to the impacts of floods, heat waves, and cold spells; to identify the factors that influence farmers' intensity and choice of intended adaptation – measured by the number of intended adaptation strategies – to these three EWEs; and to assess farmers' general interest in participating in an index-based insurance scheme.

1.7 Significance of this Study

The outcome of this study will inform the public and policymakers in understanding the outcome and implication of EWEs. In addition, it will assess how future EWEs are likely to pose increasing risks to life and property in certain regions. Event-specific studies related to climate change can be a tool for informing choices about assessing and managing risk and guiding adaptation strategies. Such information may be crucial to multiple decision-makers who focus on disaster risk reduction. The findings of this study can be used to understand the socio-economic impact of climate change on vulnerable farmers in low-income countries. In addition, it will also contribute to filling knowledge gaps in the existing literature.

1.8 Methodology

1.8.1 Framework.

Integrated conceptual frameworks have been presented in Figure 1.1, which combines the theoretical conceptual framework of Chapters 2 to 5. The study framework consists of the four components of 1) extreme weather events related to climate change, 2) risk perception and adaptation process of these three EWEs, 3) socio-economic impacts of these EWEs on farmers' households, and 4) market potential of agricultural insurance as a risk-sharing strategy for disaster risk management in Nepal. The straight lines show the interaction between the four components of the conceptual framework. Firstly, the study examines how these EWEs have affected farmers' socio-economic condition, including health and labour productivity (Chapter 2). The upper part of the diagram focuses on the causal and direct determinants of risk perception of extreme events (Chapter 3) and disaster preparedness strategies (Chapters 2, 3, and 4). Secondly, the study aims to unravel the acceptability and potential of agricultural insurance as a viable effective and efficient disaster risk management strategies in western low-lying Nepal (Chapter 5).

The determinants of risk perception and preparedness intention against EWEs' section of following theoretical framework show how various factors have impacted farmers' risk perception of EWEs over the last decade, and how these factors, along with the risk perception of EWEs will affect farmers' preparation to take various adaptation measures in the future as indicated by arrows shown in the middle section of the following diagram. At the same time, it displays how these EWEs have a direct or indirect socio-economic impact (on farmers' health and labour productivity) through the adaptation process, as mentioned in Chapter 2. Likewise, the 'Determinates of WTP for crop insurance' section depict the factors influencing willingness to pay (WTP) for agriculture insurance as one of the risk-sharing preparedness strategies against extreme events.

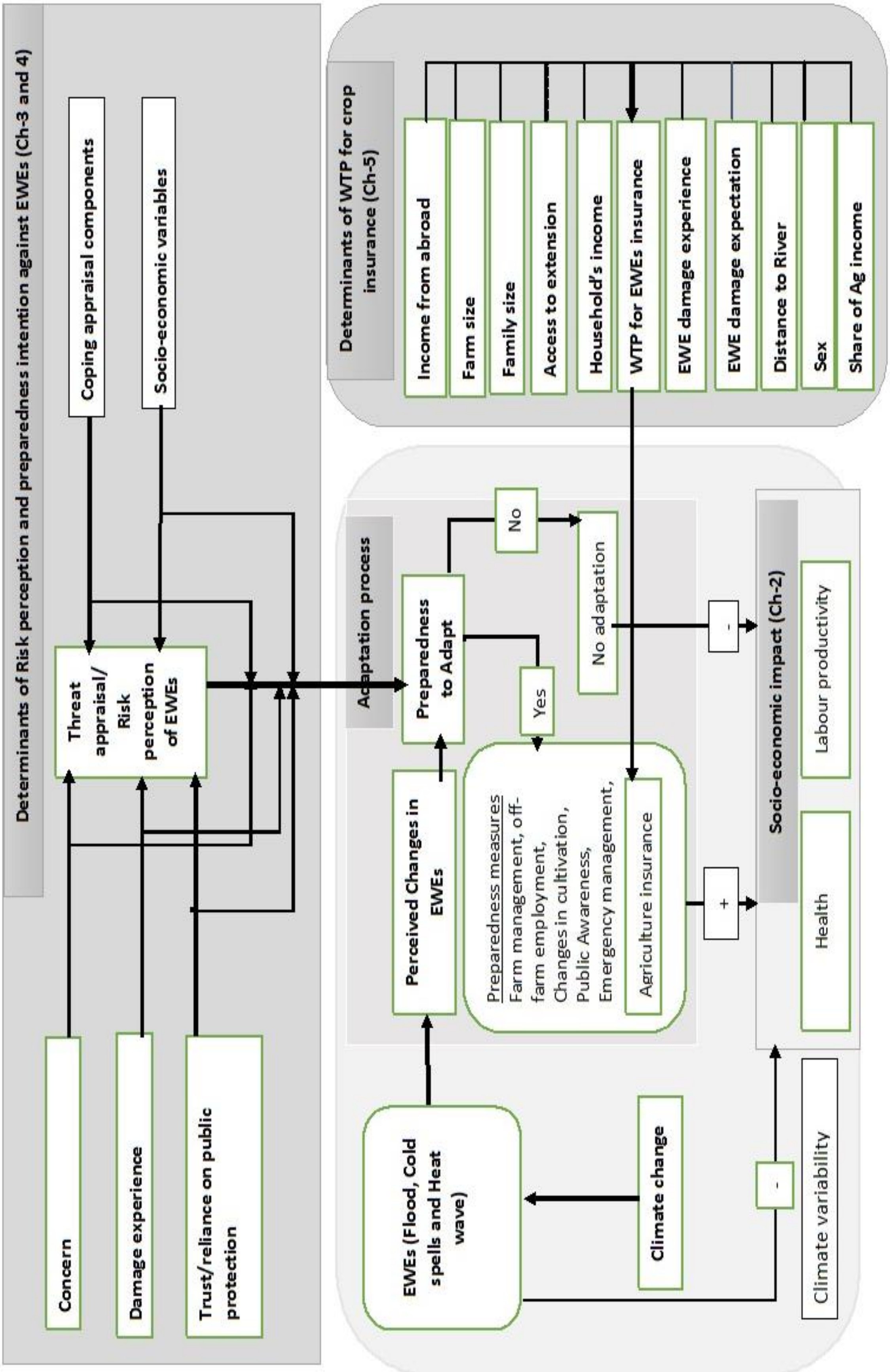
Determinants of Risk perception and preparedness intention against EWEs (Ch-3 and 4)
Coping appraisal components
Socio-economic variables
Threat appraisal/ Risk perception of EWEs
Concern
Damage experience
Trust/reliance on public protection
Determinants of WTP for crop insurance (Ch-5)
Income from abroad
Farm size
Family size
Access to extension
Household's income
WTP for EWEs insurance
EWE damage experience
EWE damage expectation
Distance to River
Sex
Share of Ag income
Adaptation process
Preparedness to Adapt
No
No adaptation
Yes
Perceived Changes in EWEs
Preparedness measures
Farm management, off-farm employment, Changes in cultivation, Public Awareness, Emergency management,
Agriculture insurance
-
+
Socio-economic impact (Ch-2)
Labour productivity
Health
EWEs (Flood, Cold spells and Heat wave)
Climate change
-
Climate variability

Figure 1.1: Conceptual Framework

1.8.2 Sampling and primary data collection.

This thesis applies a primary survey dataset to analyse the study. For the primary survey, a comprehensive household's survey was designed, organised and, using multistage sampling, conducted with 350 agricultural households from two representative districts in the western lowlands of the Terai region of Nepal. The survey was conducted between November 2017 and January 2018 by three experienced and trained research assistants who spoke Nepali, the primary language used for the survey, and who could also understand Tharu and the local dialects. A structured questionnaire was used, which was first pre-tested with 15 respondents randomly selected from villages near the study area. The pre-tested questionnaire was revised to ensure its quality and to avoid an information gap in the field.

Based on others literatures including a climate change survey of CBS (2016) and discussion with national-level stakeholders, the low lying Banke and Bardiya districts of the western Terai region were selected. Collecting data from badly affected areas increases opportunities to tap into experiences and perceptions shaped by high levels of awareness of current and future issues. The officials confirmed the severe impact of extreme weather in recent years and their fear for increasing damage as the climate changes. From these two districts, two municipalities and six respective wards (one municipality from each district and three respective wards from each municipality) were selected after consulting district and village level stakeholders, based on the magnitude of severity of the effects of the three EWEs on their livelihoods. Specifically, this included three wards (5, 8, and 12) in the Gulariya municipality of the Bardiya district and three wards (3, 4, and 5) in the Raptisonari rural municipality of the Banke district (Figure 1.2 & Table 1.2).

The formula of sampling size was, SS = $\frac{p(100-p)z^2}{E^2}$ (Bartlett, Kotrlik, & Higgins, 2001). The *p* specifies the expected proportion of the population to have the attribute that you are estimating from your survey. If *p* is unknown, 50% should be used as an estimate of *p*, as this will result result in maximization of the variance and produce the maximum sample size (Bartlett, Kotrlik, & Higgins, 2001). *z* is the value corresponding to the level of confidence required and *E* is the the percentage of maximum error is required (Taherdoost, 2017). I also used the sample size calculation interface from finite population powered by ABS (2018). Based on these methods, 367 sample size is determined at 95% confidence level, 5% margin of error and when population size is 7809. This is the number of actual responses needed to achieve the stated level of accuracy. From the 367 sample questionnaires, 17 cases were excluded due to inconsistency and missing data.

From these six wards, the final selection of farming households was conducted using systematic random sampling of 31, 33, and 105 farming households from the 5^{th}, 8^{th}, and 12^{th} wards of the Gulariya municipality, respectively, and 44, 89, and 48 households from the 3^{rd}, 4^{th}, and 5^{th} wards of the Raptisonari rural municipality, respectively. Three hundred and fifty interviews were conducted with either the household head or the primary household member (being the primary decision makers and contributing highly in financial matters). Among the sampled households, ~52% of households were interviewed in the Rapti Sonari municipality, with the remaining from Gulariya.

Table 1.2: Sampling design

Districts (Municipality)	Ward number	Household number	Sample size
Banke (Rapti Sonari)	5	782	31
	8	1027	33
	12	1786	105
Bardiya (Gulariya)	3	1142	44
	4	1571	89
	5	1501	48
Total		7809	350

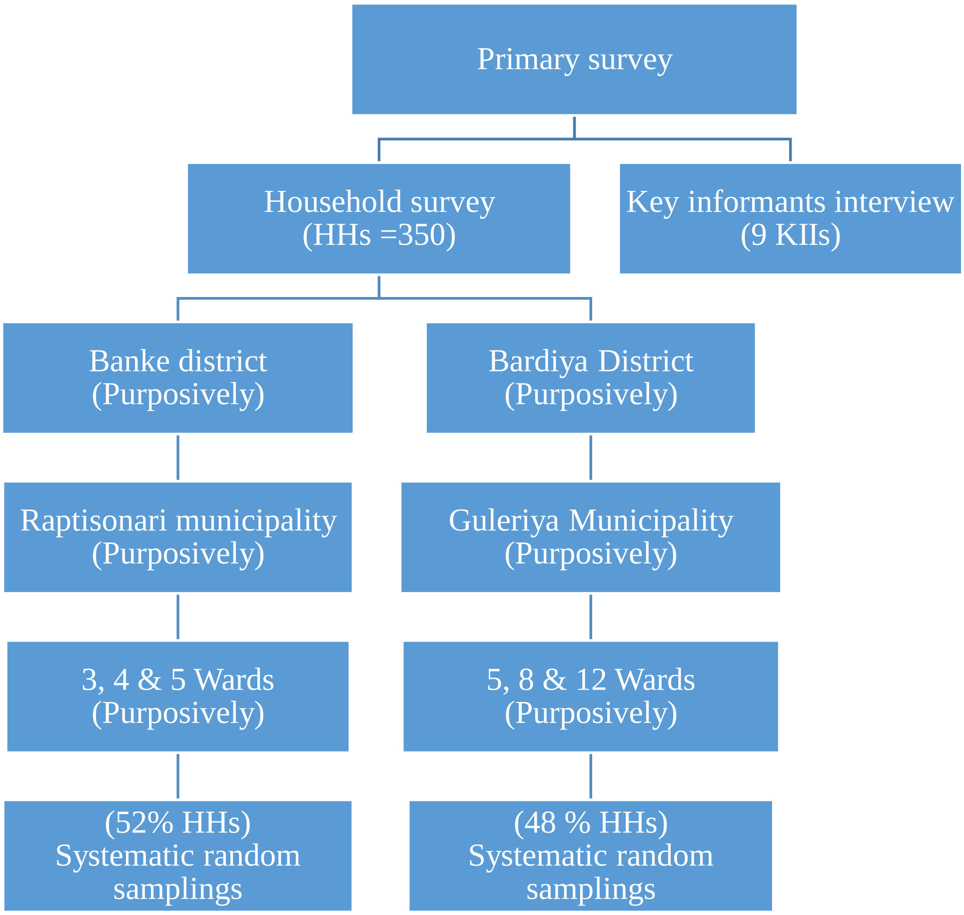

Figure 1.2: Sampling framework. HH: Household's head; KII: Key Informants Interview.

Key informant interviews were conducted using a semi-structured questionnaire prior to the main survey to inform the design of the household survey questionnaire. Altogether, nine key informants were interviewed: three central government officials from the Ministry of Agriculture and Development insurance board, four government officials from the two Banke and Bardiya district agricultural offices (two from each district), and two representatives from insurance companies (one from each district) involved in providing agricultural insurance to these areas. The key informants were asked about farmers' existing coping mechanisms in mitigating the impacts of EWEs, the current status of insurance uptake, problems with the existing insurance policies, and for suggestions of how to increase agricultural insurance penetration to poor and marginal farmers. During the survey, key informants continued to be interviewed in order to complement and interpret results from the contingent valuation study, as detailed in Chapter 5.

1.8.3 Study area.

The study took place within the low lying Terai region of western Nepal, a region comprised of 21 of the 77 districts in Nepal, home to more than half of the country’s population of 28.5 million people (CBS, 2011). The Terai region covers only 14% of the total land area of Nepal, but contributes to 72% of rice and 63% of wheat production in the country (MoAD, 2017). The Terai region is referred to as the ‘granary’ of Nepal, with more than 84% of farm households actively engaged in rice production. Wheat and maize are also important crops in the Terai region, with about 61% of households cultivating wheat and 29% spring maize (CBS, 2011). Despite being a food basket of Nepal, the low lying Terai region has been profoundly affected by extreme weather and climatic events in recent years (Budhathoki & Zander, 2020).

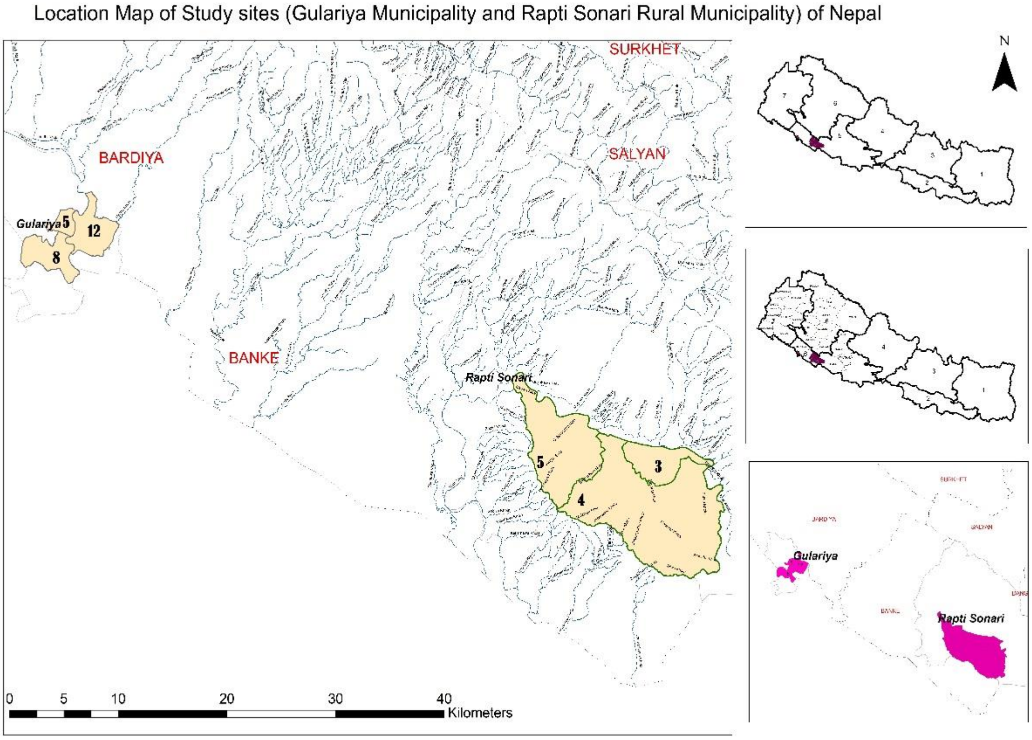

Figure 1.3: Study areas

The Banke district (Figure 1.3) is the hottest place in Nepal, reaching a maximum temperature of 45 °C in May each year and total rainfall ranges from 937 mm to 2,149 mm per annum, with an average rainfall of 1,317 mm between 1950 and 2016 (Regmi, Shrestha, Baral, & Rajbhandari, 2018). The Banke district is located between the latitudes of 27°50’N and 28°20’N and the longitudes of 81°30’E and 82°10’E. Over the last two decades, the Banke had recorded a lowest minimum winter temperature of 0 °C (32 °F) and a highest maximum summer temperature of 48 °C (118.4 °F) (DHM, 2019).

The Bardiya district (Figure 1.3) is located between the latitudes of 28°70’N and 28°350’N and the longitudes of 81°30’E and 81°410’E Over the last two decades, the

Bardiya district had recorded a lowest minimum winter temperature of 4 °C (39.2 °F) and a highest maximum summer temperature of 45 °C (113 °F) (DHM, 2019).

Based on the Social Vulnerability Index (SoVI), Banke and Bardiya districts are in the medium high vulnerability category (Gautam, 2017; Aksha, Juran, Resler, & Zhang, 2019) and according to the Human Development Index (HDI), districts such as Banke (HDI = 0.475) and Bardiya (HDI = 0.466) lag behind other districts in the region, except for several districts in central Terai (Sharma, Guha-Khasnobis, & Khanal, 2014). In 2016 and 2017, massive floods in the Rapti and Babai rivers led to widespread destruction in Banke and Bardiya districts respectively (Chhetri, Dhital, Tandong, Devkota, & Dawadi, 2020).

1.8.4 Data analysis.

This thesis uses cross-sectional primary household survey data to analyse the study objectives in each chapter. After conducting household's survey, the data was recorded on an Excel spreadsheet. Open ended responses were coded, entered and cleaned by the researcher himself to ensure consistency and reliability of the survey data. The data were analysed by using various statistical tools such as AMOS 23 (Analysis Moment Structures), STATA 15 and SPSS 25 (Statistical Product and Services Solutions) as per the necessity in the different published papers. To address the aims of Chapter 2, ordered Logit Regression Models were estimated to examine the impact of various control variables on the farmers' level of heat stress and cold stress. For the assessment of productivity loss, Binary Logit Regression Models were run. In chapter 3, the Structural Equation Model was applied to explain the causal/mediational effects of psycho-cognitive variables on risk perception and preparedness for intended adaptation of EWEs. Causal/mediation analysis explains the process and mechanism by which one variable affects another variable with the mediating variables comprised of the behavioural, social, biological, and psychological concepts (Zhao, Lynch Jr, & Chen, 2010). Chapter 4 broadly discusses the Protection Motivation Theorem to analyse the determinants that affect farmers' motivation to adopt various future coping measures. To assess the number of adaptation strategies adopted in response to the three EWEs, these determinants were then analysed by using a Poisson Regression Model, while the types of preferred intended adaptation strategies were analysed using a Multinomial Logit Model. In Chapter 5, the Double Bounded Dichotomous Choice method was applied to estimate farmers' willingness to pay for crop insurance in the hazard-prone areas in the low lying Terai region.

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Chapter 2 Socio-Economic Impact of and Adaptation to Extreme Heat and Cold of Farmers in the Food Bowl of Nepal

2.1 Preface

This chapter explores the social and economic impacts of extreme temperautre on farming households in Nepal. The chapter has been published in full in the International Journal of Environemtal Research and Public Health. Changes have been made to the formatting and the referencing style so that it is consistent with the rest of the thesis.

Budhathoki, N. K., & Zander, K. K. (2019). Socio-Economic Impact of and Adaptation to Extreme Heat and Cold of Farmers in the Food Bowl of Nepal. *International Journal of Environmental Research and Public Health*, *16*(9), 1578.

2.2 Abstract

Farmers worldwide have to deal with increasing climate variability and weather extremes. Most of the previous research has focused on impacts on agricultural production, but little is known about the related social and economic impacts on farmers. In this study, we investigated the social and economic impact of extreme weather events (EWE) on farmers in Nepal, and explored how they coped with and adapted to heat waves and cold spells between 2012 and 2017. To address these aims, we conducted a survey of 350 farms randomly selected from the Bardiya and Banke districts of the Terai lowlands of Nepal. They were specifically asked to rate the impacts of extreme temperatures, as well as their effect on labour productivity and collective farmer health, and the detailed preventative measures they had implemented. About 84% of the farmers self-reported moderate or severe heat stress during the last five years, and about 85%, moderate or severe cold stress. Likewise, the majority of respondents reported that both farmer health and labour productivity had been compromised by EWEs. Productivity loss had a strong association with the perceived levels of heat and cold stress, which, in turn, were more likely to be reported by farmers with previous EWE experience. Potentially due to the increased care required during EWEs, those farmers with livestock reported increased heat and cold stress, as, surprisingly, did those who had implemented adaptation measures. Farmers seemed to be less prepared for potential threats of cold spells than heat waves, and therefore less likely to adopt coping strategies, since these are a recent phenomenon. This study identified some limitations. The cross sectional and self-reported data, as a common source of information to estimate health impact, level of heat/cold stress and labour productivity loss. Community-based education/community engagement programs could be developed to facilitate proactive adaptation.

Keywords: climate change; cold spells; crop production; heat waves; public health; labour productivity loss

2.3 Introduction

Leading to rising temperatures and increasing climate variability, including more frequent and severe extreme weather events (EWEs) (Field et al., 2014), the global impacts of climate change on agricultural and food systems are substantial, putting food security and the livelihoods of many at risk (Rowhani, Lobell, Linderman, & Ramankutty, 2011; Thornton, Ericksen, Herrero, & Challinor, 2014). As the climate becomes more volatile, some parts of the world are projected to be profoundly affected by the intensity of extreme cold events, which are expected to persist late into the 21st century (Kodra, Steinhaeuser, & Ganguly, 2011). Climate-change-related extreme events impose substantial economic and social burdens to global society (Carleton & Hsiang, 2016), particularly in developing countries (Tol, 2018). Consequently, to reduce the social and economic burden, it is essential to understand how weather or climate, as well as social and economic factors, interact to influence the nature and implications of climate impacts, and to identify adaptation gaps and implement cost-effective strategies (Carleton & Hsiang, 2016).

While there are many studies on climate change impacts, such as the impact of floods on health (Munro et al., 2017; Waite et al., 2017), there is still little research on the social (health) and economic (labour productivity loss) effects of extreme temperature in farming communities. Rather, studies have focused on the damage from severe disasters such as floods and tsunamis (Sekulova & Van den Bergh, 2016; Shoji & Nakamura, 2017). However, slow onset climate-change-related events such as heat waves and cold spells, while not immediately deadly (Birkmann & Welle, 2015), can compromise farmers' health and capacity to work.

Heat waves are anticipated to become more common, last longer and have greater intensity (Perkins, Alexander, & Nairn, 2012). Extreme heat can result in health issues ranging from mild heat stress symptoms, such as headaches and fatigue, to severe heat strokes and fainting (Kovats & Hajat, 2008; Basu, 2009). Extreme heat can also lead to death during and after heat waves (Forzieri, Cescatti, e Silva, & Feyen, 2017; Zhang et al., 2017), and can impair mental capabilities (Rowlinson, Yunyanjia, Li, & Chuanjingju, 2014). Heat stress is considered to be a combination of an external thermal environment and the internal heat generated by physical activity (Lundgren, Kuklane, Gao, & Holmer, 2013). When temperatures exceed more than 98.6 °F (37 °C), sweating is the primary mechanism of cooling down the body, but it is impaired by high air humidity, thereby creating heat-related health problems (Parsons, 2014).

While climate change literature, including the Intergovernmental Panel on Climate Change (IPCC) Report 2014, strongly focuses on the increase of warm temperatures, it has remained silent on the health impact of cold spells (Smith, Woodward, & Campell-Lendrum, 2014). Cold temperatures and cold spells are also on the rise in some areas as climate variability increases (Arbuthnott, Hajat, Heaviside, & Vardoulakis, 2016). Stress on the human body from extreme cold can cause death from hypothermia. According to an international study analysing over 74 million deaths in 384 locations across 13 countries, extreme cold kills 20 times more people than extreme heat (Gasparrini et al., 2015). In many countries, the temperature does not reach such extreme lows, and, for the most part, people utilise behavioural thermoregulation in the cold (Castellani & Young, 2016). However, there may be situations where these behaviours are inadequate, such as when impoverished people cannot afford adequate clothing or do not have access to heating.

As with heat, extreme cold can also negatively affect the health system, through increases in the occurrence of viral flu, cough, cold diarrhoea, asthma, pneumonia, and other respiratory problems (Goutam, 2014). In the cold, vasoconstriction and lowering of tissue temperatures cause numbness, which reduces manual dexterity and strength (Singh, Hanna, & Kjellstrom, 2013; Parsons, 2014). Extreme cold can also cause cardiovascular diseases, although to a lesser extent than in cases of heat (Urban, Davídkovová, & Kyselý, 2014), while older, marginalised and underprivileged people are the most affected by extreme cold (Conlon, Rajkovich, White-Newsome, Larsen, & O'Neill, 2011). The risk of suffering frostbite, for example, increases with age (Juopperi, Hassi, Ervasti, Drebs, & Näyhä, 2002). Unintended cold exposure can also lead to various health hazards and mortality for those people working outdoors, or more impoverished people who cannot afford indoor heating (Ranhoff, 2000; Kysely, Pokorna, Kyncl, & Kriz, 2009).

Extreme heat and cold have impacts on workers' daily activities and work, which require proper coping mechanisms to minimise the impacts of extreme temperatures. Temperatures of 90 °F (32.22 °C) and above or 50 °F (10 °C) and below can detrimentally affect work performance (Pilcher, Nadler, & Busch, 2002). Exposure to extreme and prolonged heat has led to reduced worker enthusiasm and performance at their work; at the same time, a natural reaction of self-pacing working activities to maintain inner core body temperature will reduce working capacity and lower workers' productivity (Kjellstrom, Holmer, & Lemke, 2009; Kjellstrom, Kovats, Lloyd, Holt, & Tol, 2009; Lundgren, Kuklane, Gao, et al., 2013; Somanathan, Somanathan, Sudarshan, & Tewari, 2015; Zander, Botzen, Oppermann, Kjellstrom, & Garnett, 2015; Venugopal, Chinnadurai, Lucas, & Kjellstrom, 2015; Nunfam, Adusei-Asante, Van Etten, Oosthuizen, & Frimpong, 2018). There is an extensive body of literature assessing labour productivity losses from the heat in outdoor and labour intense sectors, such as agriculture (Kjellstrom, Holmer, et al., 2009; Kjellstrom, Kovats, et al., 2009; Mathee, Oba, & Rose, 2010; Crowe et al., 2013; ; Singh et al., 2013; Qi, Bravo-Ureta, & Cabrera, 2015; Rowhani, Lesk, & Ramankutty, 2017), mining (Lundgren, Kuklane, Gao, et al., 2013; Singh et al., 2013; Sahu, Sett, & Kjellstrom, 2013) and construction (Tawatsupa et al., 2012; Venugopal et al., 2016; Acharya, Boggess, & Zhang, 2018).

Heat (Morabito, Cecchi, Crisci, Modesti, & Orlandini, 2006; Tawatsupa et al., 2012) and cold (Vajda et al., 2014) can also lead to increased accident rates of outdoor workers. Recent studies have shown that even the urban population is under extreme heat stress and feels impaired in their daily activities and work, particularly in countries where air-conditioning is still under-used (Zander & Mathew, 2019). While few studies have investigated the impacts of climate-change-related extreme cold on outdoor workers' performance and labour productivity (Enander, 1984; Mäkinen & Hassi, 2009) and their adaptation strategies against cold spells (Holmér, Hassi, Ikäheimo, & Jaakkola, 2001), it has been found that extreme cold causes an unpleasant sensation and thermal discomfort. Discomfort may be a distracting factor reducing work performance through the loss of concentration and alertness, and may also cause physical injuries and accidents in the workplace (Mäkinen & Hassi, 2009).

This study aims to assess the social and economic impacts of climate change using a case study from Nepal. We specifically aimed to (1) assess the impacts of heat waves and cold spells on farmers' health and levels of heat and cold stress, (2) to explore which factors determine productivity losses, and (3) to reveal the strategies that farmers follow to relieve heat and cold stress and labour productivity loss from extreme temperature.

We used self-reported measures of health and productivity loss, obtained from a survey conducted among 350 farmers in the Terai lowlands in Nepal. This region is considered to be the 'food bowl' of the country, and significantly contributes to the national economy. Based on the data source of the Disaster Information Management System (DESINVENTAR) of the United Nations International Strategy for Disaster Reduction (UNISDR), throughout Nepal, 647 cases of cold spells and 49 heat cases of heat waves were reported from 1970 to 2013 (UNISDR, 2013). During this time, 822 cold-related and 49 heat-wave-related deaths were recorded. Of these cold-related deaths, 89% percent of deaths took place in the Terai region. The government of Nepal has identified 30 different types of disaster (MoHA, 2015); among these disaster events, the cold spell is considered to be the crucial extreme events that caused the significant damage to agriculture, livestock and human beings. During 1970–2013, economic loss from cold spells was US $835 million, 269,000 Ha of crop land were damaged and 732 cattle were lost due to cold spells (UNISDR, 2013). The effect of cold spells has been found to be higher in the low lying Terai region than in the mountain regions, where there is cold in most of the time, but it is not so significant because the population is both sparse and more adapted to the cold climate (Pradhan, Sharma, & Pradhan, 2019). On the other hand, the impact of cold is severe in Terai, where the largest share of the population resides, most of them living below the poverty line (Pradhan et al., 2019). Pradhan et al. (2019) further reported that cold-wave-related deaths increased at the rate of 13% per annum during 1970–2013. So far, there has been only one study from Nepal (Pradhan et al., 2013) on how working people in the Terai region respond to heat waves. They concluded that males were found to be highly affected by heat waves, and only a few workers had adapted to using heat wave coping mechanisms.

2.4 Materials and Methods

2.4.1 Study Area.

The Terai region covers only 14% of the total land area of Nepal, but contributes 72% of the national rice production and 63% of wheat (MoAD, 2017). It is, therefore, referred to as the ‘granary’ of Nepal, with more than 84% of farm households actively engaged in rice production. The region covers 22 districts (out of the 77 districts of Nepal), and is home to more than half of the country’s population of 28.5 million (CBS, 2011). Based on the Central Bureau of Statistics (CBS) climate change impact survey, 2016, and discussion outcomes with the Nepal Department of Hydrology and Meteorology (DHM) officials, we selected two districts in which to conduct this study, the Banke and Bardiya districts. From these districts, we selected municipalities and their respective wards (lower administrative division) that had been profoundly affected by EWEs in recent years (Maharjan, Sigdel, Sthapit, & Regmi, 2011). Over the previous two decades, the Banke and Bardiya districts had recorded, respectively, highest maximum summer temperatures of 118.4 °F (48 °C) and 113 °F (45 °C), and lowest minimum winter temperatures of 32 °F (0 °C) and 39.2 °F (4 °C).

There is no universal definition of a heat wave in Nepal. In general, a heat wave is locally known as ‘loo’ and prevails during the hot summer months. Based on discussion with district officials, they stated that a ‘loo’ normally occurs in the lowlands when the temperatures reach at least 40 °C and continue for a minimum of two days. Heat waves can cause reductions in crop productivity (Chalise, Naranpanawa, Bandara, & Sarker, 2017), and the death of livestock and people. From 1974 to 2013, 45 heat-wave-related deaths were reported, solely in the Terai region (Pradhan et al., 2019).

A cold spell is a sudden drop in temperature, taking place within 24 hours, and generally is accompanied by thick fog and lasts for many days, a condition known in Nepal as ‘sitlahar’. While cold spells are most common in winter in the low lying Terai region, their occurrence has increased substantially in the lowlands during the last 14 years (Manandhar, Vogt, Perret, & Kazama, 2011). Cold spells cause damage to crops (Shrestha, Moore, & Peel, 2018) and compromise people’s quality of life (Manandhar et al., 2011). Since 1990, cold spells have caused the death of 821 people, primarily in the Terai region (88%; 721 deaths) (Shrestha et al., 2018). Cold spells are currently considered a serious problem affecting Nepal’s food security.

2.4.2 Sampling.

Three wards (5, 8 and 12) of the Gulariya municipality in the Bardiya district and three wards (3, 4 and 5) of the Rapti Sonari rural municipality in the Banke district (shaded areas in Figure 2.1) were selected purposively. From these purposively selected wards of each municipality, farming households were selected by using systematic random sampling. In total, 350 household heads or main family members were interviewed. Among these sampled households, 52% of interviewed households were from Rapti Sonari and the remaining 48% were from Guleriya. The survey was conducted from the first week of November 2017 to the third week of January 2018 by three experienced and trained research assistants who spoke Nepali, the main language used for the survey, and who could also understand Tharu and local dialects. Ethics approval to conduct this reseach was obtained by the Charles Darwin University Human Research Ethics Committee (H17110).

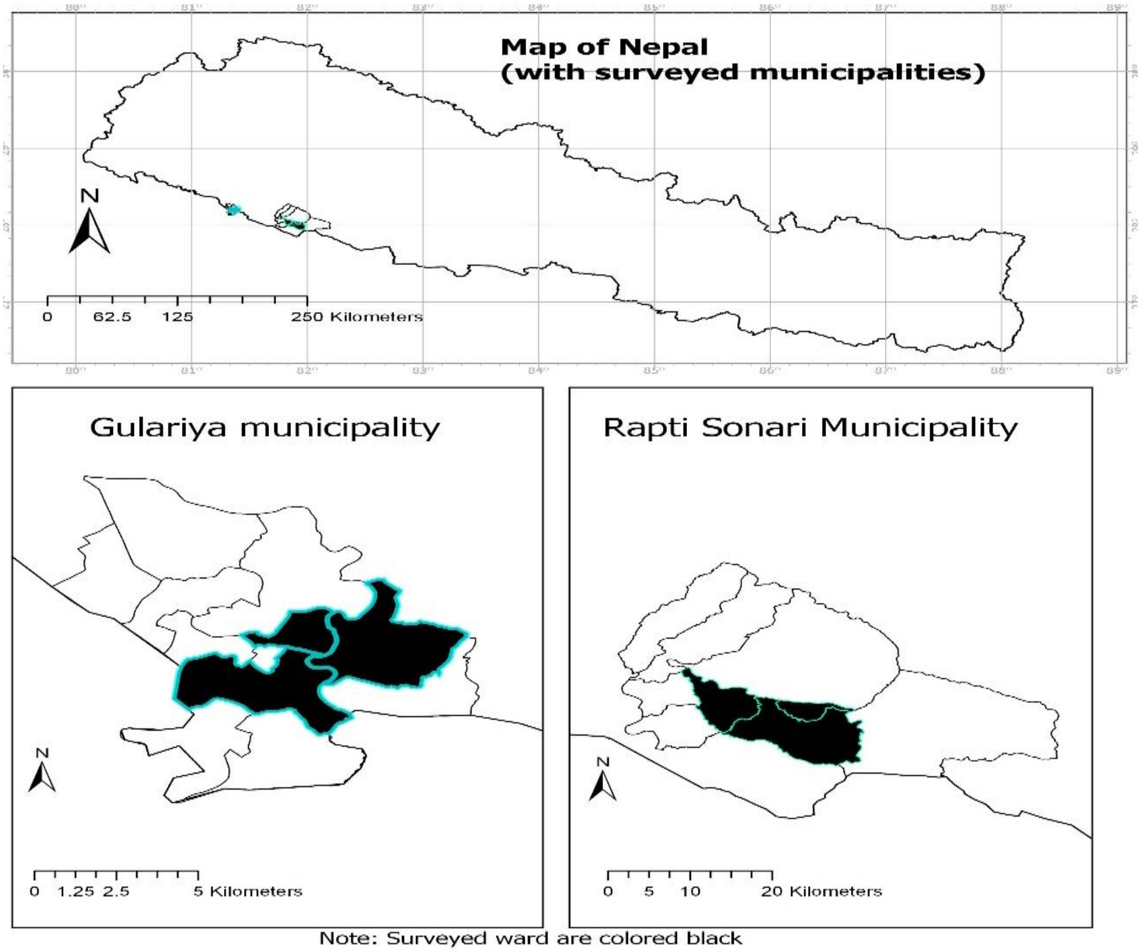

Figure 2.1: Study areas.

2.4.3 Questionnaire and Variables.

A structured questionnaire was used, which was first pre-tested with 15 respondents randomly selected from villages near to the study area. We asked around 30 questions, which took about 25 minutes, on average. The revised final survey included questions focused on three themes: (i) the farm socio-economic characteristics, (ii) EWEs and their perceived impacts on farmers' health and labour productivity, and (iii) the existing adaptation strategies used to mitigate the impact of climatic extremes. Farmers were asked to rate whether previous heat waves and cold spells affected their labour productivity, their own health and the health of their families during the previous five years (2012–2017).

Labour productivity loss was defined as a loss in production or not meeting set work targets (Venugopal et al., 2015). Labour productivity loss arises from presenteeism (when at work but unable to perform at full capacity) and absenteeism (not being at work at all) (Goetzel et al., 2004). These concepts have been used extensively to assess labour productivity loss from chronic health issues (Rizzo, Abbott III, & Berger, 1998; Osterhaus, Purcaru, & Richard, 2009). These studies used self-rated measures of perceived presenteeism and absenteeism with recall periods of 1 month (Osterhaus et al., 2009), 3 months (Nagata et al., 2018) or a year (Kessler et al., 2006; Zander et al., 2015). It was decided to use an extended recall period of five years, in order to capture both good and bad years of extreme heat and cold.

The five year period, furthermore, allowed the study to extend its focus beyond a number of variables common to subsistence farming; the households' head and other household members often work in the agricultural sector most of the time during cropping seasons, but during non-cropping seasons, they either remain unemployed or are partially involved in other off-farm activities. To cover periods of farm work, the recall period had to be extended to five years. Harvests are very volatile from year to year, and so is the farmers' workload. Thus, to capture years in which farmers worked full time on their farms, a long recall period was used. A five year or longer recall period has also been used elsewhere in climate change perception studies (Bryan, Deressa, Gbetibouo, & Ringler, 2009; Manandhar et al., 2011; Haque, Yamamoto, Malik, & Sauerborn, 2012; Budhathoki & Zander, 2019).

Perceived stress from heat and cold was measured on a five point scale ('Never,' 'Yes, rarely,' 'Sometimes,' 'Often' and 'Very often'). The associated question was: "*Have you fe*lt *that you have been heat (cold) stressed during heat waves (cold spells) when undertaking your agricultural activities in a usual year during the last five years*?" (see Appendix B.1)

Those respondents who were least stressed by heat and cold were then asked to state their perceived labour productivity. Responses were also measured on a five point scale ('Never,' 'Yes, rarely,' 'Sometimes,' 'Often' and 'Very often'). The related question was: "*If you felt heat (cold) stressed, did you find yourself, as a consequence, less productive when working on agriculture-related activities in the last five years*?" Similarly, farmers were asked open ended questions *"What preventative measures do you currently adopt to avoid heat/cold related stress in the agricultural fields?"* These responses were listed and coded for further analysis. Heat-wave- and cold-spell-related questions had separate sections in the survey instrument, and were asked separately during the households' survey.

2.4.4 Potential Determinants of Stress and Productivity Loss during Heat Waves and Cold Spells.

There has been an increase in studies over the last two decades that explain the factors that lead to human stress from environmental conditions, such as from extreme weather conditions and natural hazards (Lundgren, Kuklane, Chuansi, & Holmer, 2013; Pradhan et al., 2013; Zander, Moss, & Garnett, 2017; Zander, Mathew, & Garnett, 2018). Previous studies (Hassi, Rytkönen, Kotaniemi, & Rintamäki, 2005; Basu, 2009;

Gronlund, 2014) have found that both physiological and psychological factors influence vulnerability to extreme temperature. The variables included to explain farmers' heat stress were chosen and categorised, as conducted by Zander et al. (2017), and Kovats and Hajat (2008) in their studies (Table 2.1). Potential determinants were sorted into the following four categories: socio-economic (land size, income, access to various facilities, type of housing, and livestock); psychological (perception and experience of extreme heat waves and cold spells, and level of work satisfaction in agriculture); physical (age, number of active household members, gender and health status, average working days in agriculture during summer and winter seasons separately, and implemented heat wave and cold spell adaptation measures); and environmental factors (respondents' location in urban or rural areas).

Table 2.1: Summary of factors determining the heat and cold stress and related productivity loss.

Factor	Impact	Source
Social factors		
Income	Negative	Kovats & Hajat, 2008; Tawatsupa et al., 2010; Gronlund 2014; Zheng & Dallimer, 2016
Access to weather information	Positive	Bryan et al., 2009; Bryan et al., 2013
Type of house	Positive	Gifford & Zong, 2017; Zander et al., 2015; Pradhan et al., 2013
Education	Positive/ Negative	Gronlund, 2014
Livestock	Positive/ Negative	
Psychological factors		
Experiences of heat waves and cold spells	positive	Venugopal et al., 2015; Akerlof et al., 2010; Akompab et al., 2013; Wachinger et al., 2013
Satisfaction with job/work	Positive	Kramer & Hafner, 1989; Baruch-Feldman et al., 2002
Existing health condition	positive	Dollard & Neser, 2013; Burton et al., 1999
Physical factors		
Age	Positive	Hansen et al., 2011; Sun et al., 2016; Zander et al., 2017; Hajat et al., 2014
Male	Positive/ Negative	Tawatsupa et al., 2010; Pradhan et al., 2013; Burse, 1979, Lundgren et al., 2013
Current health status/pre-existing extreme-temperature-related symptoms/illnesses (numbers)	Positive	Hassi et al., 2005; Rocklöv & Forsberg 2008; Gifford & Zong 2017; Mathee et al., 2010; Zander et al. 2018a; Burton et al., 1999
Implemented response measures	Positive	Zaalberg et al., 2009; Wise et al., 2014
Length of exposure to extreme heat/cold	Positive	Lundgren et al., 2013:, Pilcher et al., 2002; Acharya et al., 2018; Enander, 1987
Environmental factors		
District/urban/heat island effects	Positive	Kovats & Hajat, 2008; Kleerekoper et al., 2012; Zander et al., 2018a

It was assumed that the same factors that affect cold and heat stress also affect associated productivity loss. Studies on extreme heat have shown that there is a strong correlation between the two (Zander et al., 2017; Zander, Mathew, et al., 2018). The impacts of cold spells are associated with several factors, consisting of individual, socio-economic, climatic, clothing availability, and physical activity (Mäkinen & Hassi, 2009). As the literature on cold stress is sparse, it was assumed that most factors that affect heat stress also affect cold stress.

2.4.4.1 Social Factors.

People with higher income and wealth (farm size, self-reported annual income) are less likely to be heat stressed (Kovats & Hajat, 2008; Tawatsupa et al., 2010; Gronlund, 2014; Zheng & Dallimer, 2016), probably because wealthy people have a higher adaptive capacity to cope with extreme heat. Similarly, those farmers who have access to actual weather information are assumed to be more likely to perceive extreme events and take household level adaption measures in response (Bryan et al., 2013). They would, therefore, be less likely to suffer from heat and cold stress and less likely to observe labour productivity loss from heat and cold.

Those residing in concrete or well-built houses are less likely to report heat and cold stress. It could be that extreme-temperature-resilient houses allow for a sound sleep during the night, and thus workers may be less stressed while working in the field during hot days (Krause et al., 2017). Workers with well-built and comfortable houses are, therefore, assumed to be less stressed and vulnerable to extreme temperatures, and less likely to report productivity loss than workers with poor housing (Pradhan et al., 2013; Gifford & Zong, 2017;). Farmers in better houses are also more likely to have better quality sleep during extreme temperatures, which could increase their working capacity in the following day (Zander et al., 2015).

2.4.4.2 Psychological Factors.

It is assumed that people who have had past experience with climate extremes are more likely to be worried and stressed by them (Akerlof et al., 2010; Akompab et al., 2013). Direct experiences of past climatic events will have a substantial impact on risk perception (Paton, Smith, & Johnston, 2005; Wachinger, Renn, Begg, & Kuhlicke, 2013), and may encourage farmers to take precautionary adaptation measures.

As job satisfaction is one of the crucial determinants of labour productivity improvement, the study further assumed that workers who were satisfied with their jobs were highly productive (Kramer & Hafner, 1989; Baruch-Feldman, Brondolo, Ben-Dayan, & Schwartz, 2002). An individual with a poor existing health condition leads to considerable labour productivity loss while performing a physically demanding job compared to a healthy worker (Burton, Conti, Chen, Schultz, & Edington, 1999; Dollard & Neser, 2013).

2.4.4.3 Physical Factors.

Older people and those with illnesses are particularly vulnerable to the impacts of both heat and cold (Hajat, Vardoulakis, Heaviside, & Eggen, 2014), and heat alone (Basu, 2009; Ng et al., 2014). Thus, it was expected that households with more active family members of working age, between 15 and 59 years old, would be less likely to suffer from heat and cold stress, as they could help each other to perform agricultural activities during extreme weather conditions and be less exposed to the extreme weather. Those farmers who had a higher number of family labourers on their farms were expected to be less stressed and less compromised in their productivity (Kjellstrom, Holmer, et al., 2009). In addition, those who work physically hard outside, in industries including the agricultural, construction, mining, and military sectors, are also vulnerable to the impacts of weather extremes (Wolf, Adger, & Lorenzoni, 2010).

Workload and work intensity during extreme temperatures (length of exposures to extreme temperature or task duration) is expected to have a positive impact on the levels of heat and cold stress, and a negative impact on labour productivity (Enander, 1984; Pilcher et al., 2002; Lundgren, Kuklane, Gao, et al., 2013; Pradhan et al., 2013; Acharya et al., 2018). Reduced labour productivity is a function of environmental humidity, radiant heat, air movement and ambient temperature (Parsons, 2014). Work performance is a function of physical, mental, social and psychological factors (Vänni, Neupane, & Nygård, 2017), because heat waves can have negative impacts on workers' productivity due to thermal stress on human cognitive and physical factors (Park, Bangalore, Hallegatte, & Sandhoefner, 2018). Farmers who usually work in the fields under high temperatures have been found to be affected by a range of heat-related health problems, such as exhaustion, irritability, sleeplessness or having difficulties in maintaining work level and output (Mathee et al., 2010).

Health is one of the dominant factors affecting susceptibility to both heat stress (Venugopal et al., 2015; Krishnamurthy et al., 2017; ; Zander et al., 2017; Zander, Cadag, Escarcha, & Garnett, 2018; Zander, Mathew, et al., 2018) and cold stress (Hassi et al., 2005; Rocklöv & Forsberg, 2008). Employees with recurring illness and painful symptoms are more likely to report heat and cold stress than employees without these health problems (Hassi et al., 2005; Rocklöv & Forsberg, 2008; Gifford & Zong, 2017). Similarly, older people are highly susceptible to impacts of extreme heat (Hansen et al., 2011; Sun et al., 2016; Zander et al., 2017), because elderly people are more often physically inactive and of poor health. It was additionally expected that farmers who had already adopted numerous climate change-related adaptation measures would be less worried and stressed about future extreme weather because they might think that they are sufficiently prepared for it. The nature and effectiveness of climate change responses could play a crucial role in further implementing risk mitigation behaviour (Zaalberg, Midden, Meijnders, & McCalley, 2009; Wise et al., 2014).

Men are assumed to be more stressed by heat than women (Tawatsupa et al., 2010; Pradhan et al., 2013), as men are exceedingly exposed to heat in physically demanding outdoor activities (farming, mining and construction work). Other studies have reported that men and women have slightly different physiology, endocrinal physiology and body characteristics, specifically that women have a larger surface to mass ratio, which implies that women are more prone to heat loss (Lundgren, Kuklane, Gao, et al., 2013).

The availability of weather information leading to greater awareness, and participation in community organisations or other social networks are expected to influence farmers’ behaviour in response to climate-change-related extreme events (Bryan et al., 2009; Bryan et al., 2013).

The level of physical exertion is a strong predictor for heat stress (Zander et al., 2015; Zander et al., 2017; Acharya et al., 2018). This study assumed that farmers who own livestock conduct more labour-intensive tasks that are required to be performed during extremely hot and cold days, such as fetching fodder. This study, therefore, assumed a positive relationship between owning livestock and heat and cold stress. As for labour productivity loss, there was also assumed to be a higher overall loss, as animals are also affected by extreme heat and cold (Nienaber & Hahn, 2007; Nardone, Ronchi, Lacetera, Ranieri, & Bernabucci, 2010).

On the other hand, farmers with livestock such as buffalo can rely on their aid for some labour-intensive activities, including the pulling of carts to carry agricultural products and agricultural inputs from and to the agricultural field and markets, in which case they might be less effective in their productivity during extreme temperature. We also expected a positive relationship between farmland size and labour productivity loss because of the expected higher workload with more land.

2.4.4.4 Environmental Factors.

Urban residents were found to be more heat stressed (Kovats & Hajat, 2008; Kleerekoper, Van Esch, & Salcedo, 2012; Zander, Cadag, et al., 2018) because the phenomenon of the urban heat island aggravates heat stress. The study also assumed that urban residents are less likely to be stressed due to cold spells because of the urban heat island problem.

2.4.5 Data Analysis.

Ordered logit regression models were estimated to examine the impact of various controlled variables on the farmers' level of heat stress and cold stress during 2012 and 2017. The initial responses on a five point scale were reduced to three points. The first two heat and cold stress levels ('Never' and 'Rarely') were grouped into the first point, while the third and fourth levels ('Sometimes' and 'Often') were grouped into the second point. The third point included only the highest heat stress level, 'Very often' (Section 2.3.3). The dependent variable, therefore, took on the values 1 to 3, ordered from low to very high stress levels.

For the assessment of productivity loss, binary logit regression models were run. The dependent variables were perceived as labour productivity loss from heat stress (cold stress), coded 0/1.

Responses were initially separated into four categories for both the heat wave and cold spell models. The levels of responses were, therefore, grouped according to productivity loss: “Definitely not” and “Probably not” were assigned to 0 (“Not perceiving labour productivity loss”), while 1 (“Perceived labour productivity loss”) included “Definitely Yes” and “Probably yes”. Separately ordered logit and binary logit analyses were also estimated to examine the effects of various explanatory variables on the levels of heat and cold stress and self-reported labour productivity loss from extreme temperatures at the district level respectively.

A bivariate relationship was analysed using a Kruskal–Wallis test to examine the relationship between heat and cold-related responses and other explanatory variables, such as the level of household income and the level of heat and cold stress. Multicollinearity was tested for using the ‘Collin’ command in STATA. The mean variance inflation factor (VIF) was less than 10 (Mean VIF < 1.89), meaning that there was no indication of correlation (UCLA, 2016). The correlation among the included explanatory variables did not exceed 0.56, thus no correlation exists, as shown by correlation matrices (Tables B4-B7 in Appendices). For details, see the following analytical framework (Figure 2.2).

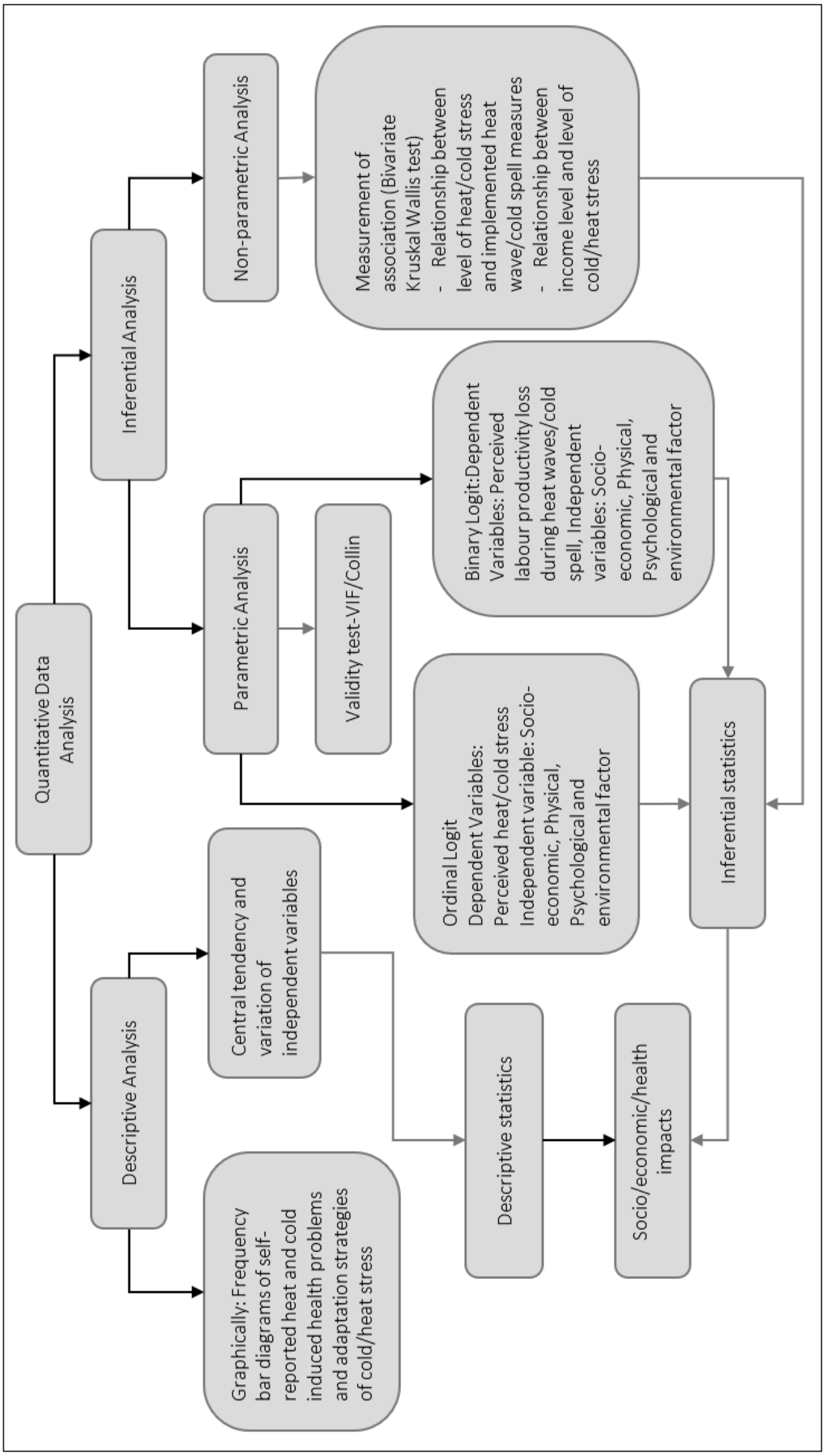

Figure 2.2: Analytical framework.

2.5 Results

2.5.1 Sample Description.

The average age of the respondents was 38.7 years (SD: 13). Approximately 62% were male, and ~67% had some formal education (Table 2.2). The average household size was 7.8 persons (SD: 5.31), and farmers' average experience in the agricultural sector was 21.2 years (SD: 12.6). Among the total respondents, nearly 38% were female, and nearly one third of the total respondents never attended school, while ~32% had completed high school.

The mean household monthly expenditure was NPR 16,130 (USD = NPR 107.10, source: https://www.nrb.org.np/fxmexchangerate.php, 8 June 2017) (SD: 18000), which was less than the national monthly household expenditure of NPR 25,928 in 2016 (Nepal Rastra Bank, 2016). Income was equally distributed among the categories (Table 2.2).

Table 2.2: Sample description (N = 350).

Variables	Bardiya Frequency (%)	Banke Frequency (%)	P-value	Overall Sample frequency (%)
Sample Households	167 (47.71)	183 (52.29)		350 (100)
Socio-economic				
Land size (Bigga) (mean; SD)	1.22 (1.47)	1.63 (1.94)	0.02	(1.42; 1.81)
Annual household's income (NRP)			0.001	
<50000	12 (7.1)	24 (13.1)		36 (10.2)
50,000–100,000	38 (22.7)	41 (22.4)		79 (22.5)
100,000–200,000	31 (18.5)	52 (28.4)		83 (23.7)
200,000–300,000	35 (20.9)	41 (22.4)		76 (21.7)
>300,000	51 (30.5)	25 (13.6)		76 (21.6)
Education			0.02	
No formal education	47 (28.1)	67 (36.6)		114 (32.5)
Primary	58 (34.7)	67 (36.6)		125 (35.7)
High school	29 (17.3)	23 (12.5)		52 (14.8)
Completed 10 + 2	14 (8.3)	16 (8.7)		30 (8.5)
Undergraduate and above	19 (11.3)	10 (5.4)		29 (8.5)
Access to weather information			0.02	
Yes	65 (38.9)	50 (27.3)		115 (32.8)
No	102 (61.1)	133 (72.6)		235 (67.2)
House type			0.0007	
1, If concrete and brick house	71 (42.5)	111 (60.7)		182 (52)
0, Otherwise (leaves, mud)	96 (57.5)	72 (39.3)		168 (48)
Livestock			0.01	
1, If have cows/buffalos	125 (74.8)	115 (62.8)		240 (68.5)
0, Otherwise	42 (25.1)	68 (37.2)		110 (31.5)
Physical				
Age (mean; SD)	37.1 (13.3)	40.1 (12.4)	0.03	(38.72; 12.9)
Sex			0.009	
Male	93 (55.6)	127 (69.4)		220 (62.8)
Female	74 (44.3)	56 (30.6)		130 (37.2)
Household size (mean; SD)	7.22 (4.87)	8.49 (5.59)	0.02	(7.82; 5.29)
Health Satisfaction			0.7215	
Not at all satisfied	4 (2.4)	0 (0)		4 (1.1)
Not very	12 (7.1)	17 (9.2)		29 (8.2)
Moderately satisfied	95 (56.8)	107 (58.4)		202 (57.7)
Fairly satisfied	56 (33.5)	57 (31.1)		113 (32.2)
Very satisfied	0 (0)	2 (1.09)		2 (0.5)
Agricultural job satisfaction			0.009	
Not at all satisfied	2 (1.2)	3 (1.6)		5 (1.4)

Variables	Bardiya Frequency (%)	Banke Frequency (%)	P-value	Overall Sample frequency (%)
Not very	23 (13.7)	25 (13.6)		48 (13.7)
Moderately satisfied	133 (79.6)	115 (62.8)		248 (70.8)
Fairly satisfied	9 (5.3)	39 (21.3)		48 (13.7)
Very satisfied	0 (0)	1 (0.5)		1 (0.2)
Perceived health condition			0.02	
Bad	3 (1.8)	11 (6)		14 (4)
Fair	66 (39.5)	83 (45.3)		149 (42.5)
Good	98 (58.6)	89 (48.6)		187 (53.5)
Heat wave measures (mean; SD)	3.8 (0.71)	3.1 (1.08)	0.00	(3.5;0.9)
Cold spell measures (mean; SD)	3.4 (0.87)	3.1 (1.03)	0.00	(3.2;0.9)
Working days in summer (mean; SD)	42.8 (23.4)	47.4 (23.6)	0.06	(45.2;23.6)
Working days in winter (mean; SD)	32.9 (26.08)	43.3 (26.8)	0.00	(38.3;26.9)
Heat-related illnesses over the previous five years (numbers) (mean; SD)	3.13 (1.39)	2.18 (1.44)	0.00	(2.64; 1.49)
Cold-related illnesses over the previous five years (numbers) (mean; SD)	2.04 (0.83)	1.39 (0.88)	0.00	(1.70; 0.92)
Psychological				
Level of perceived heat stress			0.209	
Low	23 (13.7)	31 (16.9)		54 (15.4)
Medium	60 (35.9)	72 (39.3)		132 (37.7)
High	84 (50.3)	80 (43.7)		164 (46.8)
Level of perceived cold stress			0.00	
Low	17 (10.1)	34 (18.5)		51 (14.5)
Medium	63 (37.7)	94 (51.3)		157 (44.8)
High	87 (52.1)	55 (30.05)		142 (40.5)
Heat wave perception			0.004	
Increased	156 (93.4)	155 (84.7)		311 (88.8)
Constant	6 (3.5)	9 (4.9)		15 (4.2)
Decreased	5 (2.9)	19 (10.3)		24 (6.8)
Cold spell perception			0.35	
Increased	87 (52.1)	101 (55.1)		188 (53.7)
Constant	22 (13.1)	29 (15.8)		51 (14.5)

Variables	Bardiya Frequency (%)	Banke Frequency (%)	P-value	Overall Sample frequency (%)
Decreased	58 (34.7)	53 (28.9)		111 (31.7)

Nearly 33% of households reported that they had access to actual weather information. The average land holding was 1.42 Bigga (1 Bigga = 0.6772 ha), and 75% of respondents owned their land. About 53% of farmers perceived their health as good and only 4% as poor. Approximately 16% of respondents reported that they were a little stressed during heat waves (‘low levels’), ~38% moderately, and ~47% severely stressed. Similarly, approximately 15% were a little cold stressed, ~45% moderately cold stressed, and ~ 41% were severely cold stressed. When comparing the means of various independent variables across the two study districts by using t-tests (Table 2.2), significant mean differences were observed in all the variables except cold spell perception, level of perceived heat stress and satisfaction with existing health status.

2.5.2 Heat- and Cold-Related Illnesses and Injuries.

Thirty seven per cent of respondents had experienced heat-related health problems and 34% cold-related problems in the last five years, from 2012 to 2017. Respondents made distinctions of diseases and symptoms based on winter and summer seasons. Nearly half of respondents thought that their health condition had been negatively affected during heat waves (48%) and cold spells (51%). About 8% of respondents had been highly affected by both cold spells and heat waves. Only 4% and 3% of respondents, respectively, reported without a doubt that their health had not been impacted by heat and cold.

Those farmers’ who experienced extreme heat- and cold-related illnesses were further asked about their experience. On average, farmers reported three heat-related and two cold-related illnesses. The most commonly reported illness relating to heat was fatigue (73%), followed by dizziness (63%), headaches (41%), nausea (28%), confusion (24%), heat rashes (12%), fainting (8%), loss of concentration (8%) and heat strokes (2%). Joint pains (74%), pneumonia and respiratory problems (74%), and cough and indigestion (22%) were the main illnesses relating to extreme cold (Figure 2.3).

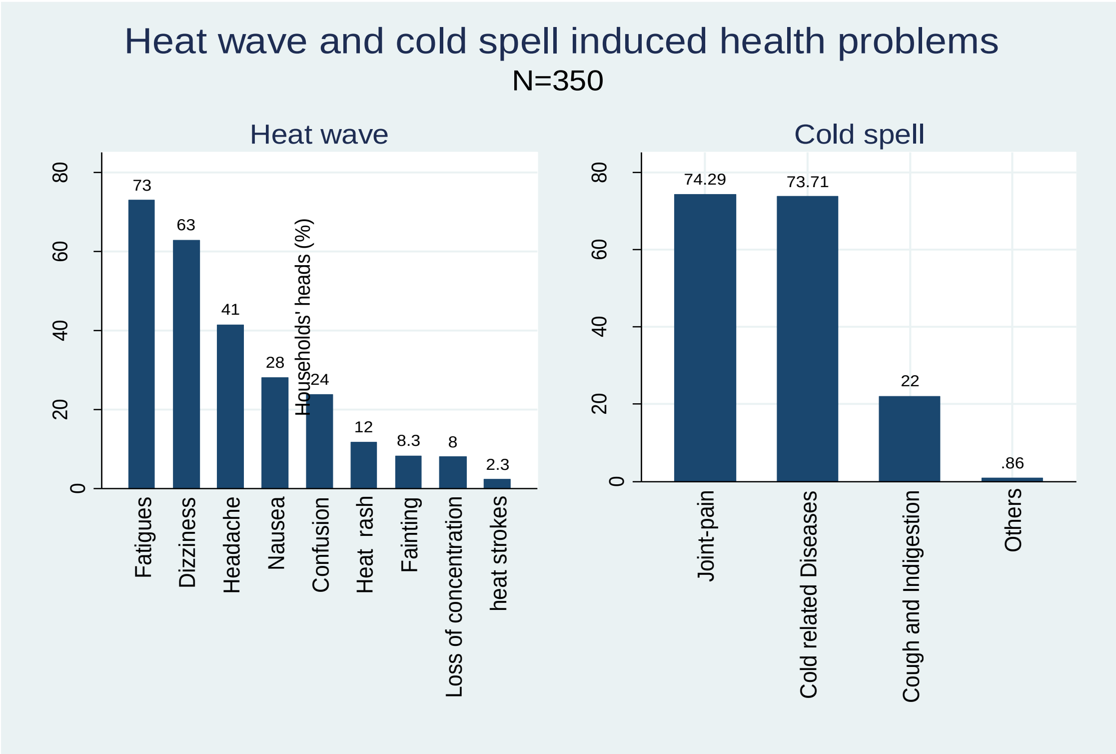

Figure 2.3: Heat wave and cold spell induced health problems.

2.5.3 Determinants of Farmers Perceived Heat and Cold Stress.

The results from the ordered logit model showed that farmers with access to actual weather information were less likely to report heat ($p < 0.01$) and cold ($p < 0.01$) stress than those without this information (Table 2.3). Owning livestock had a significant positive impact on perceived heat ($p < 0.1$) and cold stress ($p < 0.05$). Respondents who perceived an increament in the frequencies of heat waves and cold spells were more likely to have reported higher heat ($p < 0.01$) and cold stress levels ($p < 0.01$). Farmers who had implemented more heat wave and cold spell adaptation measures in the past were more heat ($p < 0.01$) and cold stressed ($p < 0.01$).

Age ($p < 0.05$) and health ($p < 0.01$) had significant positive impacts on the perceived levels of heat, but not cold, stress. Farmers from urban areas reported higher cold stress levels ($p < 0.01$) than those from rural areas, while farmers who worked more days outdoors in agricultural activities during the summer season reported higher heat stress ($p < 0.1$). District level analysis of determinants of farmers perceived levels of heat and cold stress also presented in Table B.2 (Appendices).

Table 2.3: Results of ordered logit model with the dependent variables being the level of heat stress and cold stress (from 1 very low to 3 very high).

Variables	**Perceived heat stress category**	**Perceived cold stress category**
Socio-economic		
Land size (in Bigha [1])	−0.03 (0.08)	0.0002 (0.08)
Annual income (1–5)	0.10 (0.10)	0.08 (0.11)
Having access to weather information	−1.03 *** (0.25)	−0.74 *** (0.28)
Living in concrete or brick building	−0.10 (0.23)	0.20 (0.23)
Owning livestock	0.44 * (0.24)	0.48 ** (0.24)
Level of education (1 to 5)	0.11 (0.11)	0.14 (0.12)
Physical		
Age	0.11 ** (0.05)	0.05 (0.05)
Age Square	−0.00 (0.00)	−0.00 (0.00)
Number of active family members (15–59 years)	0.02 (0.04)	−0.02 (0.04)
Male	−0.12 (0.26)	−0.01 (0.26)
Health status (1 to 3)	−0.25 (0.21)	0.18 (0.21)
Number of implemented response measures	0.35 *** (0.13)	0.58 *** (0.15)
Number of working days	0.01 * (0.01)	0.001 (0.01)
Psychological		

Perceived extreme events experiences (1 to 3)	0.71 *** (0.20)	0.38 *** (0.15)
Health satisfaction (1 to 5)	0.34 ** (0.17)	0.27 (0.18)
Environmental		
Living in an urban area	0.07 (0.24)	0.82 *** (0.24)
Constant cut 1	3.81 ** (1.51)	3.53 ** (1.58)
Constant cut 2	5.93 *** (1.53)	6.10 *** (1.61)
Observations	350	350

**** p < 0.01, ** p < 0.05, * p < 0.1; Standard errors in parentheses, [1] I Bigha = 0.67 ha.*

Note: the number of implemented response measures were either in response to heat waves or cold spells, and the number of working days was either during the summer or winter in the heat wave and cold spell model, respectively. The number of perceived events were in relation to either heat waves or cold spells, depending on the model.

2.5.4 Labour Productivity Loss during Heat Waves and Cold Spells.

Farmers' perceived heat and cold stress levels, and the number of associated illnesses or symptoms, to significantly increase labour productivity loss during heat waves ($p < 0.05$) and cold spells ($p < 0.05$) (Table 2.4). Farmers in urban areas were more likely to report productivity losses during heat waves ($p < 0.01$) and cold spells ($p < 0.01$) than farmers in rural areas. Respondents who had access to actual weather information were more likely to perceive labour productivity loss from heat waves ($p < 0.01$) and cold spells ($p < 0.01$) than those without this information. Respondents who had implemented more heat wave ($p < 0.01$) and cold spell ($p < 0.1$) adaptation measures (such as clothing adjustment, rescheduling working times, rest breaks) in the past were more likely to perceive labour productivity loss during heat waves and cold spells.

More variables affected farmers' productivity loss during cold spells than during heat waves. Respondents with higher annual income ($p < 0.05$) were more likely to report labour productivity loss during cold spells than those with lower income. Male respondents were less likely to perceive labour productivity loss from cold spells than female respondents. Age was significant ($p < 0.05$) and positive, but negative when squared ($p < 0.05$), which indicates that reported labour productivity loss increased with age but decreased eventually. District level analyses of self-reported labour productivity loss from extreme temperature are shown in Table B.3 (Appendices).

Table 2.4: Determinants of self-reported labour productivity loss.

Variables	**Perceived labour productivity loss during heat waves**	**Perceived labour productivity loss during cold spells**
Socio-economic		
Land size (in Bigha)	−0.14 (0.14)	−0.05 (0.13)
Annual income (1 to 5)	0.28 (0.19)	0.39 ** (0.18)
Access to weather information	2.22 *** (0.64)	2.60 *** (0.64)
Living in concrete or brick building	0.40 (0.43)	0.41 (0.39)
Owning livestock	0.44 (0.43)	0.03 (0.40)
Education (1 to 5)	0.16 (0.21)	0.23 (0.21)
Physical		
Age	0.09 (0.10)	0.22 *** (0.08)
Age Square	−0.009 (0.00)	−0.002 *** (0.00)
Active family members (15–59 years)	−0.02 (0.06)	−0.04 (0.06)
Male	−0.68 (0.48)	−0.75 * (0.44)
Health status (1 to 3)	−0.31 (0.36)	0.21 (0.34)
Number of perceived illnesses/symptoms	0.37 ** (0.15)	0.50 ** (0.23)
Number of implemented response measures	0.88 *** (0.23)	0.43 * (0.24)
Number of working days	0.01 (0.01)	−0.001 (0.01)
Psychological		
Perceived extreme events experience (1 to 3)	0.32 (0.34)	−0.02 (0.24)
Perceived stress medium (§)	1.69 *** (0.55)	2.70 *** (0.59)
Perceived stress high (§)	1.47 *** (0.54)	2.30 *** (0.57)
Work Satisfaction in agriculture (1 to 5)	−0.31 (0.32)	−0.31 (0.30)
Environmental		
Urban (Dummy)	1.36 *** (0.50)	1.76 *** (0.45)
Constant	−5.64 ** (2.66)	−9.14 *** (2.62)
Observations	350	350

**** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, Standard errors in parentheses. Reference case (§): low perceived stress from heat and cold.*

Note: the number of implemented response measures were in response to either heat waves or cold spells, and the number of working days was either during the summer or winter, in the perceived productivity loss from the heat wave and cold spell models, respectively. The number of perceived events were in relation to either heat waves or cold spells, depending on the model. Numbers of perceived illnessses or symptoms were related to either heat or cold in the perceived productivity loss from the heat wave and cold spell models. Perceived stress medium and perceived stress high were also in response to either heat or cold with reference to low perceived stress in self-reported productivity loss from heat waves and cold spells.

About 31% (32%) of household heads stated they had been absent from field work during cold spells (heat waves). Those who reported absenteeism during heat waves, had, on average, missed 16 days of farm work during the past year. The average number of absent days during cold spells was 11.5 during the past year. At the same time, about 85% of respondents reported that more than 50% of their work time was less productive during heat waves, and 64% of respondents reported that more than half of their working hours were less productive during cold spells. It could be that cold spells normally occur during the winter season when agricultural activities are limited.

2.5.5 Adaptation and Relief Strategies to Cope with Heat and Cold Stress.

Nearly 96% of respondents said that they wear broad-brimmed hats or used umbrellas to protect themselves from extreme heat when working on the farm. Some 93% of respondents who were heat stressed reported heat relief measures, such as resting in the shade and slowing down their working pace, while ~61% stopped their outdoor farm activities during extreme heat waves. Nearly 65% of respondents rescheduled their working shifts to moderate the impact risks of heat on their health and labour productivity. Approximately 17% of respondents adopted cooling techniques when working outside on very hot days, while ~54% stated that they had different means to cool down, such as drinking more cold water, staying in sheds, staying inside the house, and using wet clothing to reduce the impacts of heat.

Of those respondents (285) who wanted to shift their working schedules, 17% preferred to start and finish earlier, and only about 1% preferred to start and finish later. About 82% wanted to work early in the morning and late in the evening on very hot days to avoid the hottest hours. About 12% did not change their working plans at all, 22% changed their plans rarely, 61% changed sometimes, and 6% often or very often. About 42% of the respondents regularly hired additional labourers to get the work done during hot days, and further reported that nearly all those respondents found their labourers to be less productive during very hot days.

Similarly, to avoid and mitigate the impacts of extreme cold, farmers used the following adaptation measures: wearing warm clothes (99%), cessation of work if the temperature dropped or resting to warm up (82%), rescheduling working timetables (82%), and drinking hot beverages (65%). Of those who rescheduled their working times, most (94%) preferred to work in the daytime during very cold days. Stopping work (χ^2 (2) = 5.035, p = 0.0807) and rescheduling working time (χ^2 (2) = 10.39, p = 0.0055) were the two heat-related responses most affected by the level of heat stress farmers experienced.

Less stressed farmers were less likely to stop working, or to reschedule their working schedules, than highly stressed farmers. Stopping work and resting to warm (χ^2 (2) = 30.56, p = 0.0001), rescheduling working hours (χ^2 (2) = 7.556, p = 0.0229), and drinking hot beverages (χ^2 (2) = 75.35, p = 0.0001) were most highly affected by the level of cold stress. All the heat- and cold-related response strategies were more significantly affected by income level (Table B.8 in the Appendices).

2.6 Discussion

2.6.1 Health Impact of Heat Waves and Cold Spells on the Farming Community.

We found that health status has a significant impact on farmers' perceived heat stress, but not on cold stress. Rocklöv, Forsberg, Ebi, and Bellander (2014) stated that health effects from heat waves would appear within 1–2 days and are relatively easy to identify. Health effects from cold spells, however, are more likely to be associated with higher mortality and appear within two weeks following exposure, and it is difficult to infer causality between health effects and cold spells. This is supported by a previous study (Shrestha et al., 2018), which found that mortality risks associated with cold spells (721) had, since 1990, been reported as being almost 16 times higher than heat wave reported deaths (45) since 1978 in the study region.

The most common heat wave related health problems among Nepalese farmers are fatigue, dizziness and headaches, followed by nausea, fainting, confusion and heat rashes. These results confirm findings in other studies from Nepal (Pradhan et al., 2013), India (Basu, 2009; Venugopal et al., 2015) and other parts of the world (Kovats & Hajat, 2008; Xiang, Hansen, Pisaniello, & Bi, 2016; Zander, Mathew, et al., 2018). The most common symptoms during cold spells are joint pain (arthritis), cold-related diseases (such as respiratory problem, pneumonia, cold cough) and indigestion problems, as was also reported by Hassi et al. (2005), and Davídkovová, Plavcová, Kynčl, and Kyselý (2014).

People who already suffer from health problems such as cardiovascular diseases (Hassi et al., 2005; Kirkhorn, Earle-Richardson, & Banks, 2010), pre-existing diabetes (indigestion) and respiratory diseases (Sun et al., 2016), and musculoskeletal disorders (Holmér et al., 2001; Mäkinen & Hassi, 2009) are usually more vulnerable to the effects of heat waves and cold spells. Musculoskeletal disorders are considered to be a significant hazard of agricultural occupations, and can cause labour productivity loss and even disability (Kirkhorn et al., 2010). As these illnesses are related to age (Hansen et al., 2011; Zhang, Nitschke, & Bi, 2013; Rocklöv et al., 2014; Xiang, Bi, Pisaniello, & Hansen, 2014; Xiang et al., 2016; Zander et al., 2017; Zhang et al., 2017), it was not surprising that older farmers reported higher levels of heat stress.

2.6.2 Determinants of Self-Reported Heat and Cold Stress.

The land size variable did not have any significant impact on the levels of heat and cold stress. Farmers who stated themselves to have regular access to information on actual weather phenomena were less likely to perceive future heat and cold stress. Respondents were less worried and stressed about upcoming weather conditions because they were well informed about potential coping mechanisms in advance, and thus more likely to implement relevant adaptation strategies (Belay, Recha, Woldeamanuel, & Morton, 2017), which could reduce the levels of heat and cold stress. Some demographic variables were also not significant, including education and income. It was expected that better educated and more prosperous farmers would be less likely to be stressed by heat and cold than those with lower education and income, a result found elsewhere (Gronlund, 2014), because they might be more aware of heat- and cold-related coping strategies. Owning livestock had a mixed impact. Respondents who owned livestock were found to be more heat and cold stressed, probably because of the increased need to spend a significant amount of time outside and doing labour intensive tasks related to livestock rearing, such as feeding and providing water, which is even more important during very hot and cold days. Contrarily, owning livestock had no impact on productivity loss during heat waves and cold spells. This might be because the increased labour needed to rear livestock and the expected higher labour productivity loss that might occur during extreme temperatures is offset by the benefits livestock provide as, for example, draft animals.

As expected, older people reported being highly heat stressed. This is most likely related to older people's deterioting health (Basu, 2009; Ng et al., 2014). Despite adopting various heat wave and cold spell coping measures, farmers were found to suffer additional heat and cold stress. Potentially, those adopted measures were not very effective in reducing the weather risks caused by extreme events (Zaalberg et al., 2009; Wise et al., 2014) in the study area, such as heat waves and cold spells. It was expected that variables associated with a higher workload and intensity (working more days) had positive impacts on the level of heat and cold stress, but this study found a positive impact only in the context of heat stress, which is consistent with the findings of previous studies (Kyselý, Plavcová, Davídkovová, & Kynčl, 2011; Lundgren, Kuklane, Gao, et al., 2013; Pradhan et al., 2013).

As assumed, past experience with extreme weather events such as heat waves and cold spells was positively associated with the levels of heat and cold stress (Akompab et al., 2013; Wachinger et al., 2013)

Urban respondents suffered more cold stress, which could be because the majority of farmers in the urban areas were poor and their housing conditions were not cold resilient. Due to long term cold exposure resulting from factors such as poor housing conditions, the risk of hypertension due to cold stress may be increased for outdoor workers, such as farmers (Mäkinen & Hassi, 2009).

2.6.3 Impact of Heat Waves and Cold Spells on Labour Productivity.

Respondents who reported higher levels of annual income were more likely to perceive labour productivity loss from cold spells. This was surprising, because higher incomes usually provide better opportunities to implement coping mechanisms (Burse, 1979), but a lack of awareness for cold spell protection mechanisms, and farmers' decreased motivation to work could potentially explain the perceived labour productivity loss during cold spells.

Farmers with access to weather information were found to be more likely to perceive labour productivity losses from heat waves and cold spells from 2012 to 2017. This was also surprising, as information about the weather would have aided them in preparing to take precautionary measures, such as drinking enough cool or hot water and wearing appropriate clothing. They would also have had the opportunity to schedule and plan their work, while taking predicted hot or cold periods into account. However, the quality and accuracy of the weather information to which farmers have access are unknown, and probably not very reliable, as farmers did not take much notice of it.

Age had no impact on perceived productivity loss during heat waves, in contrast with other studies, which have found that age, heat stress, and productivity loss from heat stress are positively correlated (Hansen et al., 2011; Sun et al., 2016). In the cold spell model, however, age did have the expected inverse U-shape relationship with productivity loss. Those farmers of increased age self-reported higher cold stress levels, as they were more active in their physical work (Hajat et al., 2014). Level of cold stress declined after a certain age when they were less involved in physical outdoor activities.

Men were less likely to perceive labour productivity loss from cold spells than women. The peripheral vasoconstriction of women inhibits their ability to maintain safe skin temperature in extreme cold, as they have less maximum heat production capability and lower mean foot, hand, and skin temperatures, and have a relatively higher risk for cold injuries (Burse, 1979). In order to maintain their body temperature, women require better clothing insulation, which increases hobbling effects and hinders dexterity (Burse, 1979; Rodahl, 2003).

Respondents who had experienced many heat and cold-related illnesses from 2012 to 2017 were more likely to perceive labour productivity loss from heat waves and cold spells. This might be linked to their health status, meaning those who experienced many heat- and cold-related illnesses were unhealthy, and therefore more prone to stress than healthy respondents (Zander et al., 2017), which in turn hampered their working capacity. Likewise, farmers who reported respiratory symptoms and pulmonary obstructions, as triggered in cold weather, were more likely to be less productive during cold spells (Hassi et al., 2005; Kyselý et al., 2011). Farmers implemented a number of different coping strategies in response to EWEs, but their perceived labour productivity loss from heat waves and cold spells remained high. The number of adaptation mechanisms implemented might not have been sufficient enough to reduce the negative impacts of EWEs. Another reason for perceived productivity loss could be the increasing magnitude and frequencies of extreme temperatures in recent years.

As expected, farmers who perceived a moderate and high level of heat and cold stress were more likely to report labour productivity loss than farmers who perceived lower levels of heat and cold stress (Zander et al., 2015).

We found that urban farmers (Bardiya) were more likely to perceive labour productivity loss due to both heat and cold. For heat, at least, this result was not surprising, as the urban population is highly affected by temperatures increasing due to the urban heat island effect (Zander, Cadag, et al., 2018). As this study was conducted in the warm and humid region of Nepal, the effects of cold spells on health and labour productivity loss were probably higher than in other regions of Nepal, per farmer acclimatisation levels. Heat effects are generally lower in areas with higher long-term temperatures, because people have adapted to the higher average temperatures (Kirkhorn et al., 2010). As expected, therefore, cold effects were found to be higher in communities with warm temperatures.

2.6.4 Adaptation Measures against Heat Waves and Cold Spells.

Farmers adopted multiple strategies simultaneously. The most applied precautionary measure for protection against direct heat exposure while working in agricultural fields was the use of hats and umbrellas. During extreme heat, farmers would sometime stop their work completely, and preferred to reschedule shifts to minimise heat exposure. Working during the cooler parts of the day, such as early in the morning or late in the evening, is a practice widely found across the low-lying regions of Nepal. Likewise, taking frequent breaks, resting in the shade, and slowing working pace, as has been found in Australia (Singh et al., 2013), were the other primary heat exposure minimising mechanisms that respondents adopted while working in agriculture. Regularly resting and slowing working pace is a type of behaviour acclimatisation, which helps to reduce bodily heat strain while working in agriculture (Sahu, Sett, & Kjellstrom, 2013).

Similarly, farmers managed various cooling techniques such as bathing in cold water, wearing wet clothes, and drinking a lot of cold water to avoid dehydration from heat exposure, as also found by Pradhan et al. (2019). Stopping work and rescheduling work shifts are the two heat response measures found to significantly differ across the three perceived heat stress levels, low, medium, and high. As climate variability increases and temperatures get more extreme, these readily accessible measures are more likely to be abandoned and more expensive (financially, socially and personally) technologies might be needed.

Most of the respondents wore warm clothes to keep them safe from cold spells during winter, thus helping to maintain core body temperature and to protect from adverse health impacts (Hassi et al., 2005). As most of the farmers in the study areas were impoverished, they were highly affected by decreased temperatures during winter. The local governments in the study areas often issued directives to the people to stay inside, and also provided warm clothes and wood to deprived households during cold spells (Pradhan et al., 2019). Stopping work during extreme cold and altering work schedules were widely practiced coping strategies.

2.6.5 Limitation of the Study.

There are two limitations to the study. The first limitation relates to how self-perceived labour productivity loss was measured and the chosen recall period. Quantifying actual labour productivity loss measured in term of absenteeism and presenteeism in agricultural farming households is a challenging task because most of the farming household members are self-employed within the agriculture sector. Farming households are mostly busy during the planting and harvesting times of the cropping seasons, but remain partially or fully unemployed during the off-farm seasons. In that context, calculating the monetary measurement of productivity loss is hard in an unorganised agriculture sector, where there is a lot of seasonal and disguised unemployment. Rather than directly measuring the monetary value of labour productivity loss, we instead measured self-perceived labour productivity loss in the ordinal scale, while farmers were involved in the agriculture sector between 2012 and 2017. We chose five years as the recall period. The method might suffer from recall bias, because respondents may not accurately and precisely remember previous events or their experience after such a long time, or their memories might have been distorted by other experiences and events (Akerlof, Maibach, Fitzgerald, Cedeno, & Neuman, 2013). To minimise the recall bias, we carefully designed the research questions and implemented appropriate research tools. Rather than assessing the perceived productivity loss as an exact number or percentage, we allowed respondents to answer on an ordinal scale. The second limitation of the study relates to the fact that the study used cross sectional data. Since the data were collected at a single point of time, we were not able to determine the actual cause and effect relationship (Rindfleisch, Malter, Ganesan, & Moorman, 2008) between the proposed perceived heat and cold stress and perceived labour productivity loss and actual extreme temperatures. Thus, future studies should be conducted over a series of data collection waves, producing longitudinal data that can allow for climatic conditions and the occurances of EWEs across the study regions. Additionally, the results of our study would further benefit from information from local and regional hospitals on the number of patients admitted and discharged during heat waves and cold spells.

2.7 Conclusions

This study found that individual farmers and their family members had experienced various heat-wave- and cold-spell-related illnesses and health problems between 2012 and 2017. Fatigue, dizziness, headaches, nausea, confusion, heat rashes, fainting, loss of concentration and heat strokes were the most common health problems self-reported by farming households during heat waves. Likewise, joint pain, pneumonia, respiratory problems, cold cough and indigestion were the common health issues that farmers were mostly suffered during cold spells. Though farming households had been highly affected by both forms of EWE, heat waves and cold spells, in recent years, the impact of cold spells was found to be higher on farming households. Potential reasons for this could be that there was higher acclimatisation to heat waves, and less adaptation towards cold spells, due to a limited coping capacity caused by relative poverty and farmer ignorance. Farmers were found to apply broad-brimmed hats or umbrellas, resting in the shade, slowing down their working pace, and completely stopping work during extremely hot days, rescheduling their working schedules, and applying various cooling techniques to reduce the impact of heat stress on labour productivity loss from heat waves. The main coping mechanisms used as precautionary measures to mitigate labour productivity loss during cold stress included wearing warm clothes, stopping work, resting to warm up, rescheduling working timetable, and drinking hot beverages. To help mitigate the effects of extreme weather events and save lives, public awareness campaigns should specifically target the susceptible parts of the population with information on the appropriate actions to take during extreme temperatures. Extreme temperature warnings based on weather forecasts should also be publicly broadcast, as well as heat and cold stress prevention measures. The implementation of risk communication and risk awareness through local media, providing information about the possible consequences of heat waves and cold spells, and the potential coping mechanisms, could be a primary strategy by which to mitigate potential health impacts and labour productivity losses.

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Chapter 3 Assessing farmers' preparedness to cope with the impacts of multiple climate change-related hazards in the Terai lowlands of Nepal

3.1 Preface

This chapter presents factors that influence farmers' risk perception and preparedness intention to three extreme events such as floods, heatwaves, and cold spells. The chapter has been published full in the International Journal of Disaster Risk Reduction. Changes have been made to the formatting and the referencing style so that it is consistent with the rest of the thesis.

Budhathoki, N.K., Paton, D., Lassa, J. A., & Zander, K. K. (2020). Assessing farmers' preparedness to cope with the impacts of multiple climate change-related hazards in the Terai lowlands of Nepal. *International Journal of Disaster Risk Reduction*, 49, 101656.

3.2 Abstract

Climate change-related natural hazards severely affect farmers' livelihoods. This study explores how farmers in the vulnerable western lowlands of Nepal are affected by floods, heatwaves, and cold spells, how they adapt, and the factors influencing their risk perception and intended adaptation behaviour. Data were collected through a survey of 350 randomly selected farming households from the Banke and Bardiya districts in the Tarai region. Farmers identified environmental risks as the most severe risks to their agricultural production, and their main adaptation strategies, including changes to planting dates and crop varieties and increasing the use of fertilisers and pesticides. Following protection motivation theory and using structural equation modelling, we found that farmers’ risk perception and adaptation behaviour in response to three specific hazards (floods, heatwaves, and cold spells). The flood impact model showed that self-efficacy, perceived responsibility, response cost, trust, and concern partially influenced flood risk perception. These, in turn, mediated affected farmers’ intended flood adaptation strategies. Flood damage experience thoroughly explained flood adaptation behaviour and was mediated by flood risk perception. Risk perception of flood has the significant mediation effects in the flood model, but heatwave and cold spell risk perception did not have any mediation effect in neither the heatwave nor the cold spells models. We attribute this discrepancy to the fact that slow and rapid onset hazards are perceived differently. These problems were compounded by farmers also lacking both awareness and the requisite knowledge of how to deal with the impacts of the climate change related slow-onset hazards that will become more frequent as climate change continues, unabated. These differences will need to be accommodated in sustainable was in community awareness and disaster management programs to increase adaptive and resilient community capacity for the future.

Keywords: Disaster preparedness, Extreme weather events, Protection motivation theory, Risk perception, Structural equation model

3.3 Introduction

As the climate changes and becomes more volatile, the frequency and severity of natural hazards will increase (Demski, Capstick, Pidgeon, Sposato, & Spence, 2017). Natural hazards cause significant physical damage to infrastructure, take people's lives, and cause social, psychological, and economic harm to the affected population (Lindell & Hwang, 2008). Farmers in low-income countries are among the most vulnerable to these impacts because their socio-economic circumstances create both high levels of exposure and low levels of adaptive capacity (De Silva & Kawasaki, 2018; Azadi, Yazdanpanah, & Mahmoudi, 2019).

To reduce the potential socio-economic impacts of natural hazards, timely investment in preparedness strategies is essential (Lindell, 2013). However, many disaster-prone developing countries are substantially underinvesting in disaster-resilient efforts due to a lack of financial resources to cover high upfront costs and inadequate institutional capacity (Guha-Sapir, Santos, & Borde, 2013). To facilitate the latter, better information about how climate change affects farming communities and how these communities adapt or fail to adapt is a crucial prerequisite to stimulating and guiding efficient investments in rural areas, or on a communal or household level. Because preparedness can be achieved through community or regional-wide infrastructure investments, such as building dykes to prevent the effects of river flooding or using an early warning system to prepare for river flooding and cyclones, and by developing people's adaptive and coping capacities (Daramola, Oni, Ogundele, & Adesanya, 2016) it is imperative to investigate these issues collectively. While attention tends to focus more on structural mitigation, complementary strategies aimed at building people's adaptive capacities will complement structural activities and increase the likelihood that people will take precautionary measures to mitigate the impacts of natural hazards (Grothmann

& Reusswig, 2006). Adaptive capacity depends on many factors, including people's available financial resources and technical knowledge, their belief that they can adapt, their perceptions and awareness of the risk, and the severity and type of hazard (Daramola et al., 2016). Systematic research is thus required to understand how these factor act and interact in order to develop evidence-based or informed strategies.

An essential precursor for effective preparedness and adaptation (Paton, Smith, & Johnston, 2005; Ullah, Shivakoti, & Ali, 2015; Xu, Peng, Liu, & Wang, 2018), risk perception is the subjective assessment of the probability of a natural hazard occurring and the consequences of hazards activities (severity) (Slovic, 2000; Sjöberg, Moen, & Rundmo, 2004; Lindell & Hwang, 2008; Bubeck, Botzen, & Aerts, 2012). Differences in the characteristics of natural hazards, for instance, their severity and frequency, can also lead to differences in the relationship between risk perceptions and adaptation (Bubeck, Botzen, Aerts, Bubeck, & Kreibich, 2012). There is a wide breadth of literature on the role of people's risk perception for adaptation. Most studies focus either on general climate change perception adaptation strategies (Azadi et al., 2019; Budhathoki & Zander, 2020; Paudel et al., 2019) or on single specific natural hazard, such as floods (Zaalberg, Midden, Meijnders, & McCalley, 2009; Terpstra, 2011; Devkota, Maraseni, Cockfield, & Devkota, 2013; Ejeta, Ardalan, Paton, & Yaseri, 2016, 2018), hurricanes (Demuth, Morss, Lazo, & Trumbo, 2016), wildfires (Martin, Martin, & Kent, 2009), drought (Keshavarz & Karami, 2016), or landslides (Xu et al., 2018). With the exception of drought research (Keshavarz & Karami, 2016), most of these hazards are sudden and briefly devastating. Little attention has been directed at how people cope with and adapt to multiple hazards and multiple climate change-related extreme weather events, which can be slow in their onset and long-lasting. Risk perception research has emerged to support decision-makers in their understanding about how people perceive and evaluate risk and to predict levels of preparedness and adaptation. Previous risk research has shown that risk perception differs between slow and sudden-onset hazards (Wachinger, Renn, Begg, & Kuhlicke, 2013; Shreve, Begg, Fordham, & Müller, 2016) and, therefore, the way farmers prepare and adapt.

The aims of this study were to i) explore how farmers in the lowlands of Nepal (Tarai region) have previously adapted and, further, intend to adapt to the impacts of one sudden onset hazard (floods) and two slow-onset hazards (heatwaves and cold spells); ii) identify factors that determine risk perception of these three hazards; and iii) investigate the determinants that shape farmers' preparedness for future adaptation.

Among various underlying factors, psychological factors, such as risk perception, have gradually received recognition in the policy-making processes for climate change adaptation (Gandure, Walker, & Botha, 2013). Though there has yet been a lack of research regarding the psychological aspects (Le Dang, Li, Nuberg, & Bruwer, 2014). Without considering the socio-psychological factors, it would be challenging to develop a framework required to facilitate people's understanding of their risk and how to translate this into practical strategies capable of mitigating climate change risk (Azadi et al., 2019). Given the current and anticipated future impact of climate-related extreme weather events, it is crucial to heighten farmer coping capacities and preparedness in order to minimise the damage.

Our study contributes to this growing body of literature by providing evidence from Nepal with a unique focus on the psychological beliefs and processes that influence farmers' adaptation behaviour in response to multiple natural hazards of different severity. Previous studies from Nepal have investigated farmers' understanding of climate change, their risk beliefs, and their adaptation strategies at the households and farm levels, including changing cropping varieties, cropping type, water management, using pesticides, and planting drought and flood-tolerant crops varieties to minimise the agricultural losses (Manandhar, Vogt, Perret, & Kazama, 2011; CBS, 2017; Devkota et al., 2017; Budhathoki & Zander, 2019; Paudel et al., 2019). However, these studies have largely ignored the psychological factors associated with adaptation-related behaviour changes. Understanding the psychological processes is essential to providing a framework to inform the development of sustainable adaptive strategies. In particular, we contend that understanding the psychological processes that facilitate effective responses to climate-related hazards (Swim et al., 2011) through predicting the adoption of self-protective action can significantly, and more accurately, complement current strategies based on socio-economic variables alone (Grothmann & Patt, 2005). We applied a Climate Change Risk Perception Model (Van Der Linden, 2015) — pathway model that can detect direct and indirect effects of psycho-cognitive variables on risk perception and preparedness for intended adaptation — to help develop an understanding of the causal and mediational relationship between farmers' socio-economic, psychological, and experiential characteristics, and their influence on risk perception and adaptation behaviour in response to different natural hazards.

Nepal was chosen as a case study because the country is one of the most vulnerable (ranked fourth in the world) to climate change-related disasters (McSweeney, Lizcano, New, & Lu, 2010), and is profoundly affected by increasing floods and temperature extremes (Devkota et al., 2013; Budhathoki & Zander, 2019; Maharjan & Maharjan, 2019; Paudel et al., 2019). Between 1970 and 2013, nearly 4,000 floods were reported in Nepal, resulting in 3,538 fatalities and 547 injured people, while nearly 100,000 houses were destroyed and another 100,000 suffered property damage amounting to USD 6,076 million. In total, the floods affected around 0.5 million people, 500,000 cattle were lost, and thousands of hectares of cropland were destroyed (UNISDR, 2013). It is estimated that by 2030, an additional 200,000 people will be affected annually by river floods in Nepal (WRI, 2015).

Besides floods, heatwaves and cold spells have also caused a significant reduction in crop production in recent years and have compromised farmers' well-being, health, and productivity (Budhathoki & Zander, 2019; Budhathoki & Zander, 2020). Throughout Nepal, there were a reported 647 cases of cold spells and 49 cases of heatwaves between 1970 and 2013, with the cold spells resulting 269,000 hectares of damaged cropland and an economic loss of USD 835 million (UNISDR, 2013). Of the cold-related deaths, 89% of deaths took place in the Terai region (Budhathoki & Zander, 2019). These three hazards have been predicted to increase in severity as climate changes unabated, making a better understanding of how farmers in Nepal can effectively cope with the impacts essential. The results will help to guide policies and investments in Nepal to promote farmers' resilience to climate change impacts.

3.4 Risk Perception and Protection Motivation Theory

Risk perception, understanding, and concern of natural hazards vary significantly across countries and regions due to personal, cultural, environmental, and governmental influences (Sjöberg & Wåhlberg, 2002; Lee, Markowitz, Howe, Ko, & Leiserowitz, 2015). Risk perception is not only determined by the characteristics of the hazard and the threats it can present, but also by various psychological, cognitive, and social factors that relate to the individual experiences, emotion, trust, values, beliefs, and worldviews that influence people’s interpretation of their environment and the threats it may present (Kellstedt, Zahran, & Vedlitz, 2008; Slovic, 2000; Weber, 2010). Many factors directly affect risk perception, including knowledge and information (Kellstedt et al., 2008), personal, and contextual factors (Grothmann & Reusswig, 2006; Wachinger et al., 2013; van Der Linden, 2015; Frondel, Simora, & Sommer, 2017; Richert, Erdlenbruch, & Figuières, 2017). Education, for example, is assumed to negatively relate to risk perception because cognitive ability improves risk assessment and decision-making skills (Bruin, Parker, & Fischhoff, 2007). An association with community organisations can have a positive impact on farmer’s risk perception and awareness due to frequent information exchange and discussions among community members (Wachinger et al., 2013).

Some of the earlier studies defined concern as a prominent emotional reaction to risk and used it as a proxy for risk perception (Bubeck et al., 2012). Other studies (Weinstein, 1989) argue that concern and risk perception have a weak relation because an individual might be less concerned about a severe risk due to the presence of cognitive biases, such as unrealistic optimism resulting in people transferring perceived risk to others. Concerns or fear might also motivate people to adapt (Miceli, Sotgiu, & Settanni, 2008). Personal experience with natural hazards can influence risk perceptions (Dai, Kesternich, Löschel, & Ziegler, 2015), particularly if this damage has been personally experienced (Demski et al., 2017; Frondel et al., 2017).

Individuals with a high degree of trust in government-led adaptation measures perceive lower risks than individuals with limited trust (Carlton & Jacobson, 2013).

Moreover, trust in government strategies can be negatively associated with farmers' adaptation behaviour (Grothmann & Reusswig, 2006; Terpstra, 2011).

A high level of perceived risk is associated with an increased likelihood of preparedness and adapting to natural hazards (Miceli et al., 2008; Martin et al., 2009), although some studies found weak correlations between risk perception and disaster preparedness (Lindell & Whitney, 2000; Siegrist & Gutscher, 2006). The relationship between risk perception and adaptation is often contextualised by the Protection Motivation Theory (PMT) (Rogers, 1975). The concept behind this is that farmers intend to take precautionary measures through two cognitive processes: threat appraisal and coping appraisal. Coping appraisal in our study relates to how farmers cope with climate change impacts and adapt, and consists of perceived response cost, self-efficacy, and perceived responsibility. We slightly modified the coping appraisal component of response efficacy and replaced it with perceived individual responsibility and the assumption that farmers' perceived responsibility is one of the main determinants of farmer's intended adaptation strategies (Martin et al., 2009). Perceived response cost is the assumed cost of taking preventive strategies, which include the factors of finance, time, and effort, as well as self-efficacy — the belief farmers have in their own ability to adapt successfully (Grothmann & Patt, 2005; Janmaimool & Watanabe, 2014). Perceived individual responsibility is the belief that individual adaptation behaviour is essential to minimising the risk and damage of a natural hazard (Martin et al., 2009).

Both response cost and self-efficacy can influence risk perception (Janmaimool & Watanabe, 2014; Dai et al., 2015; Aksha, Juran, Resler, & Zhang, 2019) and also have a direct impact on individual preparedness intentions (Zaalberg et al., 2009; Poussin, Botzen, & Aerts, 2014; Keshavarz & Karami, 2016; Richert et al., 2017; Zander, Richerzhagen, & Garnett, 2019). People who expect that the benefits of adaptation outweigh the costs have a higher likelihood to adapt than those who expect that the costs exceed the benefits (positive and negative outcome expectancy; (Paton et al., 2005)). Farmers who assume they can reduce or avoid the negative impacts of a natural hazard by changing their behaviour are less likely to perceive the risk (Janmaimool & Watanabe, 2014).

In reference to farmers' assessments of the severity of the hazard and potential damage (Terpstra, 2011), threat appraisal comprises perceived severity and perceived probability, which we define, following Grothmann & Reusswig, (2006), as *risk perception* in this study. A high-risk perception (i.e. a high threat appraisal) can lead to heightened adaptation intention, though it depends on an individual's coping appraisal (Milne, Sheeran, & Orbell, 2000). Coping appraisal was regarded as a better predictor of adaptation intention than threat appraisal or risk perception (Grothmann & Patt, 2005; Grothmann & Reusswig, 2006; Zaalberg et al., 2009).

Factors that are expected to determine risk perception are also assumed to indirectly influence farmers' preparedness intentions through threat appraisal (risk perception). For instance, education will shape preparedness intention, which mediates through risk perception. This is because educated people have abstract reasoning and anticipation skills, which help them adapt to and cope with disasters even though they do not have hazard experience (Hoffmann & Muttarak, 2017).

Psychological and cognitive factors consist of self-efficacy (Janmaimool & Watanabe, 2014) and perceived individual responsibility (Martin et al., 2009), both of which have an indirect impact on adaptation strategies mediated through risk perception. An individual with high self-efficacy and individual responsibility beliefs will have higher risk perception, which in turn has an indirect impact on adaptation behaviour (Martin et al., 2009). Higher perceived response costs of potential preparedness strategies decrease the likelihood of undertaking these strategies (Grothmann & Patt, 2005; Poussin et al., 2014; Keshavarz & Karami, 2016), which will further increase exposure to disasters.

Experiences with disasters in terms of financial loss or emotional impact heightens risk perception, which in turn increases preparedness strategies (Demuth et al., 2016; Demski et al., 2017). Having trust in government disaster adaptation strategies lessens the individual risk perception, which will, in turn, hamper individual preparedness intentions (Terpstra, 2011). Farmers' concern or worry about natural hazards in their community will have a positive association with preparedness intention mediated through risk perception of natural hazards. Stronger attachments to community or place might induce an individual to take precautionary disaster measures (Botzen, Aerts, & van Den Bergh, 2009). Based on these findings, the following hypotheses were tested (see Figure A1 and Table B9 in the Appendix for a description of the variables).

H1. Farmers' details, including gender (H1a), age (H1b), status as a member of a community organisation (H1c), and education (H1d) have direct impacts on risk perceptions.

H2. Perceived self-efficacy (H2a), individual responsibility (H2b), and trust in government adaptation strategies (H2c) have direct negative impacts on risk perceptions, but response cost (H2d), damage experience (H2e), and concern of disasters (H2f) have a direct and positive impact on risk perception.

H3. The likelihood of preparedness intention is positively and directly influenced by education (H3a), perceived self-efficacy (H3b), individual responsibility (H3c), previous damage experience (H3d), and risk perception (H3e), but negatively and directly influenced by trust (H3g), potential response costs (H3f), and concern (H3h).

H4. Risk perception mediates the relationship between education and intended adaptation strategies of the respective extreme events.

H5. Perceived self-efficacy, individual responsibility, and potential response costs (coping appraisal) have indirect impacts on intended adaptation strategies and are mediated by risk perception.

H6. Trust, damage experience, and concern have an indirect impact on intended adaptation strategies and are mediated by risk perception.

3.5 Methods

3.5.1 Study area.

The Tarai region covers only 14% of the total land area of Nepal but contributes 72% of national rice production and 63% of wheat (MoAD, 2017). It is, therefore, referred to as the 'granary' of Nepal, with more than 84% of farm households actively engaged in rice production (CBS, 2011). Paddy and wheat are the main cereal food crops grown in the monsoon and winter seasons in the western Tarai region, including Banke and Bardiya (CBS, 2011; Budhathoki & Zander, 2020) where the study took place. Paddy rice and wheat account for 72% and 21% of the total cereal crop production in Bardiya, and to 55% and 28% in the Banke district, respectively (in 2010/2011; CBS(2012)). Some farmers also grow vegetables, oilseed, and potatoes in the study area. Farmers typically transplant paddy in the second week of August and harvest during the second or third week of November; transplanting wheat in the first week of January and harvesting in the second week of May (Manandhar et al., 2011).

The Tarai region covers 22 districts (of a total of 77 districts in Nepal) and is home to more than half of the country's population of 28.5 million people (CBS, 2012). Based on both the climate change impact survey (CBS, 2017) and the outcome of discussions with Nepal Department of Hydrology and Meteorology (DHM) officials, the Banke and Bardiya districts were selected as a case study for this research. From these districts, two municipalities and their respective wards[3] were chosen for the survey (see Figure 3.1).

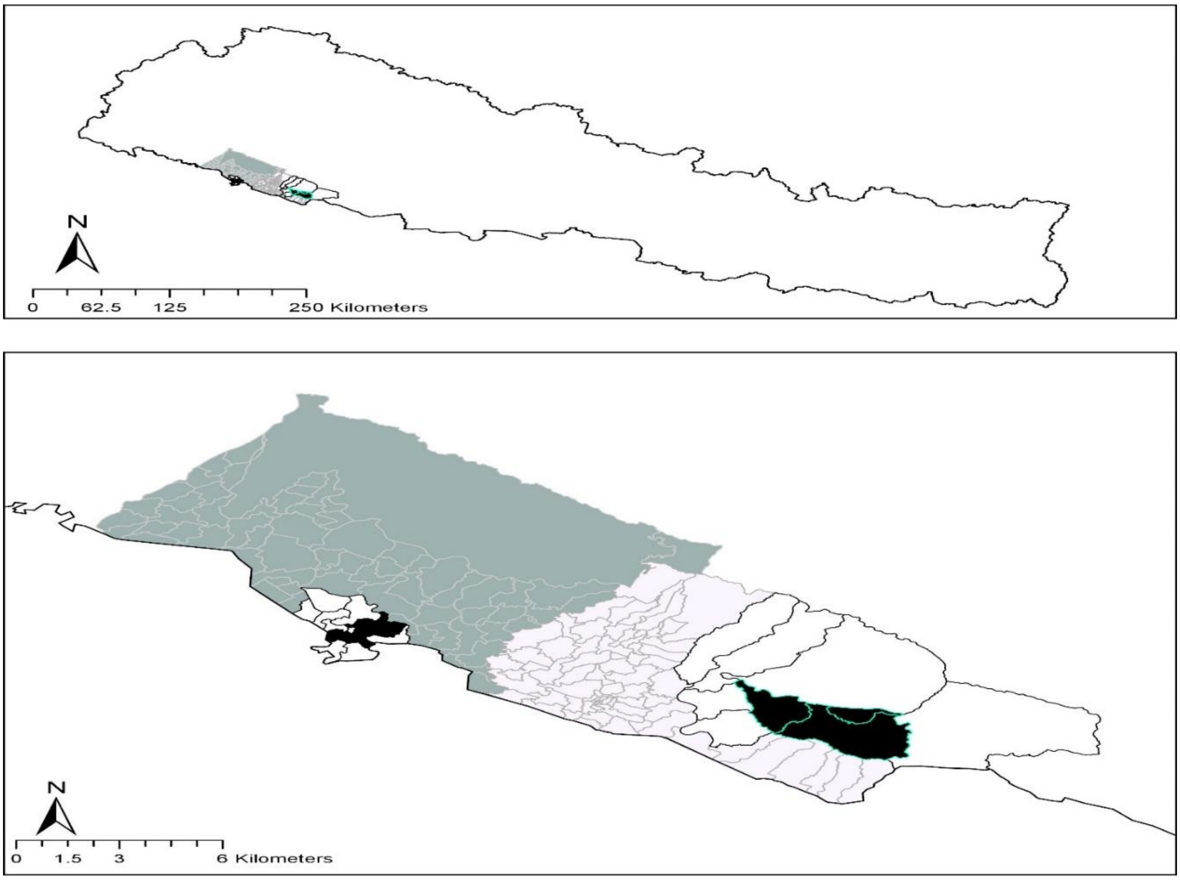

Figure 3.1: Map of the study area.

[3] lower administrative division

3.5.2 Sampling and data collection.

Within the Bardiya district, three wards (5, 8, and 12) of the Guleriya municipality and three wards (3, 4, and 5) of the Rapti Sonari rural municipality in the Banke district (study areas shaded black in Figure 3.V1) were purposively selected. These wards were chosen following discussions with district-level government officials based on the frequency and intensity of extreme event occurrence in these areas. From each municipality, farming households were selected by using random sampling (see Table B10 in Appendix). In total, 350 household heads were interviewed, 52% from Rapti Sonari and the remaining 48% from Guleriya municipality. The survey was conducted between the first week of November 2017 and the third week of January 2018 by three experienced and trained research assistants who spoke Nepali, the primary language used for the survey, and who could also understand Tharu and local dialects.

A draft survey questionnaire was prepared based on a literature review and expert consultation[4] and tested in a pilot study with 15 respondents randomly selected from a village within the study area. We chose this sample size for the pilot study based on recommendations by Moore, Carter, Nietert, and Stewart (2011) to target at least 12 participants. Based on the feedback received from the pilot survey, the survey questionnaire was modified to ensure clarity. The revised final survey contained questions

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[4] Nine expert interviews were conducted: three with central government officials from the Ministry of Agriculture and Development, four with government officials from the two Banke and Bardiya district agricultural offices and district disaster committee (two from each district), and two with representatives from NGOs (one from each district).

on farm characteristics, farmers' perceived main agricultural risk, risk perception of all three extreme weather events (EWE; floods, heatwaves, and cold spells), and farmers' existing adaptation strategies and intended preparedness strategies (see Table B9 for the key questions and variables and household survey questionnaire in the Appendix).

Questions about the perceived future impacts of the EWEs on agricultural production, farming and housing infrastructure, as well as about the farmers' and their families based on past hazard experience were posed as four-point scale questions with possible responses ranging from *Very unlikely, Quite unlikely, Quite likely,* to *Very likely* (see Table B9 and household survey questionnaires in the Appendix). Ex-ante risk perception of various climate-related hazards is commonly assessed by using self-reported scale questions [e.g. Miceli, Sotgiu, & Settanni, 2008; Van der Linden, 2015].

Each respondent was asked about their *intended adaptation strategies* for being better prepared and in order to minimise the future risk of floods, heatwaves, and cold spells. The intended adaptation strategies were listed as 'taking out agricultural insurance', 'reducing assets exposures', 'preparing for emergent facilities', 'improving communication', 'shifting to off-farm work', 'improving existing early warning systems', 'changing crop varieties or types', and 'altering crop planting dates'. These strategies were identified from existing literature (Manandhar et al., 2011; Begum, Sarkar, Jaafar, & Pereira, 2014; Poussin et al., 2014; Budhathoki & Zander, 2020), discussion with climate change experts in the district, and by interacting with farmers.

3.5.3 Data analysis.

We applied a structural equation model (SEM) over traditional regression analysis. SEM is an innovative analytical and statistical technique by which to test the research hypotheses in a single process by modelling complex relationships between observed and latent variables (Kline, 2015). SEM can analyse both direct and indirect effects between variables, and also estimate multiple and inter-related dependence relationships simultaneously (Terpstra, 2011; Le Dang et al., 2014; Demuth et al., 2016; Demski et al., 2017; Deng, Wang, & Yousefpour, 2017; Azadi et al., 2019), while traditional regression can only analyse direct effects (Byrne, 2001; Kline, 2015). Mediation analysis explains the process and mechanism by which one variable affects another variable, and mediating variables are comprised of behavioural, social, biological, and psychological variables (MacKinnon, Fairchild, & Fritz, 2007; Rucker, Zhao, Lynch Jr, & Chen, 2010; Preacher, Tormala, & Petty, 2011). In the conventional mediation approach (Baron & Kenny, 1986), the significance of the relationships between direct and indirect variables are tested both before and after introducing a mediator to examine the partial and full mediation effects. However, the conventional approach has been challenged (Zhao et al., 2010; Rucker et al., 2011) because placing undue emphasis on significance relationship between independent and dependent variables can lead to a misleading result. Significant indirect effects can occur in the absence of insignificant total or direct effects (Zhao et al., 2010; Rucker et al., 2011).

Figure A2 in the Appendix shows a mediated effect in which an independent variable exerts an indirect effect $(a \times b)$ through intervening variables (M) on the dependent variable, as mentioned by Baron and Kenny (Baron & Kenny, 1986). When indirect $(a \times b)$ and direct effects (c) are significant and point in the same direction, complementary mediation is reported. If direct and indirect effects point in a different direction, competitive mediation is indicated. Full mediation is indicated only when the indirect effect $(a \times b)$ is significant (Zhao et al., 2010).

The statistical software STATA was used for descriptive data analysis while the software SPSS (Statistical Package for the Social Sciences), precisely the module AMOS (Analysis of a Moment Structures) was used for the path analysis through structural equation models (SEM). Path analysis was employed to investigate the influence of individual self-reported characteristics on risk perception of natural hazards and farmers' preparedness intention. Prior to the SEM, multivariate normality[5] tests were performed. To address the issue of non-normality, bootstrapping was carried out to provide less biased estimates to help adjust for the non-normality of data distribution (Bollen & Stine, 1992). Model fit was judged using the guidelines provided by Byrne (Byrne, 2001) and Bollen and Stine (Bollen & Stine, 1992). Path coefficients and the amount of variance explained by the model (R^2) were examined and the following goodness of fit measures were reported: The model x^2, The Root Mean Squared Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker Lewis Index (TLI), α^2/df, and Standardised Root Mean Square Residual (SRMR). In order to evaluate the convergent validity of the measurement model, the individual item reliability of latent variable risk perception of the three climatic extremes (the standardised loadings), average variance extracted (AVE) and composite reliability (CR) were assessed.

[5] The multivariate kurtosis value was higher than 5.00 and the critical ratio greater than 1.96 or less than -1.96 indicated that the data depart significantly from multivariate normality and violated the assumption of multivariate normality [60]. Multivariate kurtosis and critical ratios were reported to be 8.80 and 4.49 in the cold spell model, 66.5 and 33.9 in the floods model, and 16.6 and 8.9 in heat waves model, respectively.

3.6 Results

3.6.1 Descriptive statistics.

Respondents' mean age was 39 years, and most respondents were male (62%) (see Table 3.1). The average household family size was approximately eight, and the average landholding was 0.96 ha. A third of the respondents (33%) had no formal education, 36% had attended only primary school, and a minority (~9%) had completed a university degree. Most farmers (24%) had an annual income of between NPR 100,000 and NPR 200,000, while 22% earned more than NPR 300,000[6].

Table 3.1: Sample description (N = 350).

Variables	
Average age (years) (SD)	38.7 (12.9)
Male (%)	62
Average household size (heads) (SD)	7.8 (5.3)
Mean level of education (SD)	2.2 (1.2)
No formal education (%)	32.5
Primary school (Years 1 to 5) (%)	35.7
High school (Years 6 to 10) (%)	14.8
Higher secondary education (Years 11 to 12) (%)	8.5
University (above undergraduate level) (%)	8.5
Average land Holding (ha)	1.0 (1.2)
Annual household income	
<50000 NPR (%)	10.2
50,000-100,000 NPR (%)	22.5
100,000-200,000 NPR (%)	23.7
200,000-300,000 NPR (%)	21.7
>300000 NPR (%)	21.6

[6] We also performed comparative descriptive statistics across two districts, but did not observe any significant differences in socio economic parameters. As such, only mean statistics have been reported.

Variables	
Being a member of a community organisation (%)	72.5

Note: SD: Standard deviation; NPR = Nepalese Rupee (1 USD ≈ 110 NPR).

Farmers were highly concerned about floods and less concerned about heatwaves and cold spells (see Table 3.2). The average risk perception index was higher for floods (14.5) than for heatwaves (11.4) or cold spells (10.9). Many respondents (78%) experienced flood damage, while only 17% and 16% experienced damages from heatwaves and cold spells in the last ten years, respectively. Most respondents found existing coping mechanisms ineffective for any of the three hazards. More people thought that adaptation to floods would be very costly (83%) than to heat waves (64%) or cold spells (61%).

Table 3.2: Description of Variables Used In The Model.

	floods	heatwaves	cold spells
Concern about future impacts			
Not at all concerned	0.2	1.1	0.8
A bit concerned	1.7	7.7	11.4
Concerned	7.4	37.1	43.1
Highly concerned	90.5	53.4	44.5
Average risk perception (SD)	14.5 (1.9)	11.4 (2.1)	10.9 (2.3)
Self-reported damage experience			
Minimal damage	0.8	4.2	4.6
Slight damage	5.4	41.4	42.2
Bad damage	16	37.7	37.7
Severe damage	77.7	16.8	15.5
Trust (satisfaction with government adaptation strategies)			
Very unsatisfied	58	72.5	68.2
Unsatisfied	25.7	17.4	21.1
Satisfied	12.8	8	8.8
Very satisfied	3.4	2	1.7
Potential response costs			
Not costly	5.1	7.4	12.8
Slightly costly	10.8	28	26.8
Very costly	51.7	51.7	50.2
Extremely costly	32.2	12.8	10

	floods	heatwaves	cold spells
Importance of perceived responsibility for coping with disaster			
Not important at all	22.2	20.5	17.7
Rather important	16.5	18	18.8
Important	22.8	38	38.7
Very Important	38.2	23.5	24.8
Agreement that perceived self-efficacy for coping with disaster is important			
Strongly disagree	30	22.2	18.5
Disagree	28.5	41.4	38.2
Agree	38.5	34.2	41.4
Strongly agree	3.2	2	1.7

3.6.2 Perceived agricultural risk and current adaptation strategies.

Farmers perceived a range of risks related to their farming (see Figure 3.2). Approximately 80% of respondents reported that drought, heatwaves, cold spells, and floods were the main climatic risks, excepting for excessive rainfall. More than 90% of the farmers perceived environmental risk[7] as the primary agricultural risk, followed by biological risk (72%) and financial risk (46%) (see Figure A3 in the Appendix).

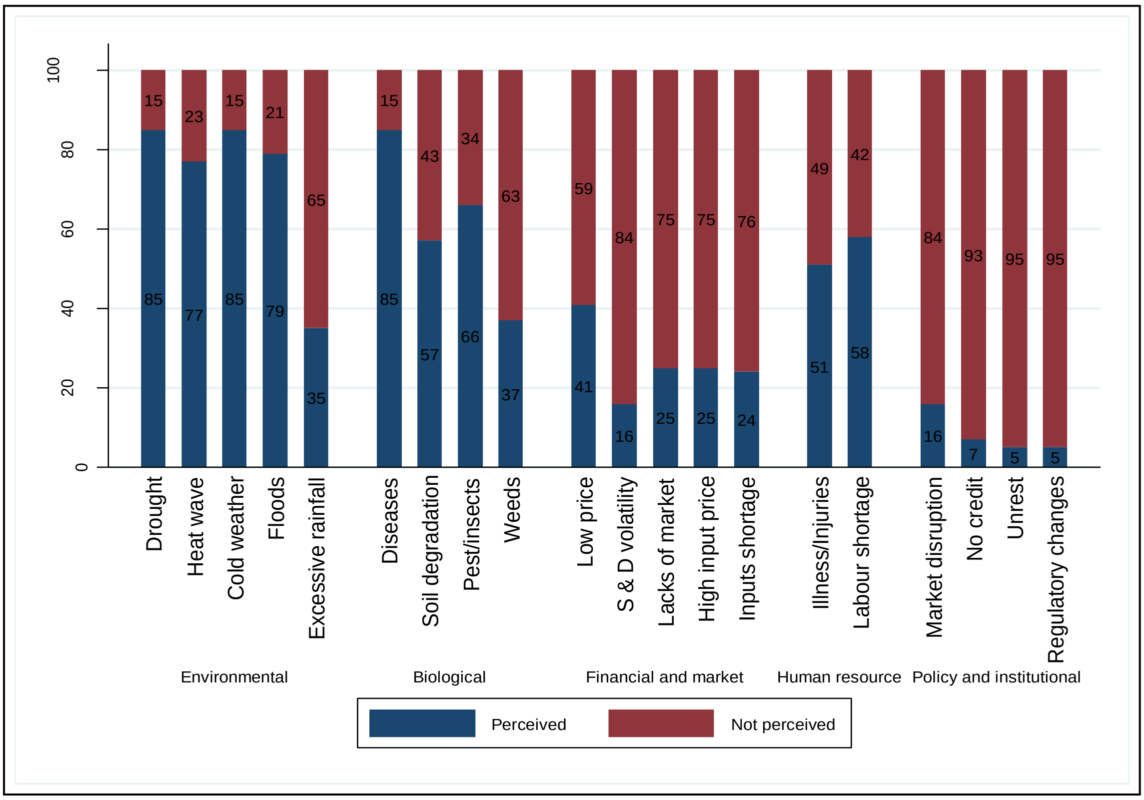

Figure 3.2: Types of risks perceived by farmers (in %; N = 350).

Farmers adapted to the impacts of cold spells by altering their fertiliser and pesticides use, changing crop types and varieties, seeking off-farm employment, and

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[7] As farmers have identified environmental risk as the most severe agricultural risk, the analysis focused on climate related environmental risk.

applying better water management practices. During heat waves, farmers mostly applied better water management practices, altered fertiliser and pesticides use, and changed crop types and planting dates. In order to cope with floods, farmers' primary strategy was to seek off-farm employment, followed by changes in fertiliser and pesticide use, as well as crop types and varieties (see Figure 3.3).

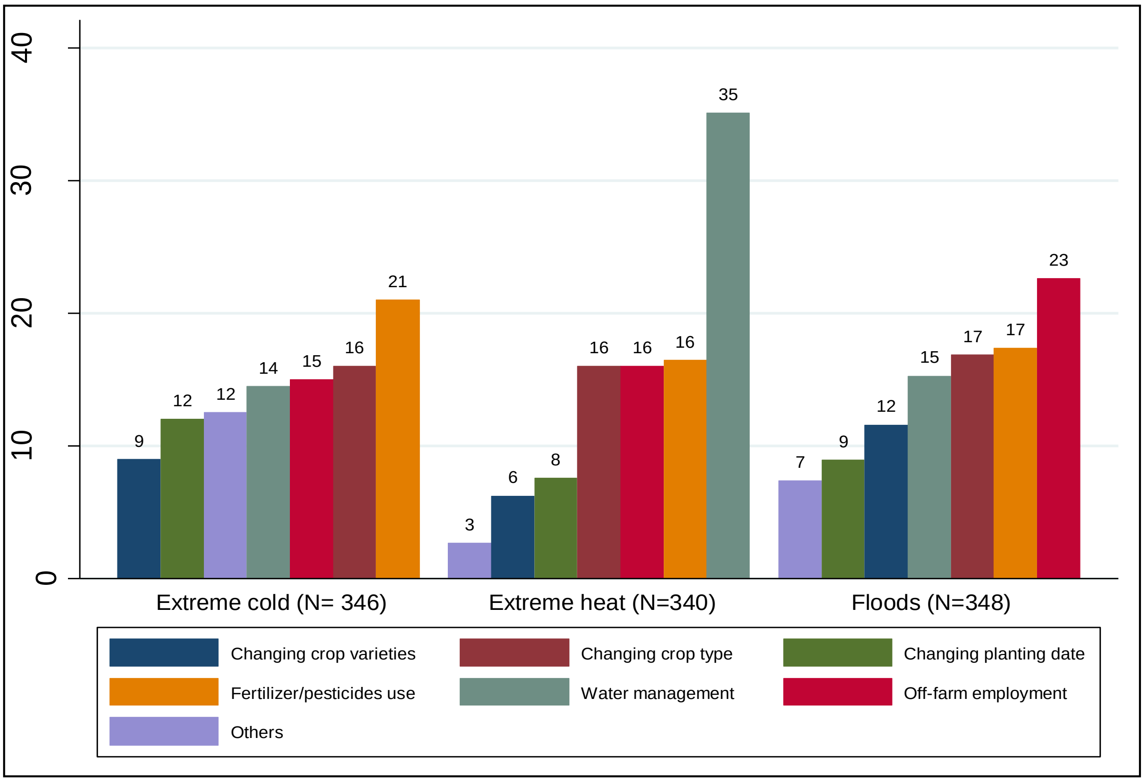

Figure 3.3: Current risk management strategies in response to three natural disasters (cold, heat and floods).

3.6.3 Preparedness to adapt.

The numbers of intended adaptation strategies varied from 0 to 7 for floods (median: 4) and from 0 to 8 for heatwaves and cold spells (medians: 3). Strategies varied according to the nature of the hazard and were associated with short, medium, or long-term risk management.

Almost all respondents (98%) intended to adapt to any of the three hazards. A small minority of farmers (less than 2 %) did not intend to take any future adaptation measures, As they believed natural hazards to be an "act of God" and that they could not do anything to stop any damages except accepting the "bitter reality of nature".

To simplify the analysis, we grouped the intended adaptation strategies into six categories (see Table 3.3). Overall, 43% of the respondents intended to make changes to farm management. This was followed by seeking off-farm employment (16%), changing cultivation dates (14%), purchasing crop insurance (13%), awareness-raising (7%), and creating an emergency management plan (6%).

Altering farm management techniques were highly preferred in response to all three hazards. Farm management techniques included the introduction of irrigation to protect crops from heat waves; water management, such as using sandbags, elevating the land, and constructing dikes and proper drainage to protect crops and their properties from flooding; and building tunnels to protect crops from cold spells. Farmers intended to apply pesticides and fertilisers to minimise the impacts of all three EWEs.

Table 3.3: Most preferred intended adaptation strategies by farmers in the Terai region of Nepal (frequencies in %; N =350).

	Natural Disaster (% of households)			
Intended Adaptation Strategies	**Floods**	**Heatwaves**	**Cold spells**	**Overall**
Purchasing agriculture insurance	13.4	13.4	11.7	12.8
Apply farm management techniques: Irrigation (HW), dykes, sandbags, land elevation, proper drainage (F), Fertiliser and pesticides (A), Tunnels (CS)	52	39.4	37.4	42.9
Emergency management plan: Shelter home (F), Post recovery and relief, selling valuables and assets (A)	6.5	4.5	5.7	5.5

Public awareness campaign and early warning, mobile SMS (A)	7.7	6.5	7.5	7.2
Seeking off-farm employment	8.2	22.2	17.1	16
Changes in cultivation: planting date, crop types and crop varieties (A)	11.2	13.4	18	14.2

Note: A: for all three disasters, F: for floods, HW: for heatwaves; CS: for cold spells.

3.6.4 Structural equation model fit statistics.

As the values of the goodness of fit statistics indices were below the threshold levels (α^2/df < 3, CFI >0.90, SRMR<0.05, and TLI>0.90, RMSEA<0.07), all three models had a good fit to the data (Hair Jr, Hult, Ringle, & Sarstedt, 2016). Table B11 in the appendices shows the relative chi-square (α^2/df), RMSEA, CFI, SRMR, and TLI of all three models.

Regarding the convergent validity of the measurement model, all the estimates of the observed variables were significant. After performing the reliability test, the risk perception[8] of flood, heatwaves, and cold spells had factor loadings of over 0.60. Based on the rule of thumb, individual items were reliable if the factor loadings were above 0.60 (Salisbury, Pearson, Pearson, & Miller, 2001). Based on the validity test of all three models, CR for all constructs were greater than 0.70 and AVE of one construct was above 0.5 and rest of two constructs were close to 0.5 (See Table B12 in the Appendix). Taking all these into account, the models for all three hazards were acceptable (Hair Jr et al., 2016).

[8] Perceived probability – farm damage, perceived probability – personal damage, perceived consequences infrastructure, and perceived severity were the four indicators of the latent variable of risk perception.

3.6.5 Direct and indirect impacts on risk perceptions.

The floods, heatwaves, and cold spells models explained the variance in the risk perception by 54%, 44%, and 56% respectively. These models also explained the variance in the preparedness to adapt by 21%, 27%, and 21%, respectively. Being male was negatively correlated with flood *risk perception* (Hla) while gender had no impact on risk perception of heat waves and cold spells. Being a *member of a community organisation* was positively and significantly associated with *risk perception* of all three hazards (H1c). The structural equation model (see Figures 3.4, 3.5 and 3.6) further showed that *perceived self-efficacy beliefs* (H2a) were negatively associated with *risk perception* in the flood and cold spell models, but not in the heatwave models. *Perceived farmers' responsibility* (H2b) had a significant negative impact on heatwave *risk perception*. *Potential response cost* (H2d) had a significant direct and positive influence on *risk perception* of all three hazards.

Having *trust* (H2c) in existing government adaptation strategies was negatively associated with *risk perception* in the flood model, but positively associated with *risk perception* in the cold spell model. *Concern* (H2e) and *damage experience* (H2f) had positive and direct impacts on *risk perception* in all three models (see Figures 3.4, 3.5, and 3.6).

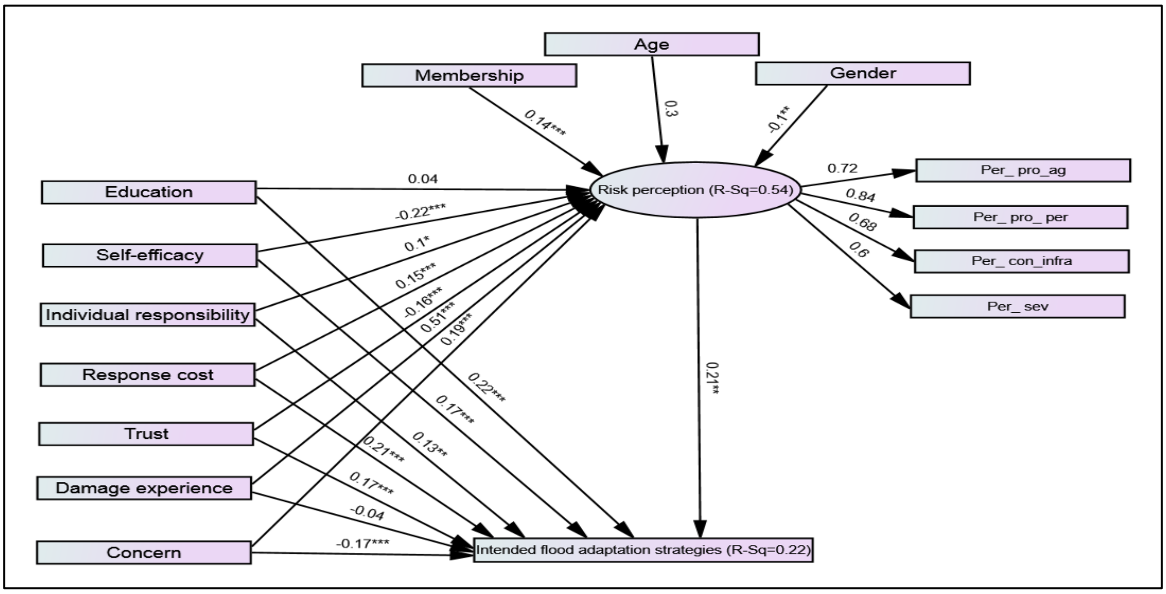

Figure 3.4: Multilevel structural equation model paths for the preparedness analysis for floods.

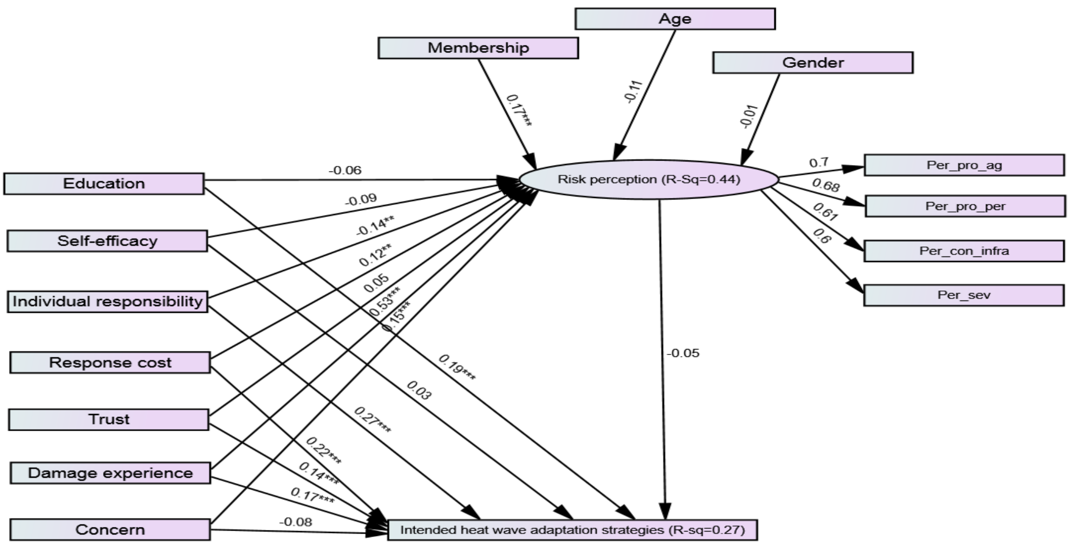

Figure 3.5: Multilevel structural equation model paths for the preparedness analysis for heat waves.

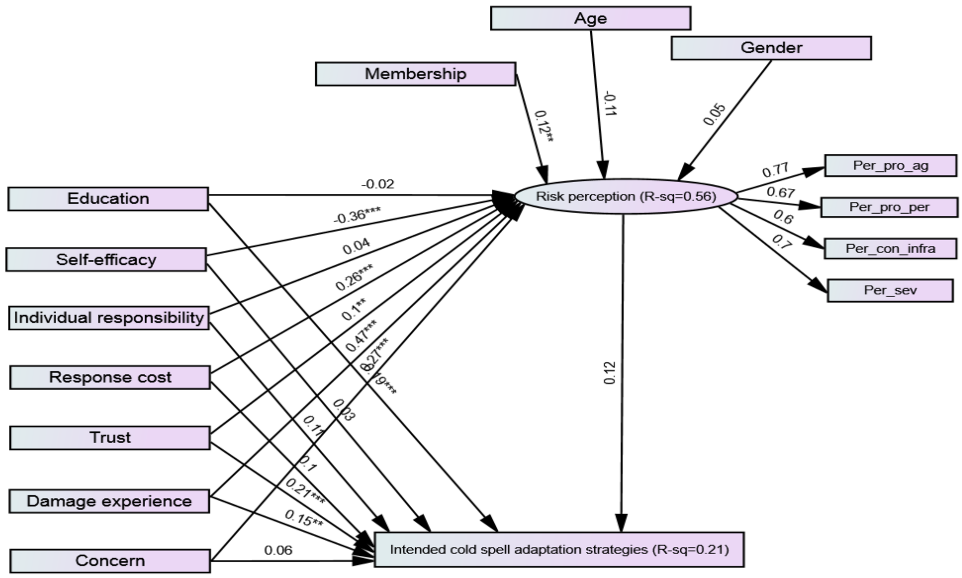

Figure 3.6: Multilevel structural equation model paths for the preparedness analysis for cold spells.

*Note (3.5, 3.5 and 3.6): Per_pro_ag: Perceived risk damage to household agriculture; Per_prob_per: Perceived personal risk probability; Per_con_infras: Perceived risk damage to farm infrastructure; Per_sev: Perceived severity. Observed variables are represented by rectangles, and latent variables are represented by ellipses. Numbers are standardised regression coefficients (β) indicating direct effects. Explained variances are denoted by R,Sq. (R2) *** = p<0.001, ** = P<0.05.*

3.6.6 Direct and indirect impacts on intended adaptation strategies.

Farmers' adaptation intentions were directly and positively influenced by education (H3a) in all three models (see Figures 3.4, 3.5 and 3.6). Having trust (H3g) in government strategies to cope with all three hazards was positively associated with the intention to adapt in all three models. The components of coping appraisal such as self-efficacy (H3b), individual responsibility (H3c), and response cost (H3f) were significant predictors of flood adaptation intention. Perceived responsibility, perceived costs of coping with heatwaves and trust were positively associated with the intention to adapt to heatwaves. Coping appraisal did not influence farmers' intentions to adapt to cold spells (see Figure 3.6).

Damage experience (H3d) had a positive significant direct impact on adaptation strategies only in the heatwave and cold spell models (see Figures 3.5 and 3.6). C*oncerns* (H3h) about future floods in the community was a negative predictor of only intended flood *adaptation strategies*. *Risk perception* only had a direct impact (positive) on intended flood *adaptation strategies* (H3e; see Figure 3.4).

There were mediation impacts of risk perception on the intention to adapt only in the flood model (see Table 3.4). Flood risk perception mediated the significant relationship between many of the coping appraisal variables (H5): perceived self-efficacy and intention to adapt ($\beta = 0.02$, $P < 0.1$), personal responsibility and intention to adapt ($\beta = -0.04$, $P < 0.05$), and flood response cost and intention to adapt ($\beta = 0.03$, $P < 0.05$). Flood risk perception further mediated the relationship between trust and intention to adapt (H6, $\beta = -0.03$, $P < 0.05$) and worry and intention to adapt (H6, $\beta = 0.04$, $P < 0.05$). Risk perception of floods fully mediated the relationship between *damage experiences* and intention to adapt (H6, $\beta = 0.10$, $P < 0.05$).

Table 3.4: Results of structural equation model with bootstrapping (n = 1000) for three natural hazards with the dependent variables

	Floods (standardized estimates)		**Heatwaves(standardized estimates)**		**Cold spells(standardized estimates)**	
Hypothesis	Direct (X → Y)	Indirect (X → M → Y)	Direct (X → Y)	Indirect (X → M → Y)	Direct (X → Y)	Indirect (X → M → Y)
Education → EWEs Risk Perception → Intended adaptation strategy	0.22***(0.0)	0.008ϯ(0.3)	0.19***(0.0)	0.03ϯ (0.3)	0.19***(0.0)	-0.003 ϯ (0.4)
Self-efficacy → EWEs Risk Perception → Intended adaptation strategy	0.13***(0.0)	0.02*(0.09)	0.03 ϯ (0.5)	0.007 ϯ(0.3)	0.03 ϯ (0.5)	0.05 ϯ (0.3)
Perceived Responsibility → EWEs Risk Perception → Intended adaptation strategy	0.17**(0.02)	- 0.04**(0.01)	0.27*** (0.0)	0.005ϯ (0.3)	0.11 ϯ (0.1)	-0.04 ϯ (0.1)
Response cost → EWEs Risk Perception → Intended adaptation strategy	0.21***(0.0)	0.03**(0.01)	0.22***(0.0)	-0.06 ϯ (0.3)	0.10 ϯ (0.08)	0.03 ϯ (0.1)
Trust → EWEs Risk Perception → Intended adaptation strategy	0.17***(0.0)	-0.03**(0.01)	0.14***(0.0)	-0.003 ϯ (0.4)	0.21***(0.0)	0.01 ϯ (0.1)
Damage experience → EWEs Risk Perception → Intended adaptation strategy	-0.04 ϯ (0.5)	0.10**(0.02)	0.17***(0.0)	-0.02 ϯ (0.5)	0.15**(0.03)	0.06 ϯ (0.1)
Worry /concern → EWEs Risk perception → Intended adaptation strategy	-0.17***(0.0)	0.04**(0.01)	-0.08 ϯ (0.2)	-0.008 ϯ (0.4)	0.06 ϯ (0.2)	0.03 ϯ (0.1)

Key	No-effect non-mediation	Complementary mediation	Direct-only no mediation	Competitive mediation	Full/complete mediation

*Note: *** = p<0.001, ** = p<0.05, * = p<0.1 ϯ = p>0.10 (non-significant), p values are in the parenthesis*

3.7 Discussion

3.7.1 Perceived agricultural risk and current adaptation strategies.

Although farmers face multiple, recurring, and substantial risks to their agricultural production and livelihoods, our survey results confirmed that environmental risks were the most important. These include those biological risks associated with pest and disease outbreaks, invasive plants (weeds), and soil degradation. Among these environmental risks, flooding, heat waves, and cold spells were identified as the three most severe natural hazards. To minimise the impacts of these hazards, farmers follow different strategies, dependant on the onset and severity of each hazard.

Our study shows that in relying on the current adaptation strategies for slow-onset hazards, farmers were not well placed to cope with the increasing temperature extremes and their consequences. Problems with coping efficacy make relying on structural mitigation less tenable. For example, relying on irrigation and water management can be problematic during heatwaves, as heatwaves and droughts often occur together (Beetge & Krüger, 2019). Using diesel generators to raise bore water to irrigate crops can also be very costly. Increased use of fertiliser and chemical pesticides during cold spells and floods, besides having detrimental effects on the environment, is also costly and can reduce farm profits substantially, particularly if the harvest then fails.

Farmers were also found to have switched to high-yield rice (*Gorakhnath, Taichin, Radha 4, Mansuli*) from traditional rice (*Rambhoj, Thapachiniya, Marsi, Didai, Mansara*) varieties. Similarly, they switched to high-yield wheat (*NL, Bhaskar,* *Khumaltar*) from traditional wheat (*RR21*, *Rato, Seto*) varieties. They changed their crops because high-yield crop varieties are more cold-tolerant and require less water (Khanal, Wilson, Hoang, & Lee, 2018; Budhathoki & Zander, 2020). To cope with floods, farmers also increasingly use flood-tolerant crop varieties, which can survive short- and long-term submergence. Apart from changing crop varieties, the most common strategies for coping with flood impacts are to seek off-farm employment and to apply fertiliser and pesticides during submergence, in order to provide nutrients to the crops and to support crops during growth stages after flooding. Increasing reliance on off-farm work eventually means a shift from farming to non-farming. The evidence that floods contribute to rural outmigration is a wide-spread trend has implications for food production in Nepal (Koubi, Stoll, & Spilker, 2016; Ishtiaque & Nazem, 2017). Rather than relying on structural measures (that are often developed through top-down processes), it becomes increasingly important to understand the social and psychological processes that influence risk perception and how it can translate into adaptive preparedness. The latter strategies lay the foundation for farmers to become more responsive and adaptable to circumstances that are likely to be more dynamic in the future. This starts with understanding risk perception.

3.7.2 Determinants of risk perception.

The structural equation model confirmed most of the hypotheses derived from the Protection Motivation Theory for all three natural hazards. Most components of the coping appraisal were predictors of risk perception with little difference across the three hazards, which was consistent with previous research (Grothmann & Reusswig, 2006; Martin et al., 2009; Zander et al., 2019). Farmers who believed in their own capability to cope with a hazard (self-efficacy) were less likely to perceive risks from floods and cold spells. This might be because farmers felt safe relying on their own knowledge and capability of how to cope, which is supported by the finding that farmers who had a higher capability of avoiding the hazards had lower risk perceptions (Grothmann & Patt, 2005; Miceli et al., 2008; Xu et al., 2018).

For heatwaves, however, those farmers who perceived themselves responsible for reducing the exposure to a hazard were less likely to perceive heatwave risks. This might be because the Tarai lowlands, in general, have a warm (tropical) climate, and farmers knew they needed to protect themselves from extreme heat exposure. As found elsewhere (Poussin et al., 2014) farmers displayed a sense of responsibility and optimism, which made them less likely to perceive the risk of heatwaves. Farmers who thought that the response cost of intended adaptations strategies would be higher were more likely to perceive risk associated with each hazard because the majority of households were poor and had a low adaptation capacity (Poussin et al., 2014; Sullivan-Wiley & Gianotti, 2017).

Households who trusted or relied on a governmental flood contingency plans had a lower risk perception, also found in studies by Grothmann & Reusswig (2006) and Terpstra (2011), while the opposite is true in the case of cold spells. This could be because, unlike floods, cold spells are harder to predict, and are a recent phenomenon in the study areas. While the Nepalese Government puts effort into alleviating damage from high-severity hazards, such as floods, minimal resources have yet been allocated to strategies that cope with slow onset hazards. Knowing this, farmers were alerted to the risk, at least of cold spells.

The study found that, for all three EWEs, farmers who had experienced these hazards were more likely to perceive their risk. This is consistent with previous studies (Tversky & Kahneman, 1974; van der Linden, 2014; Ogunbode, Demski, Capstick, & Sposato, 2019), which stated that lived experience of the destructive direct damage of natural hazards is easier to remember and, therefore, translates into a higher perception of risk.

As hypothesised, those farmers with concerns and worries about the potential future community impacts of each extreme event were more likely to perceive the risk of each of the three hazards. This is supported by the research of Zaalberg et al. (2009) and Miceli et al. (2008). This concern may also be a result of having, themselves, experienced such hazards, or having heard of affected peers, or media reports. Additionally, a sense of belonging could make a significant contribution to higher risk perceptions (Paton & Johnston, 2001; Xu et al., 2018).

Men had a lower risk perception of floods than women, which was not unexpected (Lindell & Hwang, 2008), while gender had no impact on heatwave and cold spell risk perceptions. Women are more risk-averse than men and more alert to all sorts of risks (Fothergill, 1996). Another possibility may be that most male farmers in the study area were directly involved in flood disaster management during the flooding season and had, therefore, more experience in coping with floods and a higher belief that flood management strategies would be effective (Lindell & Hwang, 2008).

An association with community organisations was found to be positively associated with risk perception of all three EWEs, consistent with Wachinger et al. (2013). This may be because information about threats to farming, including upcoming natural hazards, is exchanged in community association meetings, generating knowledge that heightens farmers’ alertness and perception of risk.

3.7.3 Determinants of farmers' adaptation behaviour.

Many of the coping appraisal factors also had direct impacts on adaptation behaviour. For instance, self-efficacy beliefs increased risk perception of floods, which in turn increased flood adaptation behaviour, as expected (Devkota et al., 2013; Keshavarz & Karami, 2016). Self-efficacy is not significantly associated with intended adaptation to heatwaves and cold spells, but individual responsibility is only positively associated with flood and heatwave adaptation. These results point to differences in the role of coping appraisal for adaptation across each of the three hazards. The differences in the impact of coping appraisal on how farmers intend to adapt could be due to the differences in the severity of the hazards, as well as differences in experience and knowledge (Rogers, 1975; Carlton & Jacobson, 2013; Demski et al., 2017; Frondel et al., 2017).

The expected response costs of floods and heatwaves increased the number of intended adaptation strategies for those hazards and contradicted the earlier finding of Keshavarz and Karami (2016), which stipulate that the higher the response cost is perceived, the lower the probability of preparing and adapting. Despite higher response cost, farmers intended to the future implementation of more preparedness measures. However, farmers might not be able to afford expensive adaptation measures at the household level, thereby inducing them to implement cheaper and shorter-term measures for risk diversification, such as emergency management plans at the farm and household levels.

Trust is positively associated with adaptation behaviour in response to all three hazards. Although farmers felt that they could trust the governmental adaptation plan and policies, they still intended to take their own adaptation measures. This was due to the poor implementation of governmental adaptation strategies, despite the well-documented policies and strategies. Too much trust or reliance on the government was found to have a negative impact on intended adaptation. For instance, farmers received flood damage compensation, which might have demotivated farmers from implementing many adaptation strategies themselves, as shown elsewhere (Slovic, 2000; Botzen et al., 2009). While education has no impact on risk perception, better-educated farmers applied more adaptation strategies in response to all three hazards, as expected (Hoffmann & Muttarak, 2017). With better education throughout rural Nepal, the awareness and knowledge of climate change impacts and natural hazards will increase, and it strengthens farmers' adaptive capacity. Perceiving risks increase farmers' preparedness strategies for all three hazards, also substantiated by Botzen, Aerts, & Van Den Bergh (2009), Lee et al. (2015) and Hoffmann and Muttarak (2017).

It was surprising to find that flood damage experience did not have an impact on intended flood adaptation strategies — though heatwave and cold spell adaptation did — given the severity of damages from floods, as compared to the slow-onset hazards. This contrasts with previous research by Richert et al. (2017) and Spence, Poortinga, Butler, & Pidgeon (2011). This might have been a result of the negative outcome expectancy of some farmers, who thought that the potential benefits of adaptation were lower than the costs (Paton et al., 2005; Paton, Smith, Daly, & Johnston, 2008), such that they refrained from using some adaptation strategies. Another reason could be that farmers individual efforts were futile to ensure safety from floods (pessimistic attitude), thus, they were less willing to undertake preparedness measures (Paton, 2013). These factors might have cancelled out the responses of those farmers who applied more strategies due to their experiences, thus leading to the variable insignificance. For heatwaves and cold spells, the positive impact of damage experience on adaptation was expected, since the experience of natural hazards directly lead to heightened protective behaviour (Wachinger et al., 2013).

Risk perception itself only had a direct and positive impact on adaptation behaviour in response to floods, consistent with other flood adaptation studies (Grothmann & Patt, 2005; Lindell & Hwang, 2008; Martin et al., 2009; Ullah et al., 2015). A lack of financial resources for adaptation and an underestimation of the risks of heatwaves and cold spells might be the reason for the insignificant relationship between risk perception and adaptation intention of heatwaves and cold spell respectively (Grothmann & Reusswig, 2006; Koubi et al., 2016). Another reason could be that a low level of belief in or a lack of knowledge about effective adaptation to these slow-onset hazards might impede their intended adaptation (Grothmann & Patt, 2005; Miceli et al., 2008). A possible explanation for this discrepancy could be that sudden-onset hazards, such as floods, cause immediate physical damage which can severely disrupt whole communities (e.g. evacuation, heightened mortality), which is more memorable than the damages of extreme heat and cold. Farmers were more likely to attribute damages from floods to high risks (Zaidi, 2018) than making the causal relationship between slow-onset hazards and damage (Zaidi, 2018).

3.7.4 Mediation effect of risk perception.

In the case of rapid onset hazard, risk perception of flood significantly mediated the effects of coping appraisals, trust in government flood adaptation plan, damage experience, and concern towards community about future flooding damage on farmers’ intended flood adaptation strategies. Martin et al. (2009) stated that coping appraisals, such as self-efficacy beliefs and an individual sense of responsibility towards hazards protection influenced farmers decisions to undertake preparedness measures mediated through risk perception.

The prior damage experience in agriculture had a significant indirect impact on preparedness behaviour for floods, mediated through *risk perception* of floods as found in Demuth et al. (2016), Demski et al. (2017) and Hoffmann and Muttarak (2017). Having prior experience of disasters may increase hazard awareness and risk perception about the potential threat of disaster and enhance their knowledge on how to recover in the aftermath of disasters, as well as teach them how to cope with potential future disasters, which in turn increases individual preparedness strategies.

Relating to slow-onset hazards, risk perception of heatwaves and cold spells was an insignificant mediator in the heatwaves and cold spell models. It might be, however, that there were omitted or undiscovered mediators that might be uncovered in future research (Lindell & Hwang, 2008; Rucker et al., 2011). Other possible explanations of such discrepancies in the research finding include the possibility that sudden onset hazards (such as floods) are quick and high-intensity events, which cause immediate physical damages, with risk perception being more readily attributed to the flood event (Zaidi, 2018). In contrast, with slow-onset hazards, Zaidi (2018) stated that the chain of causality (that underpins risk perception) is difficult to interpret, justify and estimate, since the impacts are continuously appearing, and adaptation strategies are implemented differently at various stage of hazards onset.

3.7.5 Policy implications.

In 2017, the Nepalese government endorsed the Disaster Risk Reduction and Management Act, replacing the 1982 Natural Calamity Act. The new act focused on disaster risk management by addressing the four disaster management cycles, preparedness, response, rehabilitation, and recovery. It also established a functional institutional set up from the central to the local levels for effective disaster management. However, while the revised act set out the responsibilities of the provincial governments, it failed to declare a disaster-prone zone using disaster mapping (Nepal, Khanal, & Sharma, 2018). Most of the existing policies also emphasised rapid-onset hazards (including floods, earthquakes, landslides, and avalanches), rather than slow-onset hazards (such as cold spell and heatwaves). It also assigned fewer responsibilities on the local governments, despite the Local Government Operation Act of 2017. At the same time, these existing disaster management policies provide more importance to recovery and response than to the the preparedness and mitigation process.

Our study found that the factors associated with farmers' risk perceptions and adaption behaviour depended on the specific natural hazard and that risk perception only directly affected the intended adaptation behaviour in response to floods, a severe and rapid onset hazard. There was no such response to heatwaves or cold spells. Moreover, risk perception only played a significant role in mediating the effects of coping appraisal and concern as to how farmers' intention to enact flood adaptation measures and not in how they intended to adapt to heatwaves or cold spells.

We attribute this to i) the different levels of awareness and knowledge of potential damages and ii) the available adaptation strategies farmers have for each different hazard. So far, the Nepalese Government has focused its disaster management efforts on rapid-onset hazards, such as floods. Cold spells, however, are a relatively new phenomenon and farmers' do not yet appear to have much experience on how to effectively adapt. Risk communication, public education programs, and extension services could be effective in promoting awareness and expertise in low cost coping strategies. Farmers exhibit high trust in government adaptation strategies and would probably be willing to heed such advice.

One impediment to the adaptation of farmers is the high costs of coping with extreme temperatures (cooling, heating, and irrigation). These slow-onset hazards (heatwaves and cold spell) might not be more destructive than rapid onset hazard, but as climate change continues unabated, could become more frequent. The central government should, therefore, work with local government across all disasters, managing jointly with the affected stakeholders, including public, private, and civic organisations. The existing gaps that remain in effective implementation of disaster management in vulnerable marginal communities could be overcome through technical and financial support from the Nepalese Government or other donor organisations, and include subsidies, loans, or complementary insurance,.

3.8 Conclusion

The study investigated how farmers in the vulnerable western Tarai region are affected by floods, heatwaves, and cold spells, how they adapt, and the factors influencing their risk perception and preparedness for intended adaptation. More than 90% of the respondents revealed that climate related-environmental risk is the leading agricultural risk among all the agricultural risks. Though farmers adopt similar adaptation strategies, the rate of adaptation of these strategies varied across the three types of extreme weather event. During cold spells, farmers primarily made changes to their fertiliser and pesticides use. Water management practice and seeking off-farm employment were the widely adopted strategies during heatwaves and flooding, respectively. Farm management techniques, followed by seeking off-farm employment, changes in cultivation, and purchasing agriculture insurance, were the highly preferred intended adaptation strategies for all three hazards.

We found that farmers association with community organisations, the potential response costs, previous damage experience, and community concern or worry significantly and directly influenced the risk perception of each hazard. Coping appraisal was the significant predictor of intended flood preparedness behaviour after a controlling mediator, but education and trust positively associated with preparedness intention across all three EWEs. The mediation analysis shows that coping appraisal components (self-efficacy belief, perceived individual responsibility, and the perceived response cost of a flood), trust on existing government flood adaptation strategies, flood damage experience, and concern about future flooding influenced farmers' flood preparedness behaviour through flood risk perception. However, there were no mediation effects in the case of slow-onset hazards.

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Chapter 4 Heat, Cold, and Floods: Exploring Farmers' Motivations to Adapt to Extreme Weather Events in the Terai Region of Nepal

4.1 Preface

This chapter assessess farmers' risk perceptions towards three common extreme weather events (floods, cold spells, and heat waves), and to explore their intended responses to cope with future impacts. The chapter has been published full in the Natural Hazards. Changes have been made to the formatting and the referencing style so that it is consistent with the rest of the thesis.

Budhathoki, N.K., Paton, D., Lassa, J.A., Bhatta, G.D., & Zander, K. K. (2020). Heat, cold, and floods: exploring farmers'motivations to adapt to extreme weather events in the Terai region of Nepal. *Natural Hazards*, (Accepted June 19, 2000 in print) DOI: 10.1007/s11069-020-04127-0

4.2 Abstract

Smallholder farmers in Nepal are vulnerable to climate change related extreme weather events. Adaptation in the agriculture sector is needed to mitigate social, economic, and ecological impacts from increasing levels of hazard activity. To examine this issue, a household survey of 350 farmers in the Terai region of Nepal was carried out to assess farmers' risk perceptions towards three common extreme weather events (floods, cold spells, and heat waves), and to explore their intended responses to cope with future impacts. The intended common adaptation strategies include changes in farm management, seeking off-farm employment, emergency management planning, purchasing crop insurance, and the raising of awareness. Threat appraisal is the strongest predictor of the number of intended adaptation strategies adopted in response to slow onset hazards (heat waves and cold spells), while coping appraisal is the major predictor of the number of intended adaptation strategies adopted to mitigate flood risk, a rapid onset hazard. Crop insurance and off-farm employment are farmers' most preferred flood adaptation strategies, while crop insurance is the most preferred adaptation strategy for heat waves and cold spells. Other variables such as the number of past implemented strategies, experience with extreme events, community organisation membership, and access to credit and extension services were also significantly associated with farmers' choices for adaptation strategies in response to the three extreme events. This information can be used to tailor community-centred communication about potential threats from different extreme weather events and government technical and financial support, which will be crucial for farmers to adapt effectively to climate change related weather extremes.

Keywords: cold spells, extreme temperatures, heat waves, intended adaptation, protection motivation theory

4.3 Introduction

Climate change and related extreme weather events (EWE) present a severe global risk, particularly to rural farming households in developing countries (Adger, Huq, Brown, Conway, & Hulme, 2003). The agricultural sector is one of the most sensitive sectors to climate change and also the sector upon which most people in developing countries rely (Handmer et al., 2012). Climate change is expected to make global agricultural productivity more volatile (Ahmed et al., 2011), with reductions in crop yields (Rowhani, Lobell, Linderman, & Ramankutty, 2011; Thornton, Ericksen, Herrero, & Challinor,

2014) and livestock productivity (Thornton, van de Steeg, Notenbaert, & Herrero, 2009) being the most significant anticipated problems. Agriculturally-dependent developing countries are more likely to become food insecure due to increasingly frequent extreme weather events (EWEs) in coming decades (Teixeira et al. 2011; Thornton et al. 2014). One country that is particularly exposed to such events is Nepal.

Globally, Nepal ranks 6th in susceptibility to flood hazards (Christenson, Elliott, Banerjee, Hamrick, & Bartram, 2014). It is estimated that an additional 200,000 people will be affected annually by 2030 due to river floods (WRI, 2015). The implications of this can be seen in perspective given that heavy rainfall and floods in the western Terai region caused a 30% reduction in crop production between 2005 and 2006 (Regmi, 2007). Managing anticipated losses that could exceed this 30%, given that farmers little control over escalating climatic hazard risk, thus calls for the development of novel approaches to adapt to such changes. Apart from floods, the country is severely affected by landslides (risk increases with rainfall and flooding and changes in land use), thunderstorms, cold spells and heat waves (UNISDR, 2013; Tuladhar, Yatabe, Dahal, & Bhandary, 2015).

The long-term consequences of EWEs on farming communities are diverse. Besides direct damages to yield and infrastructure, such as houses, fences, and pastures, they include damage to water resources, to ecosystems with a loss of biodiversity, and to human health, either directly or through the increasing spread of diseases (Maharjan, Sigdel, Sthapit, & Regmi, 2011). The diverse consequences of EWEs highlight the need for agricultural communities to adapt, individually and collectively, in anticipation of the growing risk posed by sudden and destructive events such as typhoons, floods or earthquakes. In response to less destructive, slow onset events, anticipatory and precautionary adaptation can be planned in the long-run. Precautionary adaptation is more effective and less costly than forced adaptation (Grothmann & Patt, 2005). Given these anticipated changes, it becomes important to develop the knowledge of adaptive options to proactively inform intervention planning and delivery.

Many studies used case studies to investigate climate change impacts on farming communities in developing countries and their adaptation practices (Deressa et al. 2009; Manandhar et al. 2011). These studies often focus on climate change impacts in general (Wheeler & von Braun, 2013; Roco, Engler, Bravo-Ureta, & Jara-Rojas, 2015; Zheng & Dallimer, 2016) or on consequences of specific EWEs (Zaalberg, Midden, Meijnders, & McCalley, 2009; Poussin, Botzen, & Aerts, 2014; Demski, Capstick, Pidgeon, Sposato, & Spence, 2017; Richert, Erdlenbruch, & Figuières, 2017). This is problematic, since most farmers are exposed to numerous EWEs, not just one. Treating impacts and adaptation the same across all climate change related EWEs does not provide information about relative damage and priorities for adaptation.

This empirical study aims to compare how farmers adapt to different EWEs. These are floods, heat waves and cold spells. The specific objectives are to 1) identify the factors that influence farmers' intended adaptation choices (measured by the number of intended adaptation strategies) to these three EWEs, 2) articulate farmers' preferred adaptation strategies in response to these three EWEs, and 3) explore the factors that explain farmers' choices for these adaptation strategies. Studying multiple EWEs also facilitates comparison of farmers' perceptions of hazards' severities and their implications for their choices. This information is useful for policy-makers. For example, it identifies the investment needs required to enable increasing farmers' adapative capacity and resilience to cope with each of the EWEs identified above. This also facilitates funding for disaster management and climate change adaptation being directed to those hazards that farmers perceive as most likely to compromise their livelihoods and food security and faciliate implementation of adaptation stratgeies that farmers prefer and that they are capable of pursuing (and in the longer term, support planning and resourcing to increase options and capabilities).

To address these objectives, protection motivation theory (PMT) is used to examine the cognitive (interpretive) processes that lead to farmers' protection motivation in response to each specific EWE. The PMT states that an individual will protect themselves against the impacts of EWEs if they assume that the threat and coping appraisals are high. Data from 350 farmers in the Terai region were collected through a household survey. This region is the most crucial agricultural region in Nepal. Climate change impacts in this region will pose significant challenges for national food security. The relevance of researching in this area is reinforced by the fact that floods, heat waves and cold spells have been identified as posing significant risk to communities in this region (Gentle et al. 2014; Bhatta and Aggarwal 2016; Budhathoki and Zander, 2019) and therefore the focus of this study.

4.4 The Conceptual Framework of Protection Motivation Theory

Responses to EWEs can be either forced or precautionary. Precautionary approaches afford greater opportunities for systematically appraising risks and the options available. This study focused on precautionary adaptation and, by investigating farmers' intention to adapt, provides insights into the anticipatiory precautionary activities that could be undertaken. Intentions are a good proxy for actual behaviour (Demski et al.2017) and prior adaptation behaviour is positively associated with future behaviour (Richert et al., 2017). Intended behaviour is affected by a range of motivations, as well as capabilities and opportunities (Michie et al. (2011). One motivation is avoiding damage and protecting themselves and families from the impacts of EWEs.

In this study, an extended PMT is applied. It provides a comprehensive framework for understanding human behaviour and has been shown to overcome many of the theoretical challenges arising from the low correlation between perceptual variables and behaviour in a wide range of applications in disaster and climate change adaptation studies (Grothmann and Reusswig 2006; Gebrehiwot and van der Veen 2015). The PMT theory was initially applied by Rogers (1975) to assess health risk and was later modified for flood risk by Bubeck, Botzen, Aerts, Bubeck, and Kreibich (2012) and Poussin et al. (2014). The PMT states that people will protect themselves against the impacts of EWEs if they assume that their threat and coping appraisals are high.

The PMT posits two types of cognitive process as the drivers of protective behaviors; threat appraisal and coping appraisal (Figure 4.1). Threat appraisal, also known as risk perception, is the primary cognitive process assessing how an individual is threatened by a specific known risk consisting of perceived probability and perceived severity (the consequences) (Grothmann & Reusswig, 2006). In coping appraisal, when a certain amount of risk is perceived, people start to think of the specific benefits that they derive from their actions, comprising their response efficacy, self-efficacy, and response cost (Grothmann & Reusswig, 2006; Zaalberg et al., 2009; Bubeck, Botzen, Kreibich, & Aerts, 2013). The coping appraisal process begins when people acknowledge and accept threats from EWEs. Besides risk perception, other predictors of precautionary adaptation behaviour that can be included in the empirical assessment of protective action choices are socioeconomic variables, experience, and prior knowledge about and concern regarding EWEs (Bubeck et al., 2012).

The higher farmers' threat appraisal, the more likely they are to adopt either precautionary strategies or non-responsive strategies, such as denial, fatalism, and wishful thinking (Zaalberg et al., 2009). Farmers who have already experienced the impacts of EWEs can be more likely to follow precautionary strategies (Feng, Liu, Huo, & Ma, 2017; Richert et al., 2017). Wachinger, Renn, Begg, and Kuhlicke (2013), however, argued that people with high risk perception still may not choose to prepare themselves personally (the risk perception paradox behaviour) due to intervening variables such as anxiety, unrealistic optimism, fatalism, denial and negative outcome expectancy, trust, and economic and personal conditions. Believing that hazards are too catastrophic, some people assume that their efforts may not be sufficient in mitigating the potential consequences of the EWEs (negative outcome expectancy) and those people will have a reduced likelihood of adaptation intentions (Paton, 2013).

The perceived severity of the impacts of EWEs plays a crucial role in the risk perception of weather events, such that those who perceive risks of EWEs are more likely to take private mitigation strategies (Bryan et al. 2013). People who rely on government management plans to protect them from the impacts of EWEs (as a result of another cognitive bias, risk compensation) are less likely to take possible precautionary strategies (Reynaud, Aubert, & Nguyen, 2013). Actively engaging in community participation activities increases opportunities for the social construction of locally relevant risk beliefs and behavioral choices, with the likelihood of these being enacted by heightened if people trust the agency sources of information they rely on when faced with a need to prepare for future challenging events (Richert et al., 2017). The outcomes of these community processes can strengthen self- and collective efficacy beliefs and reduce the influence of maladaptive dispositions such as fatalism and negative outcome expectancy that would otherwise serve to reduce the likelihood of action (Paton, 2013).

Experiences, risk attitude and appraisal, social networks, and socioeconomic characteristics such as income, education, and age can have significant effects on the choice for adaptation strategies (Bubeck et al., 2012; Poussin et al., 2014). Social capital, such as communicating adaptation to climate change effectively, particularly with peers and neighbours, can also lead to increased intended adaptation to climate change (Arunrat, Wang, Pumijumnong, Sereenonchai, & Cai, 2017). High expectation of relief payments or risk compensation also prevent some people from taking precautionary strategies (Osberghaus, 2015).

Personal experience with EWEs, particularly if this include experience of personal damages, has been found to influence on farmers' future risk perceptions (Dai, Kesternich, Löschel, & Ziegler, 2015; van Der Linden, 2015; Richert et al., 2017). Demski et al. (2017) further revealed that experiences of EWEs in one domain translate farmer's intentions to take mitigation strategies to others forms of climatic impact. However, many farmers in the selected study area have not experienced significant damage. In order to effectively adapt to climate change related EWEs, farmers need a clear understanding of the actual changes and trends in climatic conditions and the associated risks they need to anticipate, and how to moderate and or adapt to the potential impacts they could experience (Esham & Garforth, 2013). Consequently, in this study, it is assumed that farmers intend to continue their usual practices (changing cultivation, for example) if they are unable to adapt any other strategies.

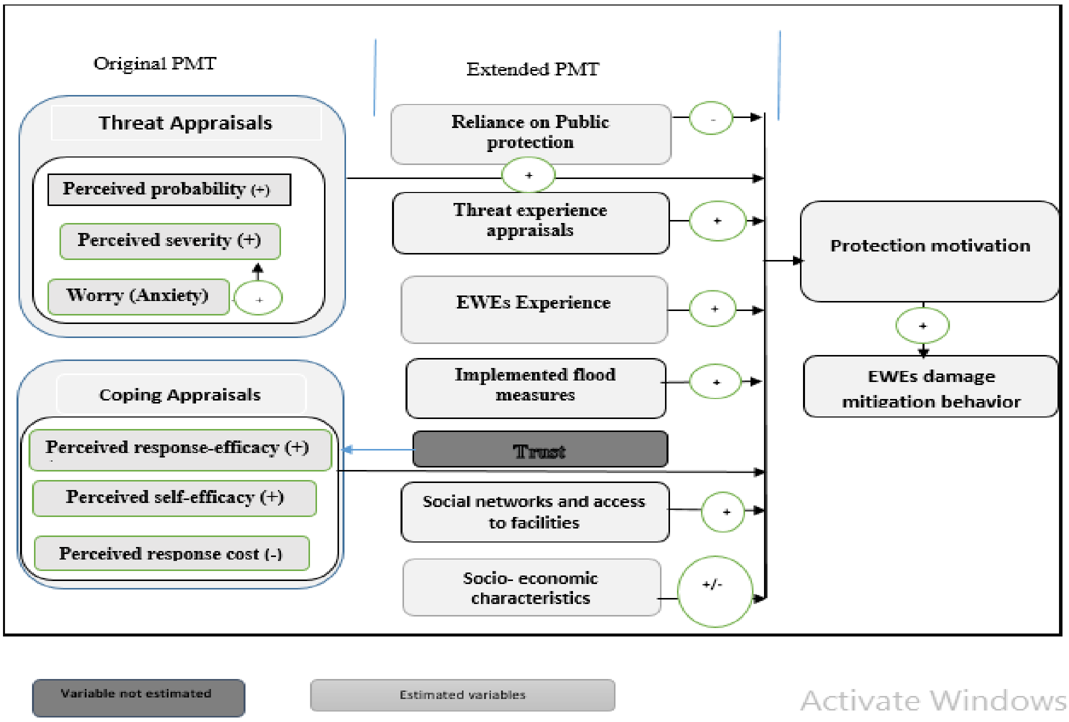

Figure 4.1: An extended framework of Protection Motivation Theory

Note: adapted from Poussin et al., (2014) and Richert et.al., (2017).

4.5 Data and Method

4.5.1 Study area.

The Terai region covers only 14% of the total land area of Nepal (147, 181km^2), but contributes 72% of the rice and 63% of the wheat production (MoAD, 2017). It is, therefore, referred to as the 'granary' of Nepal. More than 84% of farm households in this region are actively engaged in rice production, and the region is home to more than half of the country's population (28.5 million) (CBS, 2011). Based on a recent climate change impact survey by the Central Bureau of Statistics (CBS, 2017), and on discussion outcomes with the officials from the Department of Hydrology and Meteorology (DHM) of Nepal, these two districts are among the most affected by floods, heat waves and cold spells, with these events disrupting many farming households and posing serious concerns to food security (Budhathoki and Zander 2019; Budhathoki et al. 2020). Both districts are among the most densely populated within the region with 94,693 households in the Banke district (population: 491,313) and 83,147 in the Bardiya district (population: 426,576) (CBS, 2011). Together, housholds in the two districst reflect a wide range of demographic and farming related characteristics, and the implications of this diversity should be accommodated when assessing behavioural responses to EWEs.

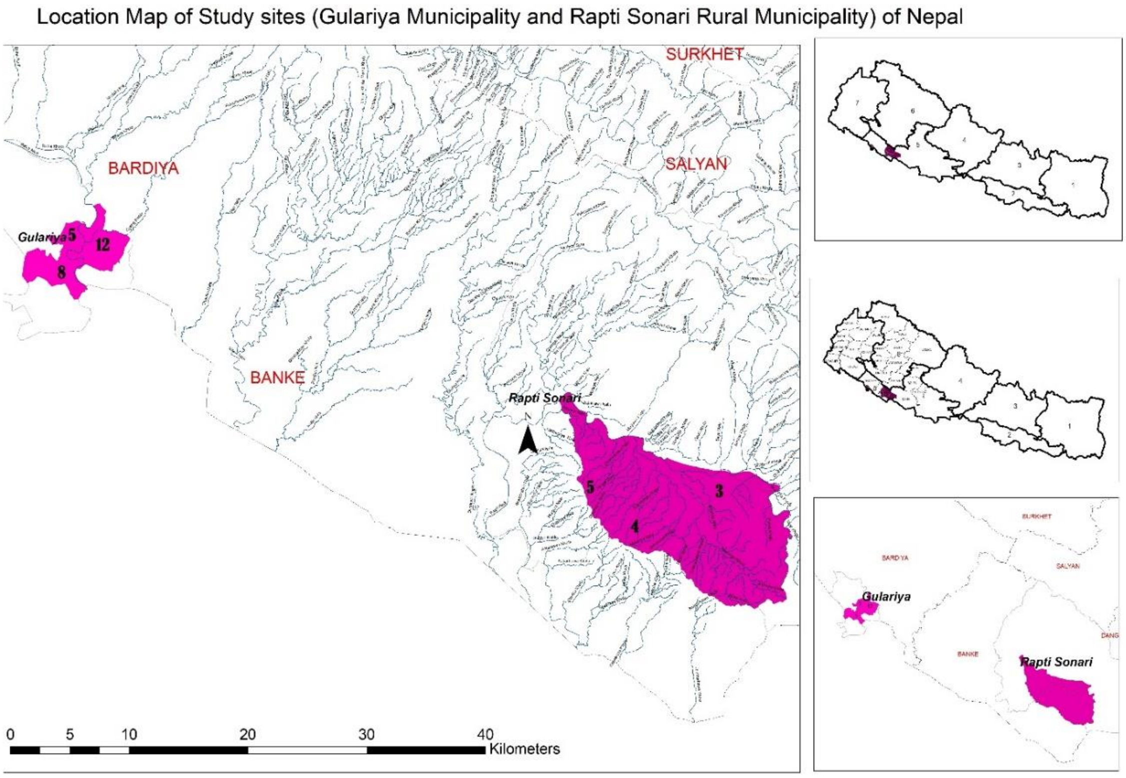

Figure 4.2: Study area.

4.5.2 Sampling.

Three wards (5, 8, and 12) of the Gulariya municipality from the Bardiya district and three wards (3, 4, and 5) of Rapti Sonari rural municipality from the Banke district were purposefully selected after discussion with the officials of the District Disaster Relief Committee (DDRC) of the Bardiya and Banke districts (Figure 4.2). From these six wards of the two municipalities, the final selection was conducted using systematic random sampling of 31, 33, and 105 farming households respectively from the 5th, 8th, and 12th wards of the Gulariya municipality, and 44, 89, and 48 households respectively from the 3rd, 4th, and 5th wards of the Raptisonari rural municipality. Three hundred and fifty interviews were conducted with either the household head or the main household member. Among the sampled households, ~52% of households were interviewed in the Rapti Sonari municipality, with the remaining from Gulariya. The survey was conducted from the first week of November 2017 to the third week of January 2018 by three experienced and trained research assistants who spoke Nepali, the primary language used for the survey, and who could also understand Tharu and the local dialects spoken in the study areas.

4.5.3 Questionnaire and variables.

The structured questionnaire included questions on socio-economic characteristics; farmers' perceptions of climate change and the three EWEs (floods, heat waves, cold spells), and farmers' planned adaptation strategies to these specific EWEs. The questionnaire was pre-tested with 15 respondents. The variables are described in more detail in Table B13 of the Appendix. Data were collected to identify farmers' key adaptation strategies and the factors that influence farmers' intensity of intended behaviours and responses to EWEs.

A four-point Likert scale was used to measure the different variables under the PMT (Figure 4.1). After identifying eight intended farm level adaptation strategies through literature, expert consultation, and feedback received from the farmers, the farmers were asked which adaptation strategies they intended to use in the future to reduce the impacts of floods, heat waves, and cold spells (Table 4.1). Finally, farmers' future adaptation motivations were measured as the sum of all intended strategies (Bubeck et al., 2013; Richert et al., 2017).

4.5.4 Data analysis.

Two different analytical methods were applied. Data collected to assess the number of adaptation strategies farmers adopt in response to the three EWEs was analysed using a Poisson regression model, while data about the type of preferred intended adaptation strategies were analysed using a multinomial logit (MNL) model. For each of the three EWEs, one Poisson and one MNL model were generated, six models in total.

The Poisson regression model was chosen because the dependent variable was count data — the number of intended adaptation strategies (van Duinen, Filatova, Geurts, & van der Veen, 2015). The underlying assumptions of the Poisson regression are that the outcome variable is non-negative and is characterised by equal mean and variance (UCLA, 2016) and both of these assumptions are met here. The incidence rate ratio (IRR) which is equal to the exponential of the coefficient was also calculated. IRR is interpreted as the rate at which an intended adaptation measure changes as a result of one unit changes in the independent variable. The VCE (robust) option was run to obtain robust standard errors to control for the potential violation of underlying assumptions of Poisson regression, as suggested by Cameron and Trivedi (2010).

The MNL model was used to investigate and cross-validate the impact of PMT parameters on the most preferred adaptation strategies (refer to Verbeek (2008) for the model specifications). The dependent variable was the type of adaptation strategy. This was chosen by respondents from a list of available strategies. The available strategies differed across the three EWEs. The explanatory variables were included as per the PMT framework.

The advantage of the MNL over binary logit model is that it allows the analysis of decisions across more than two categories it is easy to interpret the result. The change in cultivation is considered as a status quo situation (the reference strategy), as farmers in the study areas always make small adjustments in their farming practices whether they perceive climate change or not. Such adjustments include changes in planting and harvesting time, and changes in crop varieties and cropping pattern, which have been practised knowingly or unknowingly (listed under changes in cultivation) in these areas for a long time, and will continue to be continuously planned in the future.

An unbiased and consistent MNL parameter estimation requires the assumption of independence of irrelevant alternatives (IIA). More specifically, the IIA assumption requires that the probability of using a specific adaptation method by a given household be independent of the probabilities of choosing another adaptation method (Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009; Hassan & Nhemachena, 2008). Utility levels of any two alternatives are assumed independent of each other. This is mainly troublesome when utility levels of two or more alternatives are very similar (Verbeek, 2008). A

Hausman test was performed to test the IIA assumptions. The relative risk ratio (RRR)[9] was also calculated for a more straightforward interpretation of the logit coefficient in the MNL models.

4.6 Results

4.6.1 Sample description.

The average age of respondents was 38.7 (SD: 13), which was considerably higher than the national median age of 22.26 (CBS, 2012). This was because only household heads were interviewed. They tend to be older than the average person. Some 62% of respondents were male, and 67% had some formal education (Table B14 in the appendix). The average household size was 7.8 persons (SD: 5.31), and farmers' average experience in the agricultural sector was 21.2 years (SD: 12.6). This ensure that the sample is knowledgeable about and experienced in farming practices and the implications of changing conditions (even if these remain unpredictable at this point in time) for planning responses.

Some 24% of the respondents had an annual income between NPR 100,000 and NPR 200,000, and 11% earned less than NPR 50,000 per year. The mean households' monthly expenditure was NPR 16,130[10] (SD: 18,000), less than the national monthly household

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[9]When RRR>1, the risk of the outcome falling in the comparison group relative to the risk of falling in the referent group increases as the variable increases. While RRR< 1, the outcome variables will be more likely to be in the referent group.

[10] US $ = NPR 116.52 (NRB, 25th Sep, 2018)

expenditure of NPR 25,928 in 2016 (Bank, 2016). About 15% of respondents had received remittances from abroad in the previous year, about 51% had access to agricultural credits, 40% had access to extension services (support-advice, training, field visits), and nearly 75% were members of a community organisation (such as village associations, cooperatives, community forest user groups, or mother associations). The importance of the latter derives from the issue discussed above regarding the important role social network/community relationships play in socially construing risk beliefs and how these can be developed as precautionary, adaptive strategies. The high proportion of community memberships affords opportunities to tap into such social constructive processes for data collection.

4.6.2 Implemented and intended adaptation strategies.

The numbers of past implemented adaptation strategies varied from 0 to 9 for floods, 0 to 8 for heat waves, and 0 to 8 for cold spells. The numbers of intended adaptation strategies varied from 0 to 7 for floods and 0 to 8 for heat waves and cold spells. The medians of implemented and intended adaptation strategies was three for heat waves and cold spells, and four for floods. Both implemented and intended precautionary strategies varied according to the nature and type of EWE. Household and community adaptation strategies can be categorised regarding their different temporal scales: short, medium, and long-term. In this study risk management strategies of all three scales are investigated. A precautionary measure, designed to apply immediately after the occurrence of EWEs, is a short-term strategy. Strategies such as emergency management are medium-term (between one and five years after EWEs). Purchasing insurance, changes to farming practices and management are examples for long-term adaptation strategies (i.e., those intended to be effective over periods in excess of five years after the occurrence of EWEs).

Overall, some 43% of respondents intended to adopt changes in farm management. This was followed by seeking off-farm employment (16%), making changes in cultivation (14%), the intention to purchase crop insurance (13%), awareness raising (7%) and creating an emergency management plan (6%) (Table 4.1). About 2% of respondents did not intend to adapt to any of the three EWEs. These respondents were excluded from the analysis. To simplify the analysis, the researchers grouped some of the intended adaptation strategies (Table 4.1). The multinomial regression analysis was therefore based on six intended adaptation strategies.

Table 4.1: Most preferred intended household and farm level adaptation strategies of EWE based on various characteristics (Frequencies in %; N =350).

Types	**Taking out crop insurance**	**Changes in farm management**	**Emergency management planning**	**Awareness raising**	**Seeking off farm employment**	**Changes in cultivation**
Intended strategies included	Agricultural insurance-A	Irrigation- F,HW; Dykes, sandbags, land elevation, proper drainage-F; Fertilizer, pesticides-A; Tunnels-CS	Shelter home: F Post recovery and relief, selling valuables and assets-A	Public awareness campaign, early warning, Mobile SMS-A	Working in off farm sector including migration to abroad - A	Changing planting date, variety, types-A
Adaptation level	household level	household and community level	household and community level	household and community level	Household level	Household level
Subsidy and support	Premium subsidy	Some subsidy or support from government	Some support from government	Government support	No support	Some subsidy on improved varieties
Time targeted	Medium and long term	Medium and long term	short term	Short, medium and long term	Medium and long term	Short, medium and long term
Structural and non-structural measure	NS	S	NS	NS	NS	S
Cost implication	Costly	Costly	Less costly	Less costly	Depends (nature of off farm employment)	Less costly
Implementation time	No time consuming	Time consuming (depends on nature)	No time consuming	No time consuming	No time consuming	No time consuming
Percentage of respondents intending to adopt strategies	13.4 (F) 13.4 (HW) 11.7 (CS)	52 (F) 39.4 (HW) 37.4 (CS)	6.5 (F) 4.5 (HW) 5.7 (CS)	7.7 (F) 6.5 (HW) 7.4 (CS)	8.2 (F) 22.2 (HW) 17.1 (CS)	11.2 (F) 13.4 (HW) 18 (CS)
	Overall (12.8)	Overall (42.9)	Overall(5.5)	Overall(7.2)	Overall(16)	Overall(14.2)

Note: A-Adapted for all EWEs, F-Flood only, HW-Heat wave, CS-Cold Spells, NS-Non-structured measured, S-Structured structured.

4.6.3 Number of intended adaptation strategies (adaptation intensity).

While running Poisson regression, no over-dispersion[11] was detected, nor any indication of multicollinearity[12] among the explanatory variables, and the models fit the data well[13]. Nearly all the components of the threat appraisal were significant determinants of the number of intended heat waves and cold spells adaptation strategies (Table 4.2). The perceived probability of personal and farm damages had negative and perceived consequences for infrastructure while having a positive impact on the number of intended adaptation strategies. The perceived severity of damages had a positive impact in the case of heat waves. Farmers who were anxious about the risk of heat waves and floods in their community were more likely to undertake fewer adaptation strategies. The anxiety element of the threat appraisal in the case of cold spells positively explained the number of intended cold spells adaptation strategies.

Many elements from the coping appraisal process significantly explained the number of intended floods and heat waves adaptation strategies. Farmers' perceived response efficacy had a positive impact on the number of flood and cold spells adaptation strategies

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[11] *The unconditional mean and variance of the three outcome variables (floods: variance = 2.37, mean=3.50; heat wave: variance =3.13, mean =3.21;* and *cold spell: variance = 3.68, mean = 3.48) was found to be not extremely different indicating that there was no over-dispersion.*

[12] *VIF(variance of* inflator *factor) was found to be less than 10 (flood: 1.52, heat wave:1.51 and cold spell:1.68)*

[13]*After running estate GOF command after Poisson regressions, it was concluded that the models fit reasonably well because* the *Chi-Squared goodness-of-fit test is not statistically significant (P value) for all three models (flood: 1.00, heat wave:1.00, and cold spell:1.00).*

but had a negative impact for heat waves. Perceived response cost had a positive impact for flood and heat wave strategies, while perceived self-efficacy only positively and significantly influenced the intensity of intended flood adaptation strategies. Perceived responsibility positively influenced the intensity of intended flood and heat wave adaptation strategies, but this was not so for cold spells.

Social capital and access to facilities were less critical as farmers with access to extension services intended to adopt more adaptation strategies in response to floods and heat waves than those without access. Previous threat experience had no significant impact on the number of strategies adopted for any of the three EWEs, but ex-ante perception and ex-post experience had. Reliance on public protection had a positive impact on the number of adaptation strategies for cold spells, but not for the other two EWEs. Previously implemented strategies had a highly significant positive impact on the number of strategies for all three EWEs.

Respondents with high levels of education were 1.02 times more likely to undertake more flood adaptation strategies than uneducated farmers. Education had no significant impact on the intensity of adaptation in response to heat waves and cold spells. Income only had a positive effect on the number of intended adaptation strategies in response to heat waves. It had no effect on the number of cold spell and flood adaptation strategies adopted. Farmers with a higher level of income were 1.04 times more likely to express the intention to implement heat wave adaptation strategies compared to farmers with low incomes (Table B15 in the appendix).

Table 4.2: Results from the Poisson regression model with the number of intended adaptation strategies as dependent variable.

	(1)	(2)	(3)
Explanatory variables	**Coefficient (flood)**	**Coefficient (heat wave)**	**Coefficient (cold spell)**
Threat Appraisal			
Perceived probability of damage to farm	0.01	-0.04	-0.10***
Perceived probability of personal damage	0.03	-0.12***	-0.10***
Perceived consequences for infrastructure	-0.004	0.07**	0.10***
Perceived severity of damage	0.05	0.04**	0.01
Anxiety (worry)	-0.10**	-0.06**	0.06**
Coping Appraisal			
Perceived response efficacy	0.07***	-0.12***	0.11***
Perceived response cost	0.11***	0.17***	-0.03
Perceived self-efficacy	0.05**	0.03	-0.04
Perceived responsibility	0.07***	0.14***	0.02
Social capital and access to facilities			
Community Organization	-0.05	-0.03	0.05
Extension Services	0.10**	0.10	-0.02
Credit	0.002	0.01	0.03
Threat experience with EWEs			
Previous EWE related damage experiences	0.03	0.05*	0.03
Experience with EWEs			
Experience with past EWEs	0.001**	0.43***	0.26***
Ex-ante perception	0.003**	0.07**	0.08***
Reliance on public protection	0.004	-0.02	0.06**
Past implemented strategies	0.09***	0.08***	0.16***
Socio-economic characteristics			
Education	0.02*	0.01	0.02
Annual income (NPR)	0.006	0.04**	0.01
Constant	-0.37**	-0.32	-0.40**
Wald chi2(23)	390.90***	821.53***	573.22***
Log pseudo likelihood	-607.82	-577.73	-586.43
Pseudo R^2	0.088	0.1540	0.1770
Observations	350		

**** p<0.01, ** p<0.05, * p<0.1*

4.6.4 Determinants of farmers' choices of adaptation strategies.

There was no severe multicollinearity, and the results of the Hausman test also indicated that the IIA assumption was not violated[14] and all three MNL models fit[15] (Table 4.3).

Threat appraisal's components did not have a significant impact on farmers' motivation to choose the majority of flood and cold spell adaptation strategies (Table 4.3). For the heat wave model, the one element of the threat appraisal that was highly significant was perceived probability of personal damage. Farmers who perceived the likelihood of lower personal damage from heat waves were more likely to choose all of the adaptation strategies, with the exception of awareness raising.

Coping appraisal was most significant for farmers' intended adaptation strategies in response to floods and heat waves. Farmers with lower scores for response efficacy and response costs were less likely to choose crop insurance as an adaptation strategy for floods and heat waves, while those with higher perceptions of responsibility were more likely adopt this strategy. Perceived response costs were also negatively associated with taking out crop insurance to cope with cold spells. Farmers with higher perceptions of responsibility were also more likely to seek off-farm work in response to floods, heat waves, and cold spells. Deciding to seek off-farm work was also negatively associated

[14] The Hausman test failed to reject the null hypothesis of independence of all three models. This indicates that the multinomial logit model is suitable to model the intended adaptations measures in response to the three EWEs (in the flood model, χ^2 ranged from -128.85 to 81.58 with probabilities values between 0.0009 and 1.0000; in the heat wave model, χ^2 ranged from -164. 43 to 4.3 with probability values of 1.00; and in the cold spell model, χ^2 ranged from -44.61 to 25.80 with probability values of 1.00).

[15] For flood model: McFadden R^2 = 0.29, *LR chi2 (85) =288.18 and Prob> Chi2=0.0001; For heat wave model:* McFadden R^2 = 0.36, *LR chi2(85) = 397.22 and Prob> Chi2=0.0001; For cold spell model:* McFadden R^2 = 0.40, *LR chi2(85) = 441.38 and Prob> Chi2=0.0001.*

with perceived response costs in the floods and cold spells models. The likelihood of intending to choose emergency management planning was linked to two elements of the coping appraisal in response to floods, but not in response to heat waves and cold spells. Awareness raising had stronger association with intended adaptation to cold spells and heat waves compared to floods. Coping appraisal played almost no role in the intention to make changes in farm management in response to all three EWEs.

Having access to extension services was negatively associated with some strategies, particularly in the floods and cold spells models, but was positively associated with awareness raising in response to heat waves. The membership of community organisations influenced farmers' likelihood to employ flood adaptation strategies such as preparing an emergency management plan, or seeking off-farm employment. Access to agricultural credit had little impact, as it was positively associated with farmers' likelihood to purchase agricultural insurance in response to floods, but negatively with farmers' likelihood to make changes in farm management in response to cold spells.

Threat appraisal was highly significant in the choice of intended strategies in response to floods. Farmers with greater previous experience with damage from floods (or from EWEs in general) were more likely to intend to take out crop insurance and to seek off-farm employment to cope with future flood events. Farmers with greater prior experience with heat waves were also more likely to intend to take out crop insurance. In contrast, previous experience with damage from cold spells was negatively associated with the likelihood of pursuing two adaptation strategies, emergency planning and seeking off-farm work.

Previous experience with heat waves also significantly increased the probability of purchasing crop insurance and participating in awareness raising. Previous experience with cold spells also significantly increased the probability of purchasing crop insurance and emergency plan management, while previous experience with floods hardly had an impact on intended flood adaptation strategies.

Reliance on public protection was not significant in the floods or heat waves models but had a positive impact on farmers' intention to take out crop insurance to cope with cold spells. Farmers who had implemented a greater number of adaptation strategies in the past were more likely to intend to adopt many of the strategies, across all three EWEs (Table B16 in the appendix).

Income and education did little to explain the likelihood of adopting different strategies in response to all three EWEs. Education only had a highly significant and positive effect on seeking off-farm employment to cope with cold spells.

Table 4.3: Results of the multinomial logit models to explain farmers' intentions to adopt different adaptation strategies in response to flood, heat wave and cold spells.

Variables	Taking out crop insurance			Changes in farm management			Emergency management planning			Awareness raising			Seeking off farm employment		
	F	HW	CS	F	HW	CS	F	HW	CS	F	HW	CS	F	HW	CS
Threat Appraisals															
Perceived probability of damages to farm	-0.06 (0.64)	0.47 (0.54)	-0.87 (0.6)	-0.34 (0.4)	0.32 (0.39)	-0.3 (0.4)	-0.9* (0.51)	0.9 (0.6)	-0.7 (0.6)	-0.36 (0.53)	0.7 (0.4)	-0.98* (0.4)	-0.13 (0.7)	-0.07 (0.56)	0.06 (0.6)
Perceived probability of personal damage	-0.64 (0.66)	-1.5 *** (0.6)	0.21 (0.6)	-0.04 (0.50)	-0.9** (0.4)	-0.3 (0.3)	-0.20 (0.67)	-1.3** (0.6)	0.2 (0.6)	-0.22 (0.74)	-0.7 (0.5)	-0.02 (0.4)	0.39 (0.73)	-1.0* (0.6)	-0.7 (0.6)
Perceived consequences for infrastructure	0.48 (0.57)	0.05 (0.47)	-1** (0.5)	0.08 (0.38)	0.30 (0.33)	-0.3 (0.3)	0.48 (0.57)	-0.52 (0.6)	-0.04 (0.5)	0.50 (0.6)	0.5 (0.4)	0.6 (0.3)	0.7 (0.57)	0.63 (0.54)	0.87 (0.51)
Perceived severity of damage	0.25 (0.58)	0.23 (0.4)	-0.3 (0.5)	-0.28 (0.37)	0.41 (0.29)	0.2 (0.3)	0.14 (0.62)	0.26 (0.48)	0.2 (0.4)	-0.39 (0.5)	0.14 (0.32)	0.35 (0.4)	-0.65 (0.53)	0.26 (0.47)	0.13 (0.57)
Anxiety (worry)	0.09 (1.0)	-0.42 (0.44)	1.1** (0.5)	0.24 (0.63)	-0.47 (0.32)	-0.2 (0.3)	0.28 (0.97)	-0.9 (0.52)	-0.09 (0.4)	-1.2* (0.65)	-0.01 (0.38)	-0.07 (0.3)	-0.3 (0.8)	-0.64 (0.52)	-0.3 (0.5)

Variables	Taking out crop insurance			Changes in farm management			Emergency management planning			Awareness raising			Seeking off farm employment		
	F	HW	CS	F	HW	CS	F	HW	CS	F	HW	CS	F	HW	CS
Coping Appraisals															
Perceived response efficacy	-0.7 (0.4)	-0.9** (0.4)	-0.8 (0.5)	0.01 (0.2)	0.11 (0.3)	0.4 (0.3)	-0.15 (0.4)	0.03 (0.5)	-0.5 (0.4)	0.16 (0.4)	0.9** (0.4)	1*** (0.4)	0.12 (0.4)	1.5** (0.7)	-0.1 (0.5)
Perceived response cost	-1.1*** (0.4)	-1.04 ** (0.4)	-2*** (0.5)	0.26 (0.30)	0.5 (0.32)	-0.4 (0.3)	-0.35 (0.43)	-0.10 (0.5)	-0.4 (0.5)	-0.02 (0.45)	-0.55 (0.38)	-0.9** (0.3)	-1*** (0.4)	-0.19 (0.47)	-1*** (0.5)
Perceived self-efficacy	1.2*** (0.41)	0.73 (0.49)	0.003 (0.6)	0.8*** (0.3)	0.6* (0.4)	0.2 (0.3)	1.0** (0.43)	0.59 (0.56)	0.4 (0.5)	0.80* (0.4)	1.0 (0.43)	0.3 (0.3)	0.83* (0.44)	0.8 (0.56)	0.9 (0.60)
Perceived responsibility	1.5*** (0.3)	1.19 *** (0.41)	0.5 (0.5)	0.37 (0.23)	0.14 (0.26)	-0.5* (0.2)	0.7** (0.3)	0.5 (0.47)	0.4 (0.4)	-0.31 (0.38)	-0.7** (0.3)	-0.8 *** (0.3)	1.4*** (0.4)	0.8* (0.4)	1.4** (0.5)
Social capital and access to facilities															
Community Organization	1.12 (0.8)	1.7** (0.79)	1.1 (0.8)	0.9 (0.6)	0.48 (0.53)	0.27 (0.5)	1.9** (0.9)	2.7** (1.2)	1.6** (0.9)	1.58 (1.03)	0.74 (0.69)	1.89** (0.7)	1.9** (0.8)	1.9** (0.9)	1.15 (0.8)
Extension Services	-1.7** (0.7)	-1.46 (0.86)	-1.4 (0.9)	-0.60 (0.5)	0.10 (0.60)	-0.5 (0.5)	-1.13 (0.8)	-0.60 (1.07)	-1.6* (0.8)	0.18 (0.64)	1.07 (0.64)	-0.3 (0.5)	-1.16 (0.8)	0.31 (0.85)	-1.7* (0.8)
Credit	2.2*** (0.7)	0.8 (0.69)	0.8 (0.1)	0.68 (0.48)	-0.6 (0.52)	-0.8* (0.4)	0.53 (0.70)	-0.40 (0.70)	-0.3 (0.7)	0.20 (0.64)	-0.62 (0.58)	-0.6 (0.5)	1.07 (0.73)	-0.02 (0.76)	-0.5 (0.7)
Threat experience EWEs															
Previous experiences of EWEs	1.8*** (0.6)	1.1** (0.47)	-0.2 (0.5)	0.8** (0.4)	0.26 (0.32)	-0.2 (0.3)	0.6 (0.55)	0.37 (0.58)	-1** (0.5)	1.13* (0.7)	-0.24 (0.37)	-0.3 (0.3)	0.8 (0.58)	0.27 (0.55)	-1** (0.5)
EWEs Experience															
Experience EWEs	0.1 (0.53)	1.8*** (0.5)	2*** (0.6)	0.24 (0.40)	0.57 (0.35)	0.4 (0.2)	-0.53 (0.54)	0.69 (0.56)	0.8 (0.5)	0.31 (0.65)	1.5*** (0.4)	0.4 (0.3)	-1.0* (0.53)	0.44 (0.51)	-0.2 (0.5)
Reliance on public protection	0.06 (0.36)	0.52 (0.46)	1*** (0.47)	-0.07 (0.25)	-0.10 (0.39)	-0.02 (0.3)	0.26 (0.36)	0.32 (0.55)	0.2 (0.5)	-0.32 (0.4)	-0.7 (0.51)	0.04 (0.4)	-0.30 (0.41)	-0.10 (0.54)	0.21 (0.5)
Implemented EWEs strategies	0.8*** (0.2)	0.77** *(0.2)	1*** (0.2)	0.3** (0.1)	0.4** (0.2)	1*** (0.1)	0.2 (0.19)	0.5 (0.2)	0.8*** (0.2)	0.18 (0.20)	0.5** (0.2)	0.21 (0.23)	0.6*** (0.2)	0.8*** (0.2)	1.3*** (0.2)

Variables	Taking out crop insurance			Changes in farm management			Emergency management planning			Awareness raising			Seeking off farm employment		
	F	HW	CS	F	HW	CS	F	HW	CS	F	HW	CS	F	HW	CS
Socio-economic characteristics															
Education	-0.3 (0.2)	-0.1 (0.2)	0.4 (0.3)	-0.1 (0.1)	-0.1 (0.2)	-0.07 (0.1)	-0.1 (0.2)	0.5* (0.3)	0.4 (0.2)	-0.2 (0.2)	-0.08 (0.2)	0.03 (0.2)	-0.04 (0.2)	0.1 (0.2)	0.8*** (0.3)
Income	0.2 (0.1)	0.3 (0.2)	0.1 (0.3)	0.1 (0.2)	0.3 (0.2)	0.1 (0.2)	-0.04 (0.3)	-0.08 (0.3)	0.2 (0.3)	0.1 (0.2)	0.5** (0.2)	0.2 (0.2)	-0.4 (0.3)	-0.3 (0.3)	-0.6* (0.3)
Constant	-15*** (4.4)	-8*** (3.07)	-7** (3.1)	-5.1* (2.9)	-3.6* (2.2)	1.9	-5.96 (4.2)	-4.7 (3.5)	-3 (2.95)	-1.01 (3.5)	-6.9**	1.00 (2.04)	-7.01 (4.2)	-9** (3.8)	-4.9 (3.03)

Base category	Changes in cultivation(F)	Changes in cultivation(HW)	Changes in cultivation(CS)
Observations	347	349	341
LR chi2(90)	288.18***	397.22***	441.28***
Log likelihood	-355.9	-346.66	-325.81
Pseudo R2	0.29	0.36	0.40

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Standard errors in parentheses

Note: F-Flood, HW: Heat wave, and CS: Cold Spells.

4.7 Discussion

4.7.1 Adaptation intensity.

4.7.1.1 Threat appraisal.

The results provide evidence for the mixed impact to the threat appraisal, reiterating its role in previous studies (Poussin et al., 2014). The number of intended adaptation strategies in response to heat waves and cold spells was negatively influenced by perceived damage at both the farm level (loss of agricultural production) and at the personal level (damage to respondents and household members). This might reflect a lack of farmer concern about the creeping effects of slow-onset hazards and their uncertainty regarding how to cope with them. It could also reflect negative outcome expectancy and thus an emergent belief that farmers did not believe that any strategy could be effective (see (Paton, 2013). This leads to inactivity insead of adaptation (Bubeck et al. 2013; Paton, 2013; Siegrist and Gutscher, 2008). Consistent with the views expressed by Grothmann and Reusswig (2006), farmers who identified heat waves and cold spells as potential risks to infrastructure, such as farm equipment and houses, showed a greater propensity to adopt many adaptation strategies in response. Our finding of the negative impact of anxiety on the number of intended adaptation strategies for all three EWEs was unexpected, and contradicted other studies (e.g. Zaalberg et al. 2009) based on stipulating that higher anxiety could signify higher vulnerability, which in turn leads to higher the probability of adapting.

We found substantial differences in the impact of threat appraisal between heat waves and cold spells, on the one hand, and flood, on the other hand. This could be because heat waves and cold spells are slow onset hazards, while floods are sudden hazards, producing much more immediate damage. It could also be that farmers in the study region have been more susceptible to cold spells rather than heat waves and flooding or they might think that individual effort is futile in ensuring personal safety from floods and heat waves, which is consistent with previous study findings (e.g. Paton (2013). For slow onset hazards (such as heat waves and cold spells), threat appraisal is a stronger predictor than coping appraisal ((Koerth, Vafeidis, Hinkel, & Sterr, 2013). In the case of slow onset hazards, farmers have plenty of time to enact prepared strategies in response. However, anticipating changes in risk needs to occur in the short term to reduce the risk of action only occurring when the problem reaches significant proportions.

Discussions with farmers during the survey provided evidence that they are more concerned about the impact of cold spells than of heat waves, because they do not own proper cold resistant houses (see also Budhathoki and Zander et al. 2019; Budhathoki et al. 2020). The other reason is that farmers could be acclimatised to heat waves, but are less well adapted to cold spells due to these being a recent phenomenon in the study area (Budhathoki and Zander 2019).

4.7.1.2 Coping appraisal.

All elements of coping appraisal significantly influenced the number of intended adaptation strategies in response to floods, which is consistent with previous findings (Bubeck et al., 2013; Poussin et al., 2014; Keshavarz & Karami, 2016; Richert et al., 2017).

Despite the high perceived response cost of floods and heat waves adaptation strategies, farmers were more likely to enact floods and heat waves adaptation strategies, which contradicted our hypothesis that the high response cost of intended adaptation strategies would decrease farmers' intention to carry out farm and household level risk reduction strategies against EWEs (Poussin et al., 2014). One possible reason could be positive outcome expectancy, which postulates that farmers, who have the belief that the negative consequences of natural hazards can be mitigated, are more likely to take steps to adapt to EWEs (Paton, 2013). In the heat wave model, perceived response cost and perceived responsibility positively influenced the intensity of heat wave adaptation. However, perceived response efficacy is negatively associated with taking up lower numbers of heat wave adaptation strategies, which contradicted the previous finding of van Duinen et al. (2015).

For floods, a rapid onset hazard, coping appraisal is a stronger predictor of farmers' intention to undertake various adaptation strategies than threat appraisal. For heat waves, many elements of both threat and coping appraisal demonstrated significant influence on adaptive choices, while for cold spells threat appraisal elements seemed to be more critical than coping appraisal elements. This means that coping appraisal is similar in importance to the intensity of floods and heat waves adaptation; and this research cannot detect the distinctive difference between sudden and slow onset hazards, it is found to be essential to threat appraisal. The irrelevance of coping appraisal for the number of heat waves adaptation strategies could be explained by previous effective investments made by the national government. For farmers in the research area, heat waves and droughts go together and have previously had a severe impact. As a response, the national government has implemented canal irrigation and deep boring. Farmers, therefore, do not need to implement additional heat waves adaptation measures in the future and are indifferent towards response costs, self-efficacy, and responsibility. However, in the case of floods and cold spells, despite perceiving effectiveness of floods and cold spells adaptation strategies, farmers are yet willing to adopt additional future strategies. Farmers think that existing implemented measures are insufficient to mitigate the potential loss from floods and cold spells.

4.7.1.3 Socio-economic and social capital.

It was surprising that income did not, as expected, have a stronger positive influence on the number of farmers' intended adaptation strategies for all three EWES. Income is often taken as a proxy for adaptive capacity (Brooks, Adger, & Kelly, 2005), and farmers with higher income are supposed to have better access to capital, which allows them to better adapt to EWEs through economic investment (Jain, Naeem, Orlove, Modi, & DeFries, 2015). The only positive effect on the number of adaptation strategies was found in response to heat waves. A reason for this could be that farmers know about irrigation as a measure against heat and drought, since this has not been provided by the government, and they think that more irrigation is even better, though it would be costly. Education and access to extension services demonstrated significant relationships for only one EWEs; positively affecting the number of adaptation strategies for floods as found elsewhere (Deressa et al. 2009; Arunrat et al. 2017).

4.7.1.4 Direct and indirect experience.

Prior experience and future expectations were among the most significant determinants explaining the intended intensity of adaptation. Farmers who had previous experience with floods, heat waves, and cold spells and those who expected them in the future, and probably fear potential future damages, are more likely to intend to adopt more adaptation strategies, as supported by existing literature (Grothmann & Reusswig, 2006; Osberghaus, 2015; Zheng & Dallimer, 2016).

4.7.1.5 Public reliance and past implemented strategies.

Grothmann and Reusswig (2006) found a significant negative relationship between public reliance on protection and adaptation strategies, whereas this research points to a positive relationship between these variables in the cold spell model. In freezing periods, the Nepalese government provides emergency kits with warm clothes and blankets to the most impoverished communities in the study areas. Despite having support from local government during cold spells, farmers think that these responses are insufficient to reduce the effects of cold spells, so farmers are more likely to carry out more adaptation strategies in the future.

Our findings show that farmers who had implemented more adaptation strategies in the past also intended to adopt more in the future. This contradicts previous findings (Richert et al. 2017). Richert et al. (2017) argues that those farmers who have already invested significantly into existing practices to protect against EWEs do not need to invest as heavily into future adaptation strategies as those who have not yet implemented many adaptation strategies. This study found a positive correlation because farmers who have just started to adapt but do not yet feel they are sufficiently prepared. Their previous adaptation strategies might also have been ineffective or they are engaging in more future-oriented thinking and appreciating the need for additional investment.

4.7.2 Farmers' intended adaptation strategies.

4.7.2.1 Threat appraisal.

Threat appraisal had a surprisingly limited effect on farmers intended adaptation strategies across all three EWEs. This contradicts findings from previous studies (Zaalberg et al., 2009; Bubeck et al., 2012). Farmers are unaware of the risks of potential threats on their livelihood, or those with higher perceptions of EWE damage are less likely to adopt some strategies. It could be that farmers' perceived negative outcome expectancy of heat waves negatively influence the adoption of heat waves adaptation strategies, as suggested by (Paton, 2013).

The findings support the view that all the governments, and especially local government, should communicate about and encourage discuss of potential threats, as well as creating discourse about hazard specific coping mechanisms at the community level in order to overcome these challenges. Anxiety and the fear of cold spells also motivate farmers' intentions to implement future adaptation strategies, because cold spells is a recent phenomenon in the Terai region and have adversely affected the well-being of farmers in the recent years (Budhathoki et al. 2019; Budhathoki & Zander. 2019).

4.7.2.2 Coping appraisal.

Coping appraisal has a higher influence on farmers intended adaptation strategies than threat appraisal. Perceived self-efficacy and perceived responsibility are healthy and positive predictors of farmers' intended adaptation, as also found elsewhere (Grothmann & Patt, 2005; Burnham & Ma, 2017). As expected, farmers' perceived self-efficacy belief of coping appraisal positively and significantly increased the likelihood of purchasing crop insurance, preparing emergency management plans, and looking for off-farm employment. The higher response costs of potential floods adaptation strategies discourage farmers to take up more adaptation strategies, such as purchasing crop insurance and seeking off-farm employment (Gebrehiwot & van der Veen, 2015). It could be that poor farmers cannot afford crop insurance and invest in off-farm employment, such as operating new businesses, as floods adaptation strategies. In heat waves, coping appraisal variables such as perceived responsibility, response cost, and response efficacy were significant determinants of farmers' choice of purchasing crop insurance. Despite perceiving the low effectiveness of early implemented heat waves adaptation strategies (perceived response efficacy), farmers were more likely to purchase crop insurance as a potential adaptation strategy. One possible reason is that crop insurance is a strategy of risk sharing, while another reason could be the large premium subsidies for crop insurance offered by the Nepalese government (Ghimire, Timsina, & Gauchan, 2016).

Surprisingly, of the coping appraisal, perceived responsibility (individual responsibility is essential to reduce the impact of heat waves in the agriculture) is negatively associated with farmers' likelihood of participating in raising awareness. Farmers are more likely to continue with existing practices, such as changes in cultivation, rather than choosing new adaptation strategies due to available heuristic methods (Vasileiadou & Botzen, 2014), because most of the farmers are uneducated, marginally poor, and make subjective risk assessments immediately with little effort or no effort based on their experience. The national government's technical and financial support programs could help resource-constrained farming communities to plan for future adaptation.

In the cold spell model, perceived response cost and perceived responsibility of coping appraisals were also negatively associated with farmers' purchasing of agricultural insurance, raising awareness, and farm management changes. Farmers were more likely to adopt prevailing changes in cultivation practices to cope with cold spells rather than others adaptation strategies, which are costly and time-consuming.

4.7.2.3 Socio-economic and social capital.

It was surprising that income and education did not have a stronger positive impact on intended adaptation strategies, as found elsewhere (Arunrat et al., 2017).

Membership to community organizations had a positive impact on some of the adaptation strategies in response to all thee EWEs. This was expected since memberships in social groups, kinship, and friendship networks can provide channels for social interaction, as well as information sharing and dissemination, with this creating a context for social constructing understanding of risk and how best to manage that risk (Paton 2013). This social process is particularly important in circumstances, as here, where people have to make choices against a backdrop of considerable uncertainty. Furthermore, such social networks or affiliation with any community organisation can lead to access to the formal and informal credit market and this can shape farmers' daily activities and reduce the exposure to the EWEs (Deressa et al., 2009; Le Dang, Li, Nuberg, & Bruwer, 2014; Roco et al., 2015; Yaméogo, Fonta, & Wünscher, 2018). It was unexpected that access to extension services had a negative impact on intended adaptation or that farmers were less likely to undertake various intended floods and cold spells adaptation strategies than changes in cultivation practices. This could be because of expensive crop insurance and the seeking of off-farm employment adaptation strategies.

Having access to formal credit facilities had a positive impact on the intention to purchase crop insurance as an intended flood adaptation strategy. Access to credit facilities eases cash constraints and encourages new ways of adaptation at the farm level, also confirmed by previous studies (Bryan, Deressa, Gbetibouo, & Ringler, 2009; Arunrat et al., 2017).

4.7.2.4 Direct and indirect experiences.

Farmers with higher risks perceptions of EWEs (Le Dang et al., 2014) and experience of intense and life-threatening events (Vasileiadou & Botzen, 2014) are more likely to adopt personal preparedness and risk mitigation behaviour than those without such experience. In this study it was therefore expected that farmers' experience with the particular EWEs would increase their likelihood of taking adaptation strategies. However, this positive relationship was only found in the flood model: farmers with experience of flood damage (threat experience appraisal) had an increased probability of taking out crop insurance, making changes in farm management, seeking off-farm employment, and participating in awareness raising. For heat waves and cold spells, previous experience was less important, which could be because these EWEs do not occur immediately, but adaptation can occur in the long-term with a correspondingly prolonged period before the effects on agriculture and human health become apparent.

4.7.2.5 Public reliance and past implemented strategies.

High reliance on public protection mechanisms and their efficiency are supposed to negatively impact on adaptation intentions (Grothmann & Reusswig, 2006; Richert et al., 2017). This contention was not supported in this study. High reliance on public protection has no significant impact on the choice of strategies in response to floods and heat waves and only a positive impact on the likelihood of taking out crop insurance in response to cold spells. This was unexpected because the Nepalese government has recently introduced highly subsidised crop insurance as a risk-sharing strategy (not as a risk-reducing strategy) to cope with EWEs. As mentioned in Section 4.6.1.5, implemented adaptation strategies in the past also significantly influence farmers' future choices, which explain this positive relationship. Another possible explanation could be that the local governments in the study area usually distribute warm clothes, blankets, and firewood during cold spells. Farmers might not be satisfied with these provisions and adopt additional precautionary strategies to lower the potential loss from the impacts of future cold spells.

4.8 Study limitations

The study faces some limitations. First, this study uses self-reported data. The quality of farmers' responses relies on their ability to recall their experiences with EWEs and to state likely adaptation intentions. Responses to both might be suffered from social desirability bias. This bias was minimised by using self-administrative questionnaires, asking questions differently and by conducting randomised response technique. Second, cross sectional data were used which only covers a small, albeit significantly represents the homogeneous geographical and ecological region of lowlands of terai of the country. Inferring the results to farmers in other districts of the Terai region or other regions in Nepal should be made with caution.

4.9 Conclusion

This study was designed to investigate how crop farmers in the Terai lowland region of Nepal adapted to three climate change related extreme weather events (floods, heat waves, and cold spells) which are predicted to increase in severity and likelihood in the research area. The applied protection motivation theory was found to be a valid approach for understanding, analysing and predicting farmers' behavioural response to three climate change related extreme weather events: floods, colds spells, and heat waves. Making changes in farm management was the most critical adaptation strategy in response to all three EWEs. Seeking off-farm employment was also a frequently intended adaptation strategy to cope with floods and heat waves and purchase crop insurance was also crucial in response to all three EWEs. Farmers' adaptation intentions found to be varied across slow and rapid onset. Despite having higher level of threat appraisal, farmers are less likely to intend to adapt against slow onset hazards but having higher level of coping appraisal found to have positive influence on farmers' preparedness intention of rapid onset hazards. Socio-economic variables had remarkably little influence on farmers' adaptation choices in response to all three EWEs and on their adaptation intensity.

Despite perceiving risks from slow and rapid onset hazards, farmers continuingly prefer to adapt same traditional measures rather than adapting modern practices because of negative wishful thinking and outcome expectancy. Such pessimism or nothing can be done attitude against extreme events is the outcome of knowledge and resources gaps in the farming community. Our results emphasise the diverse climate change impacts and the need for hazard-specific adaptation. Agricultural policies and targeted efforts should be developed to enhance farmers' coping appraisals and risk awareness. This can be achieved via providing incentives, subsidies, loans and complementary insurance to households and communities for implementing various hazards specific measures by all three levels of governments and via collaborating with donor organizations (Budhathoki et al 2020).

At the same time, people centered risk communication including public education programs and strategies to enhance the efficiency of existing agriculture extension services can help farmers better appreciate the threats and implications of both suddenly-occurring and slow onset hazards. Such activities will facilitate motivating farmers to undertake various cost effective hazards specific measures rather relying on usual measures such as shifting planting date, changing cropping types and depending on government sourced emergency response and recovery responses to deal with extreme events consequences. The strategies proposed here shift this view towards one of shared responsibility. All of government, including federal, provincial and local government should collaborate to formulate and implement long term mitigation and preparedness policies for all types of hazards and move towards less reliance on response and recovery and greater adoption of proactive preventative and adaption approaches. Policies can only be effective and tailored to specific farming communities if the impacts and adaptive strategies needed to cope with particular events, such as floods, heat waves and cold spells, are well understood, developed and enacted.

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Chapter 5 Farmers' Interest and Willingness-to-Pay for Index-Based Crop Insurance in the Lowlands of Nepal

5.1 Preface

This chapter evaluates farmers' willingness to pay for crop insurance, indentify challenges of crop insurance market, and make some policy recomendation. The chapter has been published in full in the Land Use Policy. Changes have been made to the formatting and the referencing style so that it is consistent with the rest of the thesis.

Budhathoki, N. K., Lassa, J. A., Pun, S., & Zander, K. K. (2019). Farmers' interest and willingness-to-pay for index-based crop insurance in the lowlands of Nepal. *Land Use Policy*, 85, 1-10.

5.2 Abstract

Farmers in Nepal face many risks from extreme weather events which detrimentally impact their crop production. To support farmers in risk management, preventing financial losses, and facilitating farmers' participation in insurance schemes, the Nepalese government subsidises insurance, paying 75% of the premiums. However, the uptake of insurance schemes has been limited. This study aims to find out why. By surveying 350 farmers, we identified factors that influence farmers' general interest in, and willingness-to-pay for, crop insurance. Approximately 84% of farmers were interested in purchasing area-based crop yield insurance and were, on average, willing to pay a premium of USD 42.42/ha/cropping season for paddy rice, and USD 29.52/ha/season for wheat. This was more than three times what farmers currently have to

pay for premiums for paddy rice (USD 9.96/ha/season), and nearly three times of what they pay for wheat (USD 8.59/ha/season) premiums under the current subsidised scheme. This implies that the cause of low uptake is unlikely to be related to the price of the premiums. The results further suggest that in order to increase farmers' uptake of crop insurance, the information of the threats of climate variability to future crop failures should be communicated and subsidised insurance schemes need revision.

Keywords: area-based yield insurance; climate change impacts; double-bounded contingent valuation, extreme weather events; stated preference

5.3 Introduction

Climate change is expected to lead to rising temperatures and increasing climate variability, including frequent and intense extreme weather events (EWEs) such as heat waves, droughts, flooding, and cyclones or other heavy storms (Field et al., 2014). Extreme weather events have detrimental impacts on agricultural production, food security and livelihood, particularly in developing countries (Hanjra & Qureshi, 2010; Devkota, Maraseni, Cockfield, & Devkota, 2013; Pandey & Bardsley, 2015). Droughts and extreme heat, for example, have reduced national cereals production by 9-10% across the globe from 1964-2007 (Lesk, Rowhani, & Ramankutty, 2016). People in developing countries, like Nepal are expected to suffer the most in the future from climate related extreme events because of a heavy dependence on the traditional subsistence agricultural sector (Aryal, Maraseni, & Cockfield, 2014) and a limited adaptive capacity due to poverty and a lack of access to information and disaster support (Wheeler & von Braun, 2013; Devkota & Maraseni, 2018). Without sufficient adaptation measures against the impacts of EWEs, there will be substantial losses in crop productivity, particularly in southern Africa and southern Asia (Lobell et al., 2008; Yuzva, Botzen, Aerts, & Brouwer, 2018). Governments and other stakeholders in these regions should focus on strengthening agricultural growth and eliminating poverty through sound policy-making and investments to help farmers cope with EWEs in the long-run through better risk management (Dawson et al., 2011).

Sharing the burden of financial risk from yield losses can be achieved through agricultural insurance (Miranda, 1991; Hardaker, 2004; Binswanger-Mkhize, 2012; Mahul, Verma, & Clarke, 2012; Mobarak & Rosenzweig, 2012). There are two types of insurance scheme, traditional loss-based schemes and index-based schemes (Carter, de Janvry, Sadoulet, & Sarris, 2014; Yuzva et al., 2018). Many developing countries have abandoned individual loss-based crop insurance because these insurance mechanisms are not viable due to high transaction costs (Skees, Black, & Barnett, 1997; Greatrex et al., 2015), and have adopted index-based schemes, which are now the most commonly used. In index-based insurance, payouts are based on easily measurable environmental conditions, an 'index' that is closely related to agricultural production losses (Greatrex et al., 2015). Among the various index-based insurance schemes, the two most common for crop yields are weather-based index insurance and area-based yield insurance. Weather indices can be of rainfall or drought days, and farmers receive a payout when the particular index exceeds a certain threshold in their area (Binswanger-Mkhize, 2012). In area-based yield insurance, payouts are based on village level yields, whereby the policyholder receives an indemnity whenever the village yield falls below a specified threshold, regardless of their own farm yield (Barnett, Black, Hu, & Skees, 2005).

Despite the potential positive impacts of index-based insurance, the outreach and uptake are low in many developing countries, including Nepal, because of perceived mismatches between payouts and the actual loss experienced by farmers (Yuzva et al., 2018). Less than 0.3% farmers in low and middle-income countries have agricultural insurance (Mahul & Stutley, 2010). One reason farmers in developing countries were reluctant to adopt crop insurance is the complication in cost calculation due to the issues of moral hazard and the challenge in determining the reasons for crop productivity losses relating to climate change in general (Carter et al., 2014). Increasing the rate of insurance adoption needs a better understanding about how farmers perceive potential benefits of index-based insurance and how much they think they can afford to pay for premiums to cover potential yield losses in case of EWEs. Closing this gap between payouts and perceived losses will help to increase the demand for index-based insurance (Elabed & Carter, 2015).

The aim of this study was 1) to assess farmers' general interest in participating in an index-based insurance scheme, 2) to reveal how much they were willing to pay for premiums to insure their rice and wheat crop yields, and 3) to reveal if there were differences across farmers with different characteristics. Nepal was chosen as a case study because of an existing insurance scheme, which was launched in 2013. The Nepalese government initiated an ***index-based multi-peril crop*** insurance scheme to support farmers with their yield loss, particularly from droughts and floods (based on area yield), and heavily subsidised it by paying 75% of farmers' premiums. However, as per the communication with government officials and various unpublished sources, the uptake of this scheme has been limited despite farmers facing many risks from EWEs, including detrimental impacts on crop production.

The results of this study will help to set appropriate and fair insurance premiums that are acceptable to farmers, and that attract more farmers to participate in such schemes. The findings will further help to address the question of why the current agricultural insurance scheme has had a limited positive impact on farmers, thus far. The findings may also be used for insurance schemes in other developing countries to design appropriate insurance premiums.

To address the aims, a contingent valuation (CV) study was conducted in the Terai lowlands of Nepal, where most of the agricultural production in the country takes place, and where more than 84% of farm households produce paddy rice and 65% wheat (CBS, 2011). Only 20% of the total agricultural area in the region is under irrigation, with the vast majority being unirrigated and rain-fed, making the agricultural systems highly vulnerable to EWEs (Budhathoki & Bhatta, 2016; Chalise & Naranpanawa, 2016).

Contingent valuation has become a prominent tool by which to evaluate the effectiveness of index-based insurance schemes in developing countries through farmers' willingness-to-pay (WTP) for them. While most CV studies on farmers' WTP for index-based insurance investigated weather indices (Hill, Hoddinott, & Kumar, 2013; Abbas, Amjath-Babu, Kächele, & Müller, 2015; Bogale, 2015; Arshad, Amjath-Babu, Kächele, & Müller, 2016; Fahad & Jing, 2017) very few studies explored WTP for area-based yield insurance (Zhang, Wang, & Boyd, 2011; Ghahremanzadeh, Raheli, Eshghi, & Dashti, 2017). A study by Guo (2016) investigated weather-index based crop and livestock insurance on the hilly districts of Nepal and found that the annual mean WTP for rice insurance was around 3% of household income. A few contingent valuation studies from Nepal exist in which flood risks management strategies under different flood hazards scenarios were assessed (Devkota, Maraseni, & Cockfield, 2014; Devkota & Maraseni, 2018).

5.4 Methods

5.4.1 Study area.

The Terai region covers only 14% of the total land area of Nepal but contributes 72% of the rice and 63% of wheat production (MoAD, 2017). It is, therefore, referred to as the ‘granary’ of Nepal, as more than 84% of farm households in this region are actively engaged in rice production. The region covers 22 districts (out of the 75 districts of Nepal) and is home to more than half of the country’s population of 28.5 million people (CBS, 2011). Based on the recent climate change impact survey by the Central Bureau of Statistics (CBS, 2016) and based on discussion outcomes with the officials from the Department of Hydrology and Meteorology (DHM), two districts were selected: the Banke and Bardiya districts. The selected municipalities and their respective wards[16] from these districts had been highly affected by EWEs such as floods, heat waves, and cold spells in recent years (Maharjan, Sigdel, Sthapit, & Regmi, 2011).

[16] The lowest administrative division in Nepal.

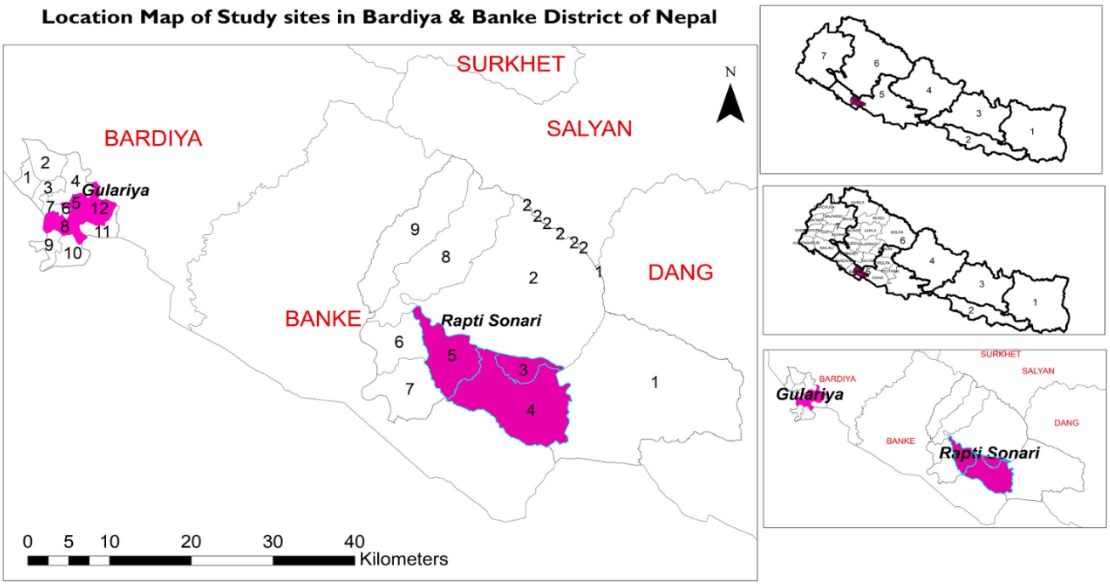

Figure 5.1: Study area.

5.4.2 Sampling method.

Three wards (5, 8 and 12) of the Gulariya municipality of the Bardiya district were purposively selected, as were three wards (3, 4 and 5) of the Rapti Sonari rural municipality of the Banke district (Figure 5.1). From each municipality, farming households were selected using systematic random sampling. A total of 350 household heads or leading household's members were interviewed. Among these sampled households, nearly 52% of interviewed households were located in Rapti Sonari and the remaining 48% in Guleriya. The survey was conducted from the first week of November 2017 to the third week of January 2018 by three experienced and trained research assistants who spoke Nepali, the primary language used for the survey, and who could also understand Tharu and others local dialects.

Key informant interviews were conducted using a pre-tested semi-structured questionnaire prior to the main survey to inform the design of the household survey questionnaire and the CV. During the survey, key informants continued to be interviewed in order to complement and interpret results from the CV. Altogether nine key informants were interviewed: three central government officials from the Ministry of Agriculture and Development insurance board, four district level government officials from two district (two from each district) agricultural office, and two representatives from insurance companies (one from each district) who were involved in providing agricultural insurance in these areas. The key informants were asked about farmers' existing coping mechanisms in mitigating the impacts of EWEs, the current status of insurance uptake, problems with the existing insurance policies, and for suggestions of how to increase agricultural insurance penetration to poor and marginal farmers.

5.4.3 An overview of crop insurance in Nepal.

The government of Nepal, through the insurance board, introduced crop and livestock insurance directives in 2013 with the aim to encourage insurance companies to develop commercial agriculture insurance schemes. The directives introduced the obligations of non-life insurance companies to offer agriculture insurance, and also introduced guidelines for agriculture insurance that they can use. Along with that, the companies were also free to submit their schemes for the approval of the insurance board (Ghimire, Timsina, & Gauchan, 2016). Seventeen out of 19 non-life insurance companies (selected by the Insurance Board of Nepal) currently offer agricultural insurance to farmers.

The introduced insurance was indemnity based (damaged based) and for all crops. This meant that based on the damage incurred in the field, indemnity was paid on the basis of damage in the respective area. The sum insured was based on the cost of production (input-based) and yield estimation was not taken into consideration. The damage was assessed on individual farm levels. If there were damage and payouts granted, the losses that had already occurred to farmers were paid back by the insurance company (Ghimire & Kumar, 2014).

The government of Nepal adopted area-based yield insurance for two crops in 2016: cereal seed crops and spring paddy rice. The reason an area-based yield index was preferred over a weather-based index was that it covers yield loss from multiple non-preventable and uncontrollable natural forces (act of god) rather than from a single weather event. The insurance payouts (the indemnity) to policyholders were paid on the basis of damage of the expected yield in the respective area, not based on the damage of the yield on the individual farm. Payouts of up to 90% of the yield loss were made to farmers if the actual village level yield had been less than the yield projected at the time of purchasing the insurance. Farmers paid a premium of 5% of the expected total yield revenue. The government initially introduced a 50% premium subsidy, which was revised in 2014 and raised to 75% to encourage farmers to take up crop insurance (Ghimire et al., 2016).

5.4.4 Questionnaire design.

The questionnaire for the household survey was prepared based on both the information obtained from the key informants and the current CV literature. The final version was pre-tested with 15 farming households in the study area and finalised after incorporating the comments received from the pilot testing.

The questionnaire contained three parts. The first part asked for socio-demographic characteristics and farming background of the respondents; the second part asked about the farmers' perceptions of and experiences with various EWEs, particularly floods, heat waves, and cold spells; and the final part included the double-bounded dichotomous choice questions on farmers' WTP. On average, it took 30 minutes to complete each interview.

WTP questions were administrated only to those respondents who confirmed that they were interested in acquiring crop insurance.

5.4.5 Contingent valuation design.

Contingent valuation is a stated preference method commonly used to evaluate goods and services that are not traded at markets, therefore having no apparent market value; and future products or programs that do not exist yet, and that hence also have no market value (Carson & Hanemann, 2005). As such, CV has been applied in many research areas, such as environmental and agricultural economics, health economics, and marketing. It is, in fact, the most commonly used technique for valuing the non-use values or passive values of the environment (Navrud, 1992). Due to the hypothetical nature of CV, the method is susceptible to biases (Navrud & Mungatana, 1994) and therefore contested (Noonan, 2003). Nevertheless, many methods exist to minimise the specific biases, and CV is still the most commonly applied stated preference method.

Different elicitation methods and designs exist, including open-ended and closed (take or leave it) formats, payment cards, and referendums. Single-bounded-dichotomous-choice (SBDC) and double-bounded-dichotomous-choice (DBDC) are the two commonly applied referendum methods (Mitchell & Carson, 2013). The SBDC model is considered as providing less information (Lopez-Feldman, 2012), and comparatively, it requires larger samples for accurate model estimations of willingness to pay (WTP) (Hanemann, Loomis, & Kanninen, 1991). Most previous studies on the WTP for crop insurances have applied the DBDC design (Hill et al., 2013; Fahad & Jing, 2017).

In this study, the DBDC design was chosen, with a single follow-up bid, a method which minimises the starting bid bias (Hadker, Sharma, David, & Muraleedharan, 1997). The anchoring bias is also unlikely to occur in DBDC designs because the second bid differs significantly from the first bid (Herriges & Shogren, 1996). The hypothetical bias was further minimised by using a short ‘cheap talk’ script (Cummings & Taylor, 1999).The associated text including the cheap talk was presented to respondents (Table B.17 in Appendices).

Each respondent was presented with one initial bid to start with and a follow-up bid (see Verbeek (2008). Those respondents who were interested in participating in the crop insurance scheme were then asked “*Are you willing to pay xx (Initial bid) NPR/Kattha as a premium for a crop insurance*? If the response to the initial bid was “Yes”, higher follow-up bids were presented, and if the responses were “No”, lower follow-up bids were presented (for details see Table B.17 in Appendices).

More than half of the respondents (53%) had land sizes of less than a Bigga (20 Kattha) and approximately 35% land sizes of less than a 0.5 Bigga (10 Kattha). We therefore estimated farmers’ WTP per Kattha and not per Bigga. Kattha is the commonly used unit in the Terai region and most of the respondents were found comfortable with this unit of land measurement. When we tested the use of Bigga in the pilot phase, farmers felt uncomfortable with it and could not easily state their WTP in Bigga. By using Kattha, we hoped to reduce the non-response rate.

5.4.6 Designing of bids.

The CV method has been criticized for the potential impact of the initial bids on the WTP results (referred to as anchoring or starting point bias; see Herriges and Shogren (1996). We therefore carefully designed the initial bids and based on those the subsequent follow-up bids. As described in this section, our initial bids are based on the premiums of the existing insurance scheme, minimizing the starting point bias and leading to realistic WTP results.

For designing the initial bids, various primary and secondary information from government and non-government sources were used. Based on this information we decided to set the insurance premium for both, paddy rice and wheat, at 5% of the total revenue (before premium subsidies). The total expected average paddy rice production in the Terai region was 32.72 Quintals[17]/ha for 2017 (MoAD, 2016) and the average minimum support price (MSP)[18] for paddy rice was NPR 2,610/quintal (MoAD, 2017) The total expected average wheat production in the Terai region was 26.30 quintals/ha in 2017 (MoAD, 2016) and the average minimum support price for wheat was about NPR 2,800/quintal (calculated based on Indian MSP price for wheat in 2017). The average total expected revenue of paddy rice and wheat was therefore NPR 85,400/ha[19] and NPR 73,640/ha[20], respectively. Since the premium rate was fixed at 5% of the total revenue, the premium for paddy rice used in our design was NPR 4270/ha/season and for wheat NPR 3682/ha/season.

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[17] 1 Quintal =1000 kg

[18] The minimum support price is fixed by the government of Nepal to purchase directly from farmers. Even if the market price of an agricultural product is below this fixed price, the government purchases the product from farmers at the minimum support price.

[19] Total Value of rice/ha = Rice production in quintal /ha * price/quintal.(32.72*2,610= NPR 85,400)

[20] Total wheat yield value/ha = Average wheat production in quintal/ha * price/quintal (NPR 26.30*2,800= NPR 73,640)

The government of Nepal already offers to pay 75% of the premiums for farmers and it is further discussed whether this should go up to 90% to encourage more farmers to participate in the crop insurance scheme. The initial bids for our design are based on the possibility that in the long-term, the government makes adjustments to the actual premium subsidy of 75%. We assume that the government might increase the premium subsidy to 90%, or reduce it to 50%, 37% or 25%. The initial bids were then set based on the calculations of the premium amount that farmers are required to pay if the government did not provide them with any subsidy of paddy, that farmers had to pay NPR 144/Kattha[21]. For paddy rice, at different scenarios of premium subsidies such as 90%, 75%, 50%, 37% and 25% were 15, 36, 72, 54 and 108 NPR/Kattha respectively. The initial bids for the wheat insurance premium were designed using the same approach. The initial bids for the wheat CV were: NRP 12, 30, 40, 60 and 90 at 90%, 75%, 63%, 50% and 25% premium subsidy of the actual premium amount (NPR 125/Kattha).

Lower follow-up bids were approximately 25% lower than the initial bids and higher follow-up bids were approximately more than doubled the lower follow-up bids (Table 5.1), which were determined after discussions with government officials and officials from the insurance companies.

Table 5.1: Bid structure used for paddy rice and wheat against extreme weather events

	Paddy rice (NPR)			**Wheat (NPR)**		
Serial Number	Initial Bid value	Follow up lower bid	Follow up higher bid	Initial Bid value	Follow up lower bid	Follow up higher bid
2	15	10	20	60	40	80

[21] 1 ha = 29.56 Kattha

1	36	25	50	30	20	40
4	54	37	75	90	60	120
3	72	50	100	40	35	70
5	108	75	200	12	10	20

Note: For the given study, we asked separately randomly selected initial bids (36, 15, 72, 54, and 108) with follow up lower bids (25, 10, 50, 37 and 75) and higher follow up bids (50, 20, 100, 75 and 200) for paddy rice. Likewise, we asked randomly selected initial bids (30, 60, 40, 90, and 12) with follow up lower bids (20, 40, 35, 60 and 10) and higher follow up bids (40, 80, 70, 120 and 20) for wheat as well. The final bid amounts were designed after discussion with key informants and the piloting of the household survey.

5.4.7 Analysis.

Individual *i*'s WTP can be modelled as a linear function:

$$WTP_i(x_{i,}, \varepsilon_i) = x_i' \beta + \varepsilon_i \qquad (1)$$

Xi, is a vector of explanatory variables which were assumed to have an impact on the WTP, such as gender, age, income, education, remittances in the last 12 months, land size, frequencies of floods in the last five years, and access to extension services, distance to the river, and proportion of agriculture income of the total household income. β is a vector of parameters to be estimated and ε_i is the error term, assumed to be normally distributed with mean zero and constant variance σ^2. The estimates of β represent the marginal effects of the explanatory variables on the WTP.

To improve the efficiency of the estimation, follow up dichotomous questions were asked after the initial dichotomous question. An individual was expected to accept the offered bid if their WTP was higher than the proposed bid and reject it if their WTP was less than the proposed bid. The second bid or follow up bid was conditional on the responses of the initial bid.

For simplicity, m^1 denotes the initial bid vehicle; m^{2l} represented the second bid if the individual answers "no" to the first question; and m^{2h} to represented the second bid if the individual's response was negative to the first question. y^1 and y^2 are the dichotomous variables which captured the responses of the first and second questions respectively. Under the assumptions of equation (1), each individual would be in one of the four categories described below (Lopez-Feldman, 2012).

For an individual whose response is 'yes' to the first and 'yes' to the second bid, m^{2h}≤WTP<∞. The probability of this case (yes, yes) is given by:

$$pr(y_i^1 = 1, y_1^2 = 1|x_i) = pr(1,1) = \phi\left(x_i' \frac{\beta}{\sigma} - \frac{m^{2h}}{\sigma}\right) \qquad (2)$$

For an individual with the answers 'yes' to the first and 'no' to the second bid, $m^{2h} > m^1$, i.e., $m^1 < WTP \leq m^{2h}$. The probability of this case (yes, no) is given by:

$$pr(y_i^1 = 1, y_1^2 = 0|x_1) = pr(1,0) = \phi\left(x_i' \frac{\beta}{\sigma} - \frac{m^1}{\sigma}\right) - \phi\left(x_1' \frac{\beta}{\sigma} - \frac{m^{2h}}{\sigma}\right) \qquad (3)$$

For an individual with the answers 'no' to the first and 'yes' to the second bid, $m^{2l} < m^1$, i.e. $m^{2l} \leq WTP < m^1$. The probability of this case (no, yes) is given by:

$$pr(y_i^1 = 0, y_1^2 = 1|x_1) = pr(0,1) = \phi\left(x_i' \frac{\beta}{\sigma} - \frac{m^{21}}{\sigma}\right) - \phi\left(x_1' \frac{\beta}{\sigma} - \frac{m^1}{\sigma}\right) \qquad (4)$$

For an individual with the answers 'no' to the first and 'no' to the second bid, $0 < WTP < m^{2l}$. The probability in this case (no, no) is given by:

$$pr(y_i^1 = 0, y_1^2 = 0|x_i) = pr(0,0) = 1 - \phi\left(x_i' \frac{\beta}{\sigma} - \frac{m^{2l}}{\sigma}\right) \quad (5)$$

Let D_i^{YY}, D_i^{YN}, D_i^{NY}, and D_i^{NN} be dummy variables that represent the relevant cases for each respondent. The values of $\beta\ and\ \sigma$ can be estimated by maximising the log-likelihood function, and the parameters estimation can be estimated by user-written command ‘doubleb’ in Stata (see Lopez-Feldman (2012).

$$Ln\ L = \sum_{i=1}^{N}\{D_i^{YN}\ ln\left[\Phi\ \left(x_i'\frac{\beta}{\sigma} - \frac{m^1}{\sigma}\right) - \Phi\left(x_1'\frac{\beta}{\sigma}\ - \frac{m^{2h}}{\sigma}\right)\right] + D_i^{YY}\ ln\left[\Phi\left(x_i'\frac{\beta}{\sigma} - \frac{m^{2h}}{\sigma}\right)\right] + D_i^{NY}\ ln\left[\Phi\ \left(x_i'\frac{\beta}{\sigma} - \frac{m^{21}}{\sigma}\right) - \Phi\left(x_1'\frac{\beta}{\sigma}\ - \frac{m^1}{\sigma}\right)\right] + D_i^{NN} ln[1 -\ \Phi\left(x_i'\frac{\beta}{\sigma} - \frac{m^{2l}}{\sigma}\right)]\} \qquad (6)$$

The ‘doubleb’ command incorporates the first bid, second bid, first response, and second response to estimate the WTP as a dependent variable in a model. Two models were estimated for each crop (wheat and rice), the first without control (explanatory) variables and the second with control variables. For the first model, the ‘doubleb’ command directly estimates β and σ in equation 1, and WTP is $\beta x_i^{'}\beta$, the constant. A model with no control variables allows the efficient use of the data to estimate WTP under the assumption that there is a single valuation function behind the responses to both bids (Maltese, Mariotti, Oppio, & Boscacci, 2017). The second model was estimated by using ‘doubleb’ command after including control variables. The mean WTP was calculated using the ‘nlcom’ command after including all the significant explanatory variables in the models, with covariates as mentioned by Haab and McConnell (2002).

To check for multicollinearity among the explanatory variables the command ‘collin’ was used to calculate the variance of inflation factor (VIF). As a rule of thumb, a variable whose VIF values are greater than 10 may need further investigation, if mean VIF value is found to be less than 10 for a model which indicated that there is no issue of multicollinearity (UCLA, 2016).

Selection of variables was based on Wald tests. For the paddy rice model, Wald test results indicated that eight control variables consist of socio-demographic and perception variables on EWEs were jointly significant at the 5% level (χ^2=25.62, df =8 and *P*-value =0.0012). The same variables were included in the wheat model. The Wald test failed to reject the null hypothesis that all variables were jointly significant (χ^2=11.71, df = 8 and *P*-value =0.16). After excluding some explanatory variables which had low explanatory power in the wheat model, the Wald test result was significant to the 10% level (χ^2=10.99, df = 6 and *P*-value =0.0887).

The selection of the initial bids will have an impact of the estimated WTP (Hanemann et al., 1991). Before estimating the WTP, separate discrete choice models were estimated for paddy rice and wheat in order to test whether the initial bid had an impact on farmers' WTP, along with others control variables. A negative significant impact of WTP indicates that as the premium payment increases, the probability of positive response to the WTP declines (Table B.18 in appendices).

5.4.8 Variables.

Based on previous studies we identified socio-demographic and attitudinal variables which are hypothesised to affect households' decisions to adopt and pay for index-based agricultural insurance. We included these variables in the models as control variables (see Table B.17 in Appendices). These factors include previous damage experience of extreme weather events, agricultural income as the primary source of household income, distance to the river, proportion of agricultural income of the total household income, age, family size, education, land ownership, farm and off-farm income, and perceptions of occurrence of EWEs in the future (Devkota et al., 2014; Abbas et al., 2015; Fahad & Jing, 2017). The higher the damage experiences from the extreme events in the past, the higher we expect the WTP for EWEs management (Devkota et al., 2014). Farmers without any off-farm income are expected to be more likely to take out crop insurance and to have a higher WTP (Arshad et al., 2016). The role of gender in taking out and paying for crop insurance is debatable. Some research showed that female household heads were less likely to pay for crop insurance because of the limited control over the economic sources (Hill et al., 2013; Guo, 2016), while others showed that women were willing to pay more for insurances than men to avoid potential flood damages (Devkota et al., 2014). Farmers' WTP for rainfall crop insurance is assumed to be positively related to farm income and to be negatively affected by off-farm income and by the age of the household head (Teshome & Bogale, 2015). Farmers with large land areas were expected to have higher WTP for insurance than those with smaller land areas (Abbas et al., 2015).

The occurrence of EWEs and experience with them positively influence farmers' interests and WTP for them (Abebe & Bogale, 2014; Greatrex et al., 2015). Floods were common in the research area, normally during the rainy season, when paddy rice was grown. The number of floods (the magnitude of floods) and the distance to the floods sources (rivers) were found to be the main influential variables for farmers' WTP for flood insurance (Botzen & van den Bergh, 2012; Devkota et al., 2014; Devkota & Maraseni, 2018). We therefore assumed that farmers would have higher a WTP for paddy rice and wheat crop insurance premiums if they live nearby rivers. Furthermore, living closer to a river makes irrigation easier throughout the year and increases crop productivity. Most of the rain-fed lands in the study area not in river catchments do not have sufficient irrigation (Devkota & Maraseni, 2018), and farmers with productive irrigated lands might be willing to pay more for crop insurance. However, Abbas, et al.(2015) found that the distance to rivers was negatively associated with the WTP for flood risk reductions because living far away from rivers reduce the severity of flood damages. Similarly, Liu, Tang, Ge, and Miranda (2018) found that the farmers of flooded villages in China were twice as likely to pay index-based insurance as compared to the farmers from non-flooded villages.

It is also assumed that risk perception towards the impacts of EWEs positively influence farmers' uptake of adaptation measures such as crop insurance (Nhemachena & Hassan, 2007; Bryan et al., 2013; Tambo & Abdoulaye, 2013).

Therefore, a composite variable representing ex-ante perceptions of farmers for three EWEs was included: floods, heat waves, and cold spells. Farmers were asked, using a four-point ordinal scale, to rate the likelihood that the EWEs would occur in the next five years (where 0 indicates 'definitely not,' 1 'probably not,' 2 'probably yes,' and 3 'definitely yes').

An ordinal scale question was presented (using four points where 0 indicates 'no damage,' 1 'minor damage,' 2 'some damage,' and 3 'extreme damage') to farmers to indicate their experiences of agricultural production damages from each of the three EWEs. The arithmetic means for each EWE was then calculated (see Zheng and Dallimer (2016).

5.5 Results

5.5.1 Sample description.

The average age of the respondents was 38.7 years (SD: 13), which was considerably higher than the national mean age of 21.6 years (NRB, 2016) because only adults were interviewed. Approximately 62% were male, and 67% had some formal education. Approximately 78% of the respondents were of Tharus ethnicity, about 10% were schedule caste, and about 7% were Bramin and Chhetri. The average household size was 7.8 persons (SD: 5.31), and farmers' average experience in the agricultural sector was 21.2 years (SD: 12.6). On average, farmers reported to have experienced almost five floods in the previous five years; and the average distance of respondents' farms and land from a river was 0.5 km (Table B.19 in Appendices).

The average monthly household expenditure was NPR 16,130 (USD 150.6) (SD: 18,000) which was less than the national monthly household expenditure of NPR 25,928 (USD 242.09) in 2016 (Nepal Rastra Bank, 2016). The annual income was well distributed with 11% of the respondents having an annual income of less than NPR 50,000 (USD 467), 23% one between NPR 50,000 and NPR 100,000 (USD 467-934), 25% one between NPR 100,000 and NPR 200,000 (USD 934-1,868), 22% one between NPR 200,000 and 300,000 (USD 1,868- 2,802) and 22% one of more than NPR 300,000 (USD 2,802). In the previous 12 months, 15% of respondents received remittances from abroad (Table B.19 in Appendices).

5.5.2 General interest for crop insurance and reasons for not participating.

Almost 84% of the total respondents (350) were interested in purchasing area-based yield crop insurance. Those who declined cited four main reasons: lack of knowledge (28%), lack of own land (28%), administrative hassle (28%), and income constraints (14%). Only 2% stated the possibility of income loss in the future as a reason because they thought they were required to pay premiums up-front, but were uncertain about timely payouts, if claimed.

Almost all (99%) of the 350 respondents stated risk sharing or risk transferring of EWE impacts as a reason for their intention to purchase crop insurance, and further stated that crop insurance is an essential question.

5.5.3 Preferred premium payment options.

Among those farmers who were generally interested in crop insurance (293), 87% said that they wished to pay premiums in cash and 13% preferred in-kind payments because of cash constraints. Approximately 56% reported that they were willing to pay the premiums right after harvest, 13% preferred to pay them during land preparation, 10% during the sowing of crops, and 8% after sowing.

5.5.4 Farmers' Willingness to Pay for area-based yield insurance.

Nearly 4% of the 293 respondents rejected both the initial and lower follow-up bids (Table 5.2) for the insurance. This means that about 96% of respondents gave a positive response to WTP for rice insurance. Likewise, almost 94% were willing to pay for wheat insurance (about 6% rejected both the initial and lowered follow up bids). Table 5.2 shows the distribution of the accepted and rejected bids for both insurances.

Table 5.2: Joint frequencies of the discrete response of WTP questions for Paddy rice and Wheat.

Response	**Paddy rice**		**Wheat**	
	Frequency	Percentage	Frequency	Percentage
Numbers of No-No Cases	10	3.4	17	5.8
Numbers of Yes-No Cases	69	23.5	59	20.2
Numbers of No-Yes Cases	31	10.7	28	9.5
Numbers of Yes-Yes Cases	183	62.4	189	64.5
Total Respondents	293	100	293	100

The mean WTP for a premium for paddy rice insurance was NPR 127.2/Kattha (USD[22] 35.13/ha) per cropping season and NPR 91.6/Kattha (USD 25.30/ha) per season for wheat insurance premiums (derived from the bid-only model; Table 5.3).

Table 5.3: Determinants of Willingness to Pay for Paddy rice and wheat crops by using interval regression.

	WTP for Paddy Rice		**WTP for Wheat**	
Variables	Coefficients (Model 1)	Coefficients (Model 2)	Coefficients (Model 3)	Coefficients (Model 4)
Constant	127.2*** (6.1)	124.6*** (39.7)	91.6*** (3.9)	82.6*** (25.4)
Distance to the flood sources(M)		-0.009 (0.007)		
Share of agricultural income to total income(Categorical)		-6.6 (5.6)		6.4* (1.8)
Agricultural income(dummy)		14.9 (24.6)		5.9 (14.7)
Floods in the last 5 years (Numbers)		-0.78** (0.4)		
Damage experience of EWEs (categorical 0-3) during previous year		1.4 (8.8)		2.06 (5.6)
Ex-ante perception of EWEs (categorical, 0-3)		3.3 (12.7)		-2.6 (8.1)
Access to extension services (Dummy)		-41.7*** (12.2)		
Household's income (Categorical)		12.8** (5.0)		2.19 (2.91)

[22] 1 USD = NPR 107.10 (source: https://www.nrb.org.np/fxmexchangerate.php, 8th June 2017)

	WTP for Paddy Rice		WTP for Wheat	
Family Size (Numerical)		-2.07* (1.09)		-1.07 (0.7)
Male (Dummy)		-17.5 (11.5)		-12.0* (7.1)
Farm size (Numerical)		6.3* (3.6)		0.5 (2.2)
Remittances received in last 12 months (Dummy)				-14.3 (9.2)
Sigma	70.15*** (5.0)	65.16*** (4.7)	44.2*** (3.31)	41.6*** (3.1)
Observations	293	293	293	293
Wald chi-squared		27.95		15.99
Probability > chi-squared		0.0033		0.068

When including control variables, and using the average values for those, the WTP for rice insurance premiums increased slightly to NPR 132.88/Kattha/season, and for wheat insurance premiums to NPR 91.78/Kattha/season (Table 5.4).

Table 5.4: Willingness to Pay for paddy rice and wheat farmers' using DBDC model (in NPR per Kattha per cropping season) (1 ha = 29.58 Kattha).

	Mean WTP	Std. Err.	Z	P>|z|	Lower bound	Upper bound
WTP for paddy rice (bids only)	127.17	6.05	21.01	< 0.001	115.31	139.03
WTP for paddy rice (with covariate)	132.88	42.07	3.16	< 0.001	50.41	215.36
WTP for wheat (bids only)	91.59	3.88	23.62	< 0.001	83.99	99.19
WTP for wheat (with covariates)	91.78	23.49	3.91	< 0.001	45.73	137.84

5.5.5 Factors affecting farmers' Willingness to Pay.

We did not find any serious multicollinearity among the explanatory variables in the model for rice (mean VIF[23] : 1. 25), nor in the model for wheat (mean VIF: 1.15). The

[23] Variance Inflation Factor

Wald test indicated the joint significance of the explanatory variables and was found to be jointly significant at the 5% level (rice model) and 10% level (wheat model), respectively. This means that both of the models had significant explanatory power. Both the intercepts and estimates of sigma were significant.

For paddy rice insurance, five of the eleven explanatory variables were found to be significant (Table 5.3). Access to extension services ($p < 0.001$), the frequency of floods in the last five years ($p < 0.05$), and household size ($p < 0.01$) all affected farmers' WTP negatively. Household income ($p < 0.05$) and farm size ($p < 0.01$) both positively affected farmers' WTP.

Two of the nine control variables significantly affected the WTP for wheat insurance premiums. Being male ($p < 0.01$) negatively and the share of agricultural income of the total household income ($p < 0.01$) positively affected farmers' WTP for wheat insurance. Perceived damage of previous EWEs, expectation of EWEs occurring in the next five years and agriculture as a major source of earning did not have a significant effect on farmers' WTP for wheat insurance.

Farming households in the higher annual income brackets of more than NPR 300,000 (USD 2802) had a WTP of NPR 153.6/Kattha/season (USD 42.42/ha/season) as compared to NPR 106.9/Kattha/season (USD 29.52/ha/season) of the households whose annual income was less than NPR 50,000 (USD 467) keeping all other explanatory variables constant (Table B.20 in Appendices). Gender had an effect on the WTP for wheat insurance premiums. Female respondents were willing to pay NPR 9.7 Kattha/season (USD 2.67/ha/season) more for wheat insurance premiums (USD 26.7/ha/season as compared to USD 24.02/ha/season).

5.5.6 Other risk management strategies.

While this study focused on insurance, we also asked farmers about other risk management strategies that they are currently applying. Key informants stated that farmers have been applying various other farm and non-farm risk reduction measures to reduce the impact of EWEs on agricultural production and these measures differ across the types of EWEs as shown in Table 5.5.

The most important off-farm reduction strategies in the case of floods included participating in awareness-raising campaigns (65%) and adopting early warning systems to stay alert of flood damage in the areas (66%). On-farm risk reduction strategies consisted of raising dykes in case of floods (62%), and during heat waves and droughts, improving irrigation facilities (96%), changing varieties (37%) and planting dates (32%), and using pesticides (48%). Applying pesticides was the most frequently mentioned risk management strategies for cold spells (93%), followed by improving irrigation (61%) and changing crop varieties (47%).

Table 5.5: Implemented risk management strategies for coping with the impacts of EWEs in the study areas (% of respondents).

Adaptation measures (Implemented)	**Types of EWEs**		
	Floods	Heat waves	Cold spells
Raising dykes#	34.5		
Shifts from crops to livestock#	4.5		
By changing crop varieties*	10	36.5	47.4
Proper drainage#	37.7		
Raising dams#	62		
Awareness raising*	64.5	37	37.5
Early warning system*	66	32.6	31.7

Changing planting dates*	22.5	31.5	36.5
Using pesticides$		47.7	93.4
By changing crops$		24.5	30.8
Improving irrigation$		96	60.8
Others*	4.3	4.8	3.7

*Notes: # Adopted for floods; * Adapted for floods, heat waves, and cold spells; $ Adapted for heat waves and cold spells*

5.6 Discussion

5.6.1 WTP for rice and wheat insurance.

Farmers were willing to pay about NPR 1381 (USD 12.9) more to insure their rice crops compared to their wheat crops (USD 42.42 vs. 29.52/ha/season). We did not find this surprising because paddy rice is the most predominant crop of Nepal.

The estimated mean WTP for paddy rice insurance was about 5.3% (NPR 4,543) of farmers' estimated gross paddy rice revenue (NPR 85,400/ha/season) and the mean WTP for wheat insurance about 4.3% (NPR 3,161) of estimated gross wheat revenue (NPR 73,640/ha/season) even after assuming a 75% premium subsidy. If farmers had taken out the subsidized insurance provided by the Government, they would receive an average payout of USD 169/ha/season in case of rice yield loss and USD 118/ha/season in case of wheat yield loss based on the mean WTP. The average payout would be much more than their actual premium rate of 5% of the total expected revenue yields (rice USD 39.90/ha/season and wheat USD 34.37/ha/season). Although farmers WTP is much higher than the actual premium rate, the uptake of the current scheme is so low as it was found in previous studies (Jensen and Barrett 2017; Jensen et al., 2017).

5.6.2 Factors affecting the uptake of crop insurance.

Many more factors affected the WTP for premiums for rice insurance than for wheat insurance (Table 5.3). Those farmers who had access to extension services had a lower WTP for paddy rice insurance than those without this access. Intuitively, this was surprising, since we expected that information about the benefits of agricultural insurances could have been obtained from those services. It is possible that farmers who had access to extension services were more likely to have information on the different risk management strategies and could, therefore, choose from a greater variety of different risk diversification and reduction options (Barrett, Reardon, & Webb, 2001; Bryan, Deressa, Gbetibouo, & Ringler, 2009). In that case, we would have expected a negative relationship, as found in Arshad et al. (2016).

We found a positive relationship between income and WTP for rice insurance, but not for wheat insurance. This result corroborates the previous finding of Danso-Abbeam, Addai, and Ehiakpor (2014). Relatively wealthy households are less cash-constrained and can pay higher premiums for agricultural insurance (Tadesse, Alfnes, Erenstein, & Holden, 2017). Similarly, farmers with large plots of land are willing to pay higher premiums to insure their rice crops from potential future hazards. This indicates that there is a clear relation between commercialisation and insurance. Farmers with larger land size are more likely to be affected by EWEs than farmers with smaller plots; hence the positive relationship between WTP and farm size for rice insurance was expected. As stated, one reason that income and farm size did not affect the WTP for wheat insurance could be the lower relevance of wheat in the production systems and the reluctance of farmers' to pay premiums for something less essential to their livelihoods.

Farmers who have off-farm income from remittances are willing to pay lower premiums for wheat insurance than those who do not receive remittances from abroad. This study found that remittances did not have any impact on farmers' WTP for wheat premiums which contradicts findings of Bogale (2015) and Abbas et al. (2015).

Our finding that farmers who have experienced floods in the last five years had lower WTP for rice insurance contrasts with the findings of Fahad et al. (2018) conducted in Pakistan, which found a positive relationship between flood experience and farmers' WTP for crop insurance. Initially, we expected a positive relationship since experience usually strengthen the awareness of potential damage (Arshad et al., 2016). The negative relationship might be because of the poor economic conditions of the farmers in the study areas who have experienced more floods, and therefore are unable to pay higher premiums. Another reason might be that farmers were not able to connect the occurrences of past floods to the insurance mechanism and the expected payouts. The past damages experience with previous EWEs has no impact on farmers' WTP which could be because wheat and rice crops are less affected by these EWEs in 2016. Farmers' expectations of future EWEs also do not have a significant impact on farmers' WTP for the insurance for both crops.

Based on the wheat model, we found that male households' head found to have a negative significant impact on farmers' WTP for crop insurance. It indicates that the probability of WTP for wheat insurance for a male is lower than that of the female household's head. This study had been conducted in the Tharu community in which women are more empowered and highly aware of agricultural insurance and climate hazards. Our results are also consistent with the finding of (Devkota et al., 2014) which suggest that women are more concerned about future impacts of extreme events than men, thus they have a higher WTP for crop insurances than men. This and the fact that extension services specifically target women could be the reason for this gender effect. Family size is negatively associated with WTP paddy rice insurance, suggesting that in larger households there might be less disposable income to pay for insurance premiums, as confirmed by Danso-Abbeam et al. (2014). However, the findings of this study contradicted the earlier findings of Arshad et al. (2016), which found that family size positively related to the demand for crop insurance. We also found that the higher the proportion of agricultural income of the total household income, the higher the WTP for wheat insurance, as confirmed by Devkota et al. (2014) and Arshad et al. (2016) because income from crop agriculture is usually the main source of household income and therefor needs to be protected against EWEs.

5.6.3 Reasons for not purchasing crop insurance.

The major impediments for farmers in purchasing crop insurance were a lack of product understanding, a lack of trust to the insurance providers and cash-constraints, as confirmed elsewhere (Binswanger-Mkhize, 2012; Cole et al., 2013; Carter et al., 2014). Despite being fully aware of the insurance schemes, some farmers were not interested because of the arduous and cumbersome administration associated with it, as well as the excessively complicated documentation and paperwork needed for claims (Jin, Wang, & Wang, 2016). The expectation of payout delay after a claim is made is another reason that farmers do not want crop insurance. This mismatch between farmers’ expectations and actual payouts have been highlight previously as the main reason for the low uptake (Ghimire et al., 2016; Johnson, Wandera, Jensen, & Banerjee, 2018).

Many respondents felt that their small land sizes (28%), fragmented land (28%), and lack of land ownership (renting; 28%) also provided little incentive to purchase crop insurance, consistent with previous findings (Abbas et al., 2015). They further reiterated that they grow multiple mixed crops in the same land in one season, such as pulse types with paddy rice, which could be another issues, when buying single crop contracts. Income constraint is considered to be the fourth main reasons of not being willing to take part in the insurance market because farmers from the study areas were found to be poor, and thus could not afford to buy crop insurance.

Another main reason is the competing risk-mitigation strategies (also see (Binswanger-Mkhize, 2012). Crop insurance is only one of many risk management strategies and one that distributes the risk rather than reduces it, so farmers might be aware of this and prefer other risk reduction strategies.

5.6.4 Impacts of premium subsidy on the government's budget.

Providing the generous subsidy of 75% will have negative implications on the annual budget of Nepal and is unlikely to be sustained in the long run. In the 2017/2018 fiscal year, the government allocated around NPR 350 million (USD 3.2 million) to pay the premium subsidy for both livestock and crop insurance and this share is expected to increase in the next few years if subsidised insurance policies are in place and more farmers are aware of the scheme. In the 2015/2016 fiscal year, 1362,908 ha was used for rice and 745, 823 ha (MoAD, 2016) for wheat production. Based on the average WTP for rice, the government allocation of USD 3.2 million in the 2017/2018 fiscal year will be sufficient enough to insure 25,145 ha of rice if the allocated budget is used to insure rice only under the current subsidy scheme. If all rice growers were to purchase the insurance, the Government would need to allocate NPR 18.5 billion (USD 173.4) solely to rice premium subsidies. If all wheat growers were to take up the insurance, the Government would need to spend NPR 7.07 billion (USD 66.05 million) to wheat premium subsidies only.

5.7 Conclusion, Policy Implication, and Recommendations

The primary objective of this study was to assess farmers' interest in, and WTP for, area-yield based crop insurance in the Terai lowlands of Nepal. Crop insurance can share the risks of financial damages from yield losses after extreme weather events, but its rate of adoption remains very low in developing countries. This study was undertaken under the premises that the Nepalese Government heavily subsidised farmers 'participation in crop insurance schemes, but that the uptake has remained very low. Results of a contingent valuation revealed that respondents who did not intend to join the crop insurance scheme did so because of a lack of knowledge, the complex administrative procedures, and cash-constraint. Moreover, those farmers who wanted to join would prefer to pay insurance premium after harvesting their crops. About 87% respondents preferred to pay their premium in cash, while the other 13% wanted to pay their premium in-kind, due to limited cash availability. Farmers' mean WTP for premiums was about NPR 4543/ha/season (USD 42.42) for paddy rice, and NPR 3162 ha/season (USD 29.52) for wheat, assuming that the government continues to pay 75% of the premium.

The majority of farmers (84%) were interested in purchasing crop insurance, and were willing to pay much more of the premiums than they currently did under the subsidised scheme. It was estimated that their WTP for rice insurance premiums was still about 5.3% of the gross rice revenue per season, and the WTP for wheat insurance is about 4.3% of the wheat revenue per season (assuming that farmers only paid 25% of the premiums). Income was a strong determinant of farmers' WTP, suggesting that the most impoverished farmers had the most substantial Impediments to join. It is, therefore, unlikely that the price of the premiums, even if the subsidy were to be reduced, is the only impediment for farmers participating in the scheme.

Of respondents, twenty-eight percent of respondents were not familiar with the crop insurance mechanism, suggesting that there is a definite need for training (such as orientation programs) of farmers and village leaders, which might then lead to higher insurance uptake (Dercon, Hill, Clarke, Outes-Leon, & Taffesse, 2014). The raising of awareness and reducing the ignorance of future damages from climate variability might also increase the uptake (Treby, Clark, & Priest, 2006; Greatrex et al., 2015). At the same time, the tedious administrative processes should be simplified to bring a maximum number of farmers into the insurance scheme.

Given that the Nepalese Government is unlikely to sustain the generous subsidies if the uptake of crop insurance increases substantially, it is essential that farmers attuned to the possibility of purchasing the insurance without the subsidies-to pay 100% of the premiums themselves once the insurance scheme has been widely established. To minimize the risk for the government for uncontrolled costs when many more farmers join the scheme, it is suggested that the government could 1) start reducing the premium subsidy to 50%, 2) make the subsidy means tested (income and land size), and 3) encourage the larger farms to become more commercialised. The 75% premium subsidy could still be paid for the poorest farmers. Further, losses from the impact of EWEs vary across regions, and this factor also warrants more flexible subsidies, away from the current uniform premium structure, which might not be suitable in the context of Nepal.

The mismatch between farmers' expectation can be minimised by closely working together with the insurance providers. Trust of insurance companies needs to be strengthened by removing supply-side constraints, such as offering reliable weather data and crop risks model to assess catastrophic risks exposures. The government should also play an important role in providing farmers with awareness and insurance education to support the marketing and promotion of the private insurance providers (Mahul & Stutley, 2010).

Finally, insurance providers might face liquidity problems and solvency in the long run due to climate change-related increases in EWEs and spikes in payouts. Key-informants pointed out that a lack of technical workforce and the issue of moral hazards are future impediments to providing affordable insurance. The government should create an environment of reinsurance and further assistance in the future by offering financial incentives to providers to ensure the viability of their businesses, but without over-benefiting them. The government has to bear in mind that there are other risk management and reduction strategies that farmers adopt and for which they might need support. The insurance premium subsidy provision puts a high financial burden on the government, which will ultimately fall on the general taxpayers. Focusing too much on risk sharing and the provision of agricultural insurance might hamper risk mitigation and adaptation in the long run (Skees, Barnett, & Collier, 2008).

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Chapter 6 Conclusion

6.1 Concluding remarks

In this final chapter, I synthesize the findings of Chapters 2 to 5, provide policy implications, and discuss study limitations and further research needs.

Climate change affects millions of people, and its impacts are felt mostly by people in low-income countries. The agricultural sector is both the most sensitive to climate change and is a major contributor to the livelihoods of people in low-income countries. Avoiding present and future climate change impacts is no longer possible, however, mitigation could limit the extent of future climate change (Pachauri, et al., 2014; Pittock, 2017), and adaptation is needed to protect societies (Adger et al., 2009; Noble et al., 2014; Mimura et al., 2014). Without adequate adaptation, farmers will be more likely to suffer from production, income loss, and health problems. This thesis contributes to a growing body of literature on the economics of climate change through a case study from Nepal, by assessing the social and economic impacts to farmers by three climate change-related extreme weather events (floods, heatwaves, and cold spells) and how they adapt, now and into the future.

To capture the socio-economic impact of EWEs at the farming household level in Nepal, this thesis specifically focuses on comparing risk perception of multiple extreme events; the factors determining risk perception and preparedness strategies of three significant extreme weather events; assessing of impacts of extreme temperature on farmers' health and their labour productivity; and, lastly, estimating and discussing crop insurance potential as a risk management strategy.

6.1.1 Socio-economic impact of and adaptation to extreme heat and cold of farmers.

In Chapter 2 *("Socio-economic impact of and adaptation to extreme heat and cold of farmers in the food bowl of Nepal*"), I explored the social and economic impacts of two of the three extreme weather events, the two slow onset weather-related events (heatwaves and cold spells). I investigated how farmers were affected by and coped with these two events between 2012 and 2017. This study is important because as summer grows hotter, winter grows colder in the lowland Terai region of Nepal, confirming the global trend of increases in extreme temperatures. Increasing extreme temperatures (slow-onset hazards) has deadly impact on farmers' livelihoods, particularly in family health and their extended working capacity.

This study is novel, as it looks at both the social (health) and economic (labour productivity) impacts of extreme heat and cold in the farming community of Nepal, whereas most studies are limited to extreme heat and labour productivity loss in the manufacturing and industrial sectors.

Most farmers reported that they and their family members had experienced various heat wave related illnesses, such as fatigue (73%), dizziness (63%), headaches (41%), nausea (28%), confusion (24%), heat rashes (12%), fainting (8%), loss of concentration (8%), and heat strokes (2%). The most common cold spell related health issues were joint pain (74%), pneumonia and respiratory problems (74%), and cold cough and indignation (22%). Most farmers thought that their labour productivity had been reduced during heat waves (85%) and during cold spells (64%) in the last five years

(2012-2017). This result confirms global analyses of labour productivity loss from increasing heat, which will be further exacerbated by climate change. For instance, approximately 85% of respondents reported that more than half of their working hours in agriculture were less productive during heat waves.

I also found that farmers perceived their productivity loss to be increasing during cold spells, with nearly 65% of the respondents stating that more than half of their working hours in agriculture were less productive during cold spells. These results show that farmers should be communicated with to adopt various extreme heat and cold prevention measures to enhance their health and work performance.

I then investigated the impact of various (social, psychological, physical, and environmental) factors that might influence farmers' level of heat and cold stress over the same period of 2012-2017. Results of an ordered logit model showed that those farmers' who had already implemented heat wave and cold spell coping strategies were less affected by these slow-onset hazards. Farmers who owned livestock and had perceived an increasing number of heatwaves and cold spells were more likely to be heat- and cold-stressed. Older farmers and those working more days in agriculture during the summer were more likely to suffer heat stress than younger farmers and those with fewer numbers of working days during summer.

The perceived level of health satisfaction had a positive impact on heat stress, while access to weather information had a negative impact. Farmers who stated more heat and cold-related illness had implemented more heat wave and cold spell adaptation strategies in the past, and those who had more involvement in outdoor agricultural activities were more likely to perceive labour productivity loss from heat waves and cold spells.

Apart from investigating the impacts, I also investigated how farmers coped with these slow-onset extreme events. I found that farmers used a series of strategies to work under extreme temperatures; most of them cheap and easy to adopt.

To cope with extreme heat, farmers wore broad-brimmed hats or used umbrellas, rested more often in the shade, slowed down their working pace, worked at different times of the day (rescheduling to early mornings and late afternoons), and sometimes stopped working. Some farmers (54%) also applied various cooling techniques, such as drinking cold water and wearing wet clothes.

To cope with extreme cold when working, farmers wore warm clothes, rested to warm up (usually near lit fires), drank hot beverages, rescheduled working times, and stopped work, if needed.

The implementation of risk communication and risk awareness through various networks, providing information about the possible consequences of these slow-onset hazards, and the potential coping strategies, could be conducive to mitigate potential health impacts and labour productivity losses from these hazards.

6.1.2 Assessing farmers' preparedness to cope with the impacts of multiple climate change-related hazards in the Terai lowlands of Nepal.

Chapter 3 ("*Assessing farmers' preparedness to cope with the impacts of multiple climate change-related hazards in the Terai lowlands of Nepal*") focused on the main agricultural risks faced by farmers' in the Terai lowlands of Nepal. I also examined farmers' existing and intended coping mechanisms in response to three EWEs (floods, heatwaves, and cold spells) and investigated the main factors that influenced farmers' risk perception and preparedness intentions to adapt to these three hazards. The reason I investigated farmers' risk perceptions first was that this is a good indicator of farmers' adaptive capacity. Previous research has shown that those farmers who perceived risks were better prepared to cope and to adapt than those farmers who did not. The results of the household survey showed that farmers perceived climate change related environmental risk as the most severe agricultural risk, followed by biological and market-related risks. Even in climate change related environmental risk, farmers in the study areas were highly affected by three main EWEs related to climate change.

I also found that farmers coped with each of the three hazards differently, depending on whether the hazard was slow- or sudden-onset. To cope with the impact of flooding (sudden-onset), farmers mainly adapted by seeking off-farm employment, followed by an increasing use of fertilisers and pesticides, changing crop types and varieties, and adjusting their water management. Farmers' strategies to reduce the impacts of heatwaves (slow-onset), were primarily to manage water use, followed by an increase in pesticide and fertiliser use, changes in crop types and varieties, and changes to planting and harvesting times.

Increases in pesticides and fertiliser use and changes to crop varieties were the main adaptation strategies for reducing the impacts of cold spells, another slow-onset hazard. This finding is important because many climate change and natural disaster policies, so far, deal with general climate change impacts and adaptation, but according to farmers', each hazard is perceived differently, depending on the severity, and needs to have different coping strategies. This chapter follows on from the previous one, confirming that while farmers were affected differently by the three hazards, they also responded differently to each one.

Those farmers who had past damage experience of EWEs perceived the high response cost of the potential preparedness strategies, were highly anxious and concerned about future EWEs, perceived an increasing number of intended adaptation measures, and were likely to perceive the additional risk of future extreme events. However, lack of trust in government preparedness strategies negatively influenced farmers risk perception of EWEs.

The findings further specified that past damage experience of EWEs partially influenced farmers' risk perception of EWEs due to concern and anxiety about possible future events, among other reasons. A mediation analysis shows that risk perception of floods, directly and indirectly, explains the association between education and preparedness strategies, response cost and flood preparedness, concern and anxiety about flooding and flood preparedness intention, trust of government adaptation strategies, and flood preparedness intention. Farmers with prior flood damage experience were likely to take more flood preparedness measures in the future. However, there are no causation effects in the case of slow-onset hazards (heatwaves and cold spells). This implies that other mediator variables need to be discovered in the case of slow-onset hazards if direct-but no mediation effect was encountered (Zhao, Lynch Jr, & Chen, 2010), which could have a significant causal impact on preparation for slow-onset hazards.

In general, farmers are more concerned about the sudden-onset hazards than slow-onset hazards because sudden-onset hazards are commonly rapid and destructive and cause a lot of psychological fears and stress to the community. Thus, farmers were more likely to perceive the risk of floods than the slow-onset hazards, and thus were more likely to take various flood preparedness strategies.

6.1.3 Farmers’ motivations to adapt to extreme weather events.

Chapter 4 (“*Heat, cold, and floods: exploring farmers’ motivations to adapt to extreme weather events in the Terai region of Nepal*”) investigated potential differences in adaptation strategies between farmers.

In this chapter, I used the protection motivation theory to analyse farmers’ most important adaptation strategies in more detail. The most important intended adaptation strategies included changing farm management practices, seeking off-farm employment, emergency management planning, purchasing crop insurance, and the raising of awareness. The findings of this study will be useful in assessing their individual intentions to adapt and could help in the understanding of future potential responses against EWEs, while guiding and supporting the government in making suitably prepared strategies in advance of the EWEs.

The findings clearly state that perception of the threats of slow-onset hazards had increased impact on farmers’ intentions to adopt various preparedness measures. Farmers who perceived the impact of EWEs had a higher coping capacity and were more likely to undertake measures against various sudden onset hazards (floods) and slow-onset hazards (heatwaves). Similarly, farmers who had previously implemented a great number of adaptation strategies were more likely to take additional adaptation strategies, across all three EWEs. The choice of preferred adaptation strategies was found to differ substantially across the three EWEs. Crop insurance and off-farm employment were the most preferred intended adaptation strategies for sudden-onset hazards (floods) while crop insurance was the most preferred intended adaptation strategies for slow-onset hazards.

6.1.4 Farmers’ Interest for Index-Based Crop Insurances in the Lowlands of Nepal.

Chapter 5 (“*Farmers’ interest for index-based crop insurances in the lowlands of Nepal*”) investigated a particular adaptation strategy, insurance, which aims to reduce the risk of losses from EWEs and other disasters. While it is common for farmers to have insurance in developed countries, it is still not the policy in every developing country, though many more farmers are affected by natural hazards.

I focused on index-based insurance because it is one of the disaster risk management strategies that can help to share or transfer the risk faced by insured farmers’ shielding against the potential losses of climate-related EWEs. The Nepalese Government has already implemented index-based crop insurance and has also supported farmers by offering a 75% premium subsidy in the crop insurance.

Despite this 75% subsidy, the uptake of crop insurance is very low. This research may be helpful in aiding the government in identifying causes and in recommending solutions for increasing farmers’ participation in crop insurance. The primary objective of this study was to assess farmers’ willingness-to-pay (WTP) for area-yield based crop insurance and to determine the WTP in the Terai lowlands of Nepal. The study applied double bounded contingent methods to estimate the farmers WTP for insurance for the two main cereal crops –rice and wheat.

The study revealed that respondents who did not intend to join the crop insurance market did so because of a lack of knowledge, poor understanding of the complex administrative procedures, and financial constraints. Moreover, those farmers who wanted to join preferred to pay insurance premiums after harvesting their crops, and 87% respondents preferred to pay their premium in cash, while the other 13% wanted to pay their premium in-kind due to limited cash availability at the household level. Based on the households' survey, farmers' mean willingness to pay for a premium for paddy rice area-based index insurance was about NPR 4,543/ha/season (USD 42.42), and NPR 3,162 ha/season (USD 29.52), assuming a 75% premium subsidy (Budhathoki, Lassa, Pun, & Zander, 2019).

6.2 Overall conclusion – linking Paper 1, 2 3 and 4.

Several conclusions can be drawn from the thesis. Firstly, farmers were found to be exposed to different types of agricultural risks at the household level. These agricultural risks consist of climate-related environmental risks, financial and market-related risks, biological risks, and policy and institutional risks. Among these risks, climate-related environmental risks were perceived to be the most severe agricultural risk, followed by biological and market-related risks. Floods, heatwaves, and cold spells were the three most severe climate-related risks in the study areas and were labelled extreme weather events in this study. Due to these extreme events particularly heatwaves and cold spells, farmers' socio-economic condition such as their labour productivity have been highly compromised and thier health wellbeing also declined consequently.

The study further reports that past damage experience, concern and worry about future extreme events, farmers' perceived responsibility and perceived self-efficacy beliefs of the three extreme events were found to have significant impacts on farmers' risk perceptions of the three extreme events.

In the western lowland Terai region, farmers' have implemented various coping strategies, which were found to vary based on the specific characteristics and nature of extreme weather events. For sudden–onset hazards (floods), farmers largely relied on seeking off-farm employment, fertiliser and pesticides use, and changing crop type and varieties. For slow-onset hazards (heatwaves), farmers largely focused on water management and changing cropping type and varieties. Pesticides, fertiliser use and changing crop varieties were the main existing adaptation strategies to reduce the impacts of cold spells. Likewise, the study further demonstrates that crop insurance and off-farm employment are the most preferred intended flood adaptation strategies and that crop insurance is the highly preferred intended heatwave and cold spell mitigation strategy in the Terai region.

Though agriculture insurance is a highly preferred intended adaptation measure, with a generous premium subsidy, the uptake of agriculture insurance is very low in Nepal. The low uptake of agricultural insurance is unlikely to be related to the premium amount; rather, it is due to farmers' ignorance of potential future damages of extreme events and to a tedious administrative process.

Farmers' intention to adapt to slow-onset hazards is influenced by various components of threat appraisal, such as the perceived probability of personal damage; the perceived probability of infrastructure damage; and anxiety of respective extreme events, such as heatwaves and cold spells. The various components of coping appraisals, including perceived response efficacy, perceived response cost, perceived self-efficacy belief, and perceived responsibility of respective extreme events significantly determined farmers' intentions to adapt against sudden onset hazards (floods). Other explanatory variables, such as previously implemented respective extreme events adaptation strategies and reliance on public protection mechanisms, were also significant determinants of farmers' intensity of intended adaptation and choice of intended adaptation.

Moreover, the structural model reported that variables including level of education, damage experience of floods, potential response cost of flood, concern/anxiety about future flooding, and mistrust of government adaptation strategies were indirectly linked to the farmers' intention to adopt flood adaptation measures through risk perception of sudden-onset hazards, but had no casual impacts in the case of slow-onset hazards. Lastly, the thesis found that farmers have reported various heat-related and cold-related illnesses over the last five years, which caused a significant reduction in labour productivity.

6.3 Policy implications

The overall aim of this thesis was to investigate the socio-economic impacts of extreme weather events on farming households in the Terai lowlands in Nepal. The significance of the study is to increase the understanding of the factors influencing farmers' risk perception and preparedness decisions to cope with sudden-onset hazards, such as floods, and slow-onset hazards, such as heatwaves and cold spells, in the western lowland of Terai region.

Farmers who perceive the potential threats of slow-onset hazards are likely to take various slow-onset coping strategies in the future; likewise, farmers who have a higher coping capacity, have a higher possibility of undertaking various flood (sudden-onset hazards) adaptation measures. The difference in factors that influence farmers' adaptation intention across three EWEs (slow-onset verses sudden-onset hazards) suggests that local authorities should pay attention to the characteristics of each hazard and their corresponding factors in order to design suitable future adaptation strategies. This information can be used to tailor community-centred communication about potential threats from different extreme weather events and government technical and financial support, which will be crucial for farmers' to adapt effectively to weather extremes.

The results of this thesis demonstrate that the impacts of EWEs are very apparent and already affect the livelihood of the farming community in the Terai region. Farmers' have clearly perceived the risk and adverse impact of EWEs on their health, agriculture. and economic activities. As climate changes, these effects will worsen, calling for effective policies to help these farmers maintain their livelihood. Despite noticeably witnessing the risks and adverse impacts of these EWEs, poor farming communities could not afford to take adaptation and mitigation measures due to low adaptive capacity. These phenomenon further trigger food insecurity and poverty in the community. To address this issue, urgent action is required both from the government and at the community level to increase community resilience. The government could extend more financial support to construct critical infrastructure, for instance, establishing an early warning system to alert to potential disasters, building dams and dykes to control floods, or proper irrigation facilities for use during heatwaves and drought.

The findings of *this* thesis emphasise the diverse climate change impacts and the need for hazard-specific adaptation. Policies can only be effective and tailored to specific farming communities if the impacts and adaptation needed to cope with particular events, such as floods, heatwaves, and cold spells, are well understood. In 2017, the Nepalese government endorsed the Disaster Risk Reduction and Management Act, replacing the 1982 Natural Calamity Act. The new act focused on disaster risk management by addressing the four disaster management cycles, preparedness, response, rehabilitation, and recovery. It also established a functional institutional setup from the central to the local levels for effective disaster management. However, while the revised act set out the responsibilities of the provincial governments, it failed to declare a disaster-prone zone using disaster mapping (Nepal, Khanal, & Sharma, 2018). Most of the existing policies also emphasised rapid-onset hazards (including floods, earthquakes, landslides, and avalanches), rather than slow-onset hazards (such as cold spell and heatwaves). It also assigned fewer responsibilities on the local governments, despite the Local Government Operation Act of 2017. At the same time, these existing disaster management policies provide more importance to recovery and response than to the the preparedness and mitigation process. Risk communication, public education programs, and extension services could be effective in promoting awareness and expertise in low cost coping and preparedness strategies to mitigate the loss from disaster (Budhathoki, Paton, Lassa, & Zander, 2020).

Effective risk governance could be the one strategy that engages all the concerned stakeholders in the process of exchanging and integrating information and knowledge sharing, such as to be well prepared against potential losses from anticipated future extreme events (Lavell et al., 2012). Along with this, there should be a clear message about who is responsible for the risk of extreme events, and the responsibility of each stakeholder for preparedness of disaster risk in the community should be clearly underlined. The integration of local knowledge and experiences with scientific and technical knowledge could improve disaster preparedness. Understanding local knowledge and experiences regarding EWEs related with climate change will help to reveal existing coping capacities of farming community communities and their current limitations (Smit & Wandel, 2006; Adger et al., 2009).

To help mitigate the effects of EWEs, public awareness campaigns could be introduced specifically targeting the susceptible parts of the population with information on the appropriate actions to take during extreme temperatures. Extreme temperature warnings, as are found in other countries, such as Sweden and China (Toloo, FitzGerald, Aitken, Verrall, & Tong, 2013; Åström, Ebi, Langner, & Forsberg, 2015; Chen et al., 2019), based on weather forecasts, should also be publicly broadcast, as well as heat and cold stress prevention measures. The implementation of risk communication and risk awareness through local and social media, providing information about the possible consequences of heatwaves and cold spells, and the potential coping mechanisms, could be primary strategies by which to mitigate potential health impacts and labour productivity losses (Budhathoki & Zander, 2019).

Community-centred risk communication campaigns focusing on coping and threat appraisal aspects over top-down communication would be more effective to implement because local community targeted communication are more likely to address the needs of the local people (IPCC, 2012). Communicating both about the risk of EWEs along with their potential adaptation or coping strategies would be more effective than communicating about risks of these extreme phenomena, as mentioned in Haer, Botzen, & Aerts (2016). Additionally, Paton (2013) stated that risk communication and community outreach programs could be an effective way of dealing with multiple hazards that a community has faces. Paton (2013) further elaborated that effective preparedness to act depend upon two things: firstly, how community members interact regarding the hazards and identify resources and information in order to cope with the consequences of the hazard and, secondly, how risk management agencies empower community members, while community empowerment depends on their trust of the agencies (Paton, 2008) – as such, empowering farming communities through agencies (such as agricultural extension services, NGOs, or community leaders) would help to identify community needs and motivate individuals to prepare for hazards.

Farmers' in Nepal have a low adaptive capacity due to poverty and existing inequalities expressed in terms of demographical, health, wealth, institutional, and geographical characteristics (Gentle, Thwaites, Race, & Alexander, 2014). These communities, which already suffer from natural hazards, as well as their livelihoods, resources, and their capacities, are more likely to be affected and thus, are less prepared for disaster risk management. To address this issue, three tiers of government (national, provincial, and local government) should work together and form their disaster risk plan and strategies according to their accepted functions and capacities, translating these plans and strategies into actions targeting the most vulnerable groups and communities. Due to the social and economic constraints, developing countries alone could not implement such plan and strategies, so these countries should form a partnership with donor and lending organisations and should heavily invest on capacity building to ensure sustainable disaster management in future (Mirza, 2003).

Nepal has only recently accepted a federal government system after practicing many years of unitary system of government. Despite this change, clear demarcation of roles and responsibilities of disaster risk management among three tiers of government is still ambigious. Earlier, during unitary government system, central government was highly responsible for designing and implementing all sorts of disaster reduction policies particularly ministry of home affairs. To overcome such challenges, national and state governments should issue disaster management and planning policy. Along with that, national government should be rsponsible for forecasting, issuing warning about extreme events and coordinating disasters planning nationally. National government should also operate a flood defense system in the affected and hazard prone areas, because building and investing in large-scale flood defense systems is beyond the capacity of local and state governments. Likewise, the state/provincial government is still in infancy stage of forming state level disaster and climate change policy in Nepal. However, its role is crucial for policy formulation and implementation in the coming years. For large scale extreme events' damages and mitigation, communities require more resources from federal and provincial government roles. Local governments should implement extreme events management strategies, providing emergency rescue and response services at the local level. In short, central and provincial roles are important for policy formulation, resources mobilization and channelizing their resources to the local communities through local government to implement disaster preparedness plan.

Likewise, various voluntary organisations and civil society such as I/NGOs should work with local governments to prevent such extreme events or focus on preparedness to mitigate the potential losses from extreme events. Additionally, they can also provide various supports during and after disasters as found in Adger, Quinn, Lorenzoni, & Murphy (2016).

These slow-onset hazards (heatwaves and cold spell) might not be more destructive than rapid onset hazard, but as climate change continues unabated, could become more frequent. The central government should therefore work with local government across all disasters, cooperating with the affected stakeholders, including public, private, and civic organisations. The existing gaps that remain in effective implementation of disaster management in vulnerable marginal communities could be overcome through technical and financial support from the Nepalese Government or other donor organisations, and include subsidies, loans, or complementary insurance (Budhathoki, Paton, Lassa, & Zander, 2020).

The findings of this study further emphasise that agriculture insurance could be an effective risk mitigation strategy. However, there are certain challenges and barriers. One of these is an issue of mismatch between claim payments and losses incurred; the mismatch between farmers' expectations that can be minimised by working closely with the insurance providers. Trust of insurance companies needs to be strengthened by removing supply-side constraints, to allow for offering reliable weather data and crop risks models to assess catastrophic risks exposures. The government could also play an essential role in providing farmers with awareness and insurance education to support the marketing and promotion of private insurance providers.

Finally, insurance providers might face liquidity problems and solvency in the long run due to climate change-related increases in EWEs and spikes in payouts. This study further revealed that a lack of technical workforce and the issue of moral hazards are future impediments to providing affordable insurance. The government could create an environment of reinsurance and further assistance in the future by offering financial incentives to providers to ensure the viability of their businesses, but without over-benefiting them. The government has to bear in mind that there are other risk management and reduction strategies that farmers' adopt and for which they might need support. The insurance premium subsidy provision puts a high financial burden on the government, which will ultimately fall on general taxpayers. Based on this study, farmers intended to take on agricultural insurance and off-farm working activities. Risk sharing and a transfer mechanism could increase resilience to weather-related climate extreme, but focusing too much on risk-sharing and the provision of agricultural insurance might provide disincentives for risk mitigation and adaptation in the long run (Budhathoki, Lassa, Pun, & Zander, 2019)**.**

For climate-related risk, farmers are adapting and intend to adopt various disaster risk management strategies, which consist of reducing risk through mitigation, spreading risk through diversification, and transferring and sharing risk through agricultural insurance. In the case of transferring and sharing risk such as agriculture insurance, these often have the issue of moral hazards. Insured farmers might not take enough precautionary measures to protect their crops from extreme weather events because their losses will be covered. Risk-sharing mechanisms, such as agricultural insurance, should be taken as a tool that protects farmers' income during volatile production. Farmers' should be encouraged to adapt to a changing climate using mitigation.

6.4 Study Limitation and further research

This study had some limitations regarding the data collection methodology and the coverage of study areas. This study was conducted using cross-sectional data, which provides snapshots of the particular phenomenon at a specific point of time; however, farmers' perception, their behavioural responses to the extreme events and social processes are usually dynamic phenomena and change over time. Moreover, the cross-sectional data does not provide causality of relationship. Therefore, future research would benefit from a more longitudinal design in order to show cause and effect relationships, such as between a farming community's loss of labour productivity and exposure to extreme events (Budhathoki & Zander, 2019). Another limitation of the study was farmers' self-reported data derived from recalling prior hazard experiences and preparedness plans. The recalled data may have been overstated due to social desirability bias. A different study design, such as an observational study might be more appropriate for reducing self-reporting bias (Hoffmann & Muttarak, 2017).

This study applied the Multi-Stage Sampling Method to collect information from the Banke and Bardiya districts of western low-lying Terai region of Nepal. The survey was carefully administrated to obtain required information from the adequately represented local population of the specific study areas. Despite that, the study has a limited sample size and only focused on the western low-lying Terai region due to budget and time limitation. A future study should be attempted to execute a broad survey that could represent more of the 22 districts in Terai, covering central, eastern, and western regions to observe the differences in public understanding of different extreme events, risk perceptions, preparedness plan, and behavioural response across farming communities in different socio-economic and geographic regions.

The Intergovernmental Panel on Climate Change (2014) projects reported that there would be more hot days and less cold days in most areas when global mean temperature increases, while occasional winter cold spells will continue to occur. In this thesis, I only explored the impact of slow onset hazards on socio-economic condition measured in term of self-reported labour productivity loss and health of farmers. These extreme cold spell phenomena cause significant health and economic problems, such as production and productivity loss, particularly in the developing world (Budhathoki & Zander, 2019). The recent IPCC (2018) special report, announced a "*global warming of 1.5 ºC"* but lacked any information on cold spells despite the importance of the issue to countries highly affected by this climatic phenomenon in recent years. Future research should specifically focus on cold spells and their impact such that both governments and affected communities might benefit.

Future studies would also highly benefit if other drivers of change, such as social media networks and the news media, could be included since these are factors that could play a crucial role in farmers' perceived risk perception and preparedness intentions of taking various disaster management strategies (Houston et al., 2015; Haer et al., 2016). Proxy indicators of these variables could be developed and analysed to observe the direct and indirect impact on farmers' risk perception and preparedness intention of taking various behavioural changes.

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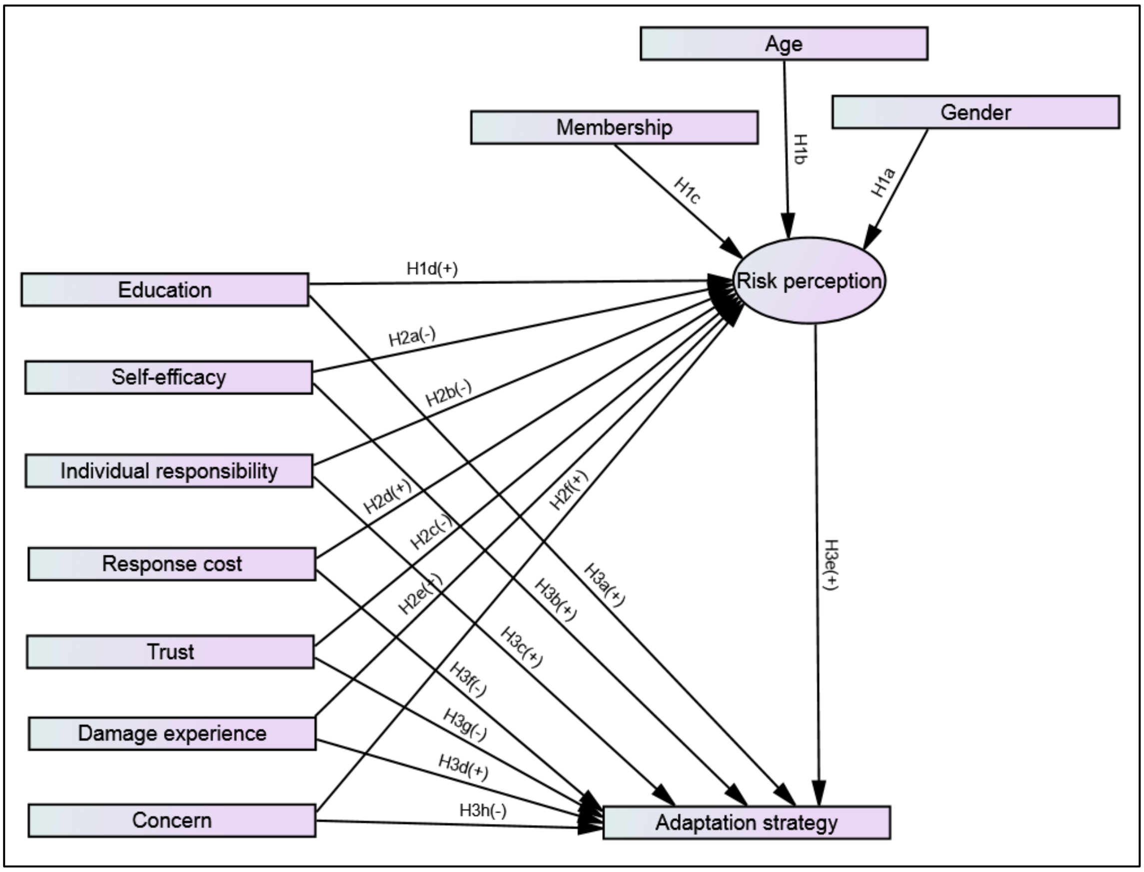
Appendices

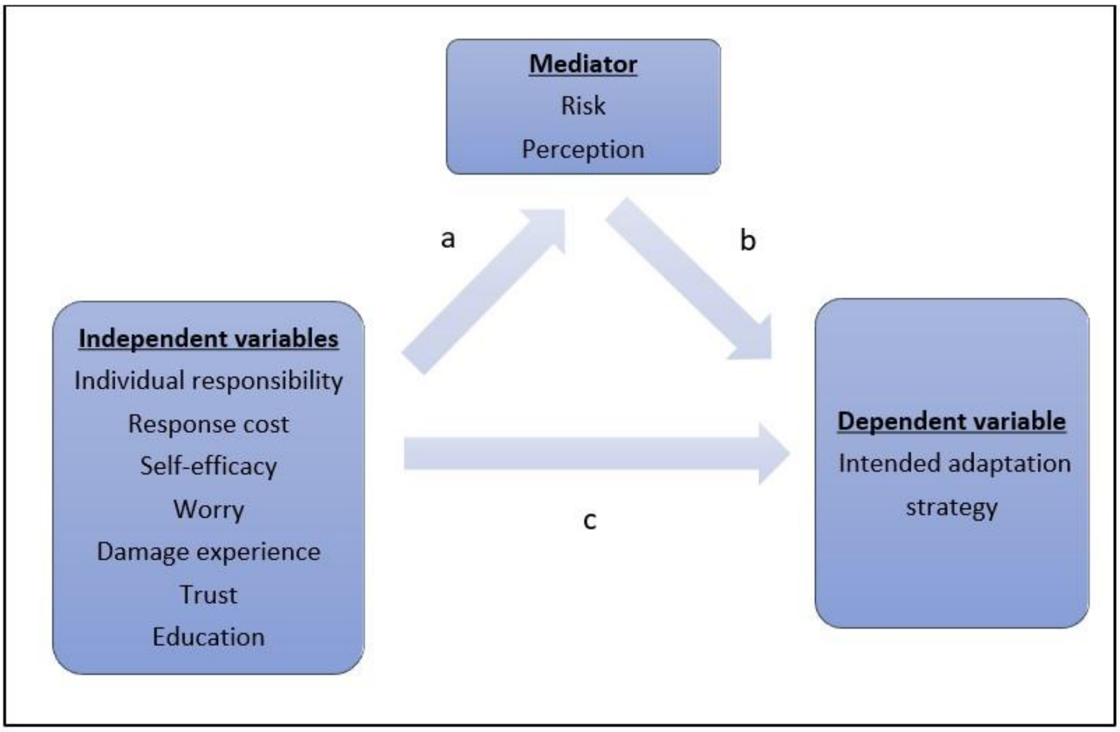
Appendix A: Figures

Appendix A.1: Hypothesized model of risk perception of and adaptation intention to natural hazards.

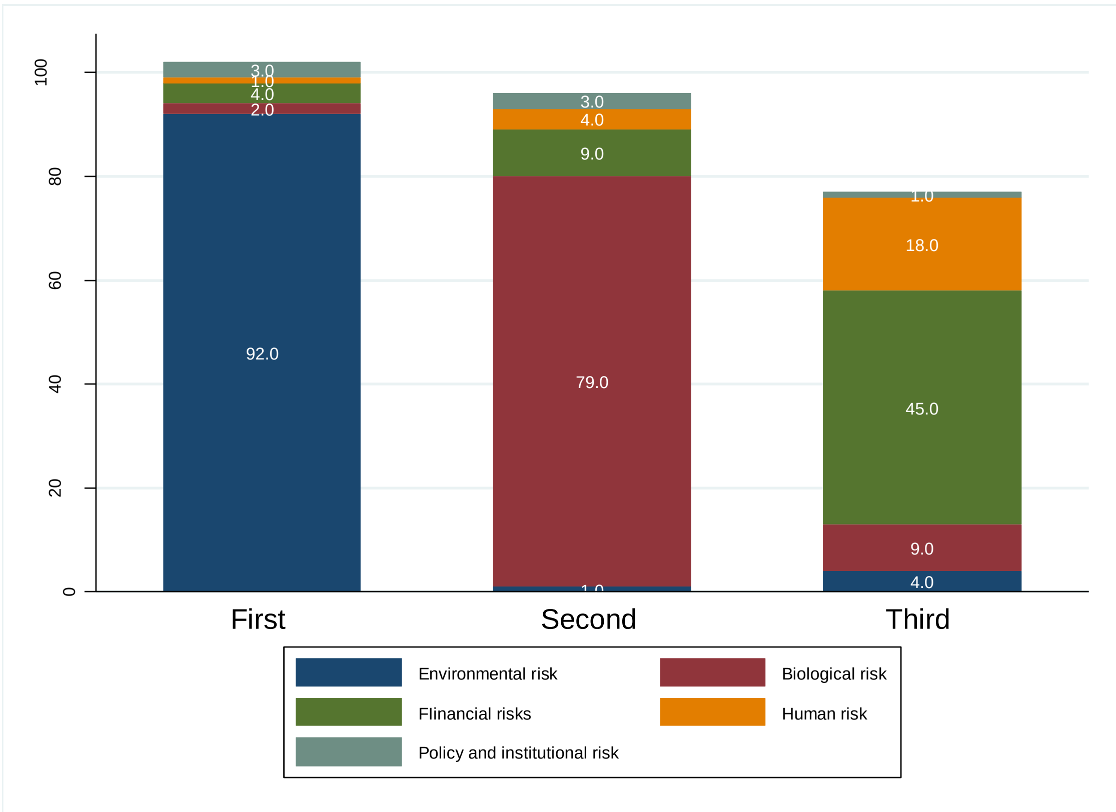


**Note: EWEs indicate three types of extreme events (floods/heat waves/cold spells). This theoretical framework of the hypothesised model is used for floods, heat waves, and cold spells model*

Appendix A.2: General mediation model.



Appendix A 3: Three most severe perceived risks (% of farmers').



Appendix B: Tables

Appendix B.1: Questions on perceived stress from heat and cold and associated productivity loss and health effects.

Do you feel the heat (cold) stressed during heat waves (cold spells) when you undertake your agricultural activities in a usual year during the last five years?	1. No, not at all 2. Yes, rarely 3. Sometimes 4. Often 5. Very often
"If you felt the heat (cold) stressed, did you find yourself, as a consequence, less productive when working on agricultural related activities?"	1. No, not at all 2. Yes, rarely 3. Sometimes 4. Often 5. Very often
Have the heat wave/cold spells affected your health and the health of your family in the last five years	1. Definitely yes 2. Probably yes 3. Probably not 4. Definitely not
If **yes,** how have heat wave/cold spells affected your and family health over the last five years?	
Were there days in the last year when you could not work at all in the agricultural field because of extreme heat/ cold?	1. Yes 2. No
If yes, how many days were you absent during extreme heat/cold?	
What preventative measures do you currently adopt to avoid heat /cold related stress in the agricultural fields?	

Appendix B.2: Results of ordered logit model with the dependent variables being the level of heat stress and cold stress (from 1: very low - 3: very high), by district.

	Perceived heat stress		Perceived cold stress	
Variables	***Bardiya***	***Banke***	***Bardiya***	***Banke***
Socio-economic				
Land size(In Bigga)	-0.05 (0.12)	0.02 (0.11)	-0.04 (0.11)	-0.03 (0.12)
Annual income(1-5)	0.33** (0.16)	0.08 (0.14)	-0.04 (0.19)	0.23 (0.15)
Having access to weather information	-1.9*** (0.4)	-0.51(0.37)	-1.09** (0.43)	-0.35 (0.38)
Living in concrete or brick house	0.17 (0.34)	-0.06 (0.34)	0.24 (0.32)	0.31 (0.32)
Owning livestock	0.31 (0.39)	0.59* (0.33)	0.60 (0.39)	0.40 (0.32)
Education (1 to 5)	0.47*** (0.1)	-0.31* (0.16)	0.24 (0.18)	0.09 (0.16)
Physical				
Age	0.20*** (0.08)	0.05 (0.08)	0.16** (0.07)	0.02 (0.07)
Age Square	-0.001** (0.00)	-0.00 (0.001)	-0.001** (0.00)	-0.001 (0.00)
Active family members(15-59 years)	0.01 (0.07)	-0.01 (0.05)	0.02 (0.06)	-0.05 (0.05)
Male	-0.18 (0.39)	-0.10 (0.38)	-0.11 (0.37)	0.03 (0.34)
Health status(1 to 3)	0.16 (0.36)	-0.63** (0.29)	0.28 (0.32)	0.07 (0.27)
Implemented response measures	0.79** (0.32)	0.24 (0.17)	0.97*** (0.28)	0.37* (0.19)
Working days	0.01 (0.01)	0.01** (0.01)	0.00 (0.01)	0.00 (0.01)
Psychological				
Perceived events(1 to 3)	0.24 (0.43)	1.11*** (0.25)	0.42* (0.26)	0.46** (0.19)
Health Satisfaction(1 to 3)	0.22 (0.26)	0.42 (0.26)	0.24 (0.26)	-0.03 (0.24)
Observations	167	183	167	183

**** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses, [1] I Bigha = 0.67 ha. Note: the number of implemented response measures were either in response to heat waves or cold spells, and the number of working days was either during the summer or winter in the heat wave and cold spell model, respectively. The number of perceived events were either in relation to heat waves or cold spells, depending on the model.*

Appendix B.3: Determinants of self-reported labour productivity loss, by district.

	Perceived labour productivity loss during heat wave		**Perceived labour productivity loss during cold spells**	
Variables	***Bardiya***	***Banke***	***Bardiya***	***Banke***
Socio-economic				
Land size (in Bigga)	-0.66 (0.42)	-0.12 (0.25)	-0.37 (0.29)	0.05 (0.18)
Annual income (1 to 5)	0.52 (0.69)	0.35 (0.24)	0.16 (0.50)	0.63*** (0.23)
Access to weather information	4.69 (3.57)	2.65*** (0.79)	2.1 (0.28)	2.56*** (0.68)
Living in concrete or brick house	1.17 (1.65)	0.44 (0.52)	0.01 (0.99)	0.60 (0.48)
Owning livestock	-2.63 (2.17)	0.85 (0.52)	-2.76 (1.75)	0.50 (0.46)
Education (1 to 5)	0.45 (0.87)	0.16 (0.24)	1.44* (0.80)	0.08 (0.23)
Physical				
Age	0.37 (0.28)	-0.05 (0.14)	0.55** (0.25)	0.20* (0.11)
Age Square	-0.01* (0.00)	0.00 (0.00)	-0.01** (0.00)	-0.00* (0.00)
Active family members (15-59 years)	0.25 (0.29)	-0.07 (0.08)	0.02 (0.19)	-0.08 (0.07)
Male	0.72 (1.75)	-0.68 (0.57)	-1.91 (1.29)	-0.83 (0.54)
Health status (1 to 3)	-1.39 (1.57)	-0.13 (0.42)	1.78 (1.11)	-0.20 (0.38)
Perceived illnesses/symptoms	-0.43 (0.55)	0.54*** (0.19)	0.80 (0.74)	0.40 (0.27)
Implemented response measures	0.19 (1.07)	0.88*** (0.27)	0.46 (0.56)	0.40 (0.30)
Working days	-0.02 (0.04)	0.01 (0.01)	0.03 (0.03)	-0.01 (0.01)
Psychological				
Perceived events (1 to 3)	4.18** (1.72)	-0.05 (0.43)	0.08 (0.72)	0.13 (0.29)
Perceived stress medium (§)	3.24* (1.85)	1.93*** (0.71)	1.67 (1.43)	2.66*** (0.66)
Perceived stress high (§)	2.84 (1.76)	1.57** (0.66)	3.26** (1.50)	1.62** (0.64)
Work satisfaction in agriculture (1 to 5)	-1.01 (1.95)	-0.26 (0.36)	0.18 (1.06)	-0.29 (0.33)
Constant	-1.15 (10.78)	-4.39 (3.25)	-18.6** (9.47)	-8.18*** (2.95)
Observations	167	183	167	183

**** p<0.01, ** p<0.05, * p<0.1, Standard errors in parentheses. Reference case(§): low perceived stress from heat and cold. Note: the number of implemented response measures* *were either in response to heat waves or cold spells, and the number of working days was either during the summer or winter, in the perceived productivity loss from the heat wave and cold spell models, respectively. The number of perceived events were either in relation to heat waves or cold spells, depending on the model. Numbers of perceived illnesses or symptoms were either related to heat or cold in the perceived productivity loss from the heat wave and cold spell models. Perceived stress medium and perceived stress high were also either in response to heat or cold with reference to low perceived stress in self-reported productivity loss from heat waves and cold spells.*

Appendix B.4: Correlation matrix of determinants of the perceived level of heat stress (N=350).

	Land	Income	Met	House	Livestock	Edu	Age	Active	Sex	Health	Cope	Days	PerC	Health PerC
Income	0.166	1												
Met	0.099	0.262	1											
House	-0.12	-0.177	0.099	1										
Livestock	0.178	0.077	-0.05	-0.02	1									
Edu	0.256	0.218	0.283	-0.06	-0.03	1								
Age	-0.08	-0.091	-0.14	0.052	0.102	-0.49	1							
Active	0.548	0.236	0.062	0.059	0.224	0.165	-0.03	1						
Sex	0.12	-0.024	-0.01	0.03	0.078	0.128	0.301	0.172	1					
Health	0.122	0.057	0.288	0.08	0.046	0.174	-0.14	0.035	-0.00	1				
Cope	0.095	0.204	0.104	-0.05	0.08	0.113	-0.08	-0.087	-0.16	0.307	1			
Days	0.114	-0.255	-0.06	0.09	0.081	-0.14	0.074	0.083	0.094	-0.069	-0.35	1		
PerC	-0.01	0.057	-0.07	-0.05	0.06	0.027	0	-0.016	-0.00	-0.036	0.009	-0.01	1	
Health PerC	0.032	-0.06	0.072	0.073	0.039	0.095	-0.12	0.056	0.097	0.287	0.098	-0.02	-0.12	1
Urban	0.12	0.169	0.123	-0.18	0.129	0.123	-0.11	-0.06	-0.14	0.124	0.335	-0.09	0.151	-0.019

Note: Land- Household land size; Income- Annual household Income; Met- Access to weather information; House- Type of house; Livestock- Having livestock or not; Edu- Household's head level of education; Age- Age of household's head; Active- Total households' member (age between 15 - 59); Sex- Sex of the household's head; Health- Existing health status; Cope- Numbers of implemented heatwave/cold spells adaptation measures; Days- Numbers of working days during summer/winter seasons; PerC- Perception of heatwaves/cold spells; Stress- Perceived level of heat (cold) stress *during summer (winter); Work- Level of work satisfaction working in agriculture; Health PerC- Numbers of heat/cold-related illness; Urban- Urban or rural areas.*

Appendix B.5: Correlation matrix of determinants of the perceived level of cold Stress (N=350).

	Land	Income	Met	House	Livestock	Edu	Age	Active	Sex	Health	Cope	Work	PerC	Health PerC
Income	0.166	1												
Met	0.099	0.262	1											
House	-0.12	-0.177	0.099	1										
Livestock	0.178	0.077	-0.05	-0.02	1									
Edu	0.256	0.218	0.283	-0.06	-0.03	1								
Age	-0.08	-0.091	-0.14	0.052	0.102	-0.49	1							
Active	0.548	0.236	0.062	0.059	0.224	0.165	-0.03	1						
Sex	0.12	-0.024	-0.01	0.03	0.078	0.128	0.301	0.172	1					
Health	0.122	0.057	0.288	0.08	0.046	0.174	-0.14	0.035	-0.00	1				
Cope	0.032	0.401	-0.06	-0.11	0.123	0.175	-0.07	0.021	-0.12	0.013	1			
Work	0.101	-0.399	-0.03	0.212	0.001	-0.07	0.095	0.057	0.148	-0.043	-0.56	1		
PerC	-0.06	0.404	0.296	-0.02	-0.067	-0.01	0.027	0.026	0.01	-0.128	0.157	-0.26	1	
Health PerC	0.032	-0.063	0.072	0.073	0.039	0.095	-0.12	0.056	0.097	0.287	-0.02	-0.06	-0.09	1
Urban	0.12	0.169	0.123	-0.18	0.129	0.123	-0.11	-0.068	-0.14	0.124	0.155	-0.19	-0.04	-0.019

Note: Land- Household land size; Income- Annual household Income; Met- Access to weather information; House- Type of house;Livestock- Having livestock or not; Edu- Household's head level of education; Age- Age of household's head; Active- Total households' member (age between 15 - 59); Sex- Sex of the household's head; Health- Existing health status; Cope- Numbers of implemented heatwave/cold spells adaptation measures; Days- Numbers of working days during summer/winter *seasons; PerC- Perception of heatwaves/cold spells; Stress- Perceived level of heat (cold) stress during summer (winter); Work- Level of work satisfaction working in agriculture; Health PerC- Numbers of heat/cold-related illness; Urban- Urban or rural areas.*

Appendix B.6: Correlations matrix of determinants of perceived labour productivity loss from heat waves (N=350).

	Land	Income	Met	House	Livestock	Edu	Age	Active	Sex	Health	Health PerC	Cope	Days	PerC	Stress	Work
Income	0.16	1														
Met	0.09	0.26	1													
House	-0.12	-0.17	0.09	1												
Livestock	0.17	0.07	-0.05	-0.02	1											
Edu	0.25	0.21	0.28	-0.06	-0.03	1										
Age	-0.08	-0.09	-0.1	0.05	0.1	-0.49	1									
Active	0.54	0.23	0.06	0.05	0.22	0.16	-0.03	1								
Sex	0.12	-0.02	-0.01	0.03	0.07	0.12	0.3	0.17	1							
Health	0.12	0.05	0.28	0.08	0.04	0.17	-0.14	0.03	-0.007	1						
Health PerC	0.04	0.35	0.08	-0.16	0.12	0.1	-0.07	0.06	-0.1	0.04	1					
Cope	0.09	0.2	0.1	-0.05	0.08	0.11	-0.08	-0.08	-0.16	0.3	0.4	1				
Days	0.11	-0.25	-0.06	0.09	0.08	-0.14	0.07	0.08	0.09	-0.06	-0.36	-0.35	1			
PerC	-0.01	0.05	-0.07	-0.05	0.06	0.02	-0.006	-0.01	-0.004	-0.03	0.15	0.009	-0.01	1		
Stress	0.01	0.008	-0.24	-0.07	0.17	-0.07	0.16	0.02	0.03	-0.07	0.15	0.1	0.06	0.2	1	
Work	0.04	-0.04	0.02	0.07	0.05	-0.08	0.004	0.04	0.01	0.08	-0.08	0.009	0.11	-0.17	-0.04	1
Urban	0.12	0.16	0.12	-0.18	0.12	0.12	-0.11	-0.6	-0.14	0.12	0.31	0.33	-0.09	0.15	0.06	-0.13

Note: Land- Household land size; Income- Annual household Income; Met- Access to weather information; House- Type of house;Livestock- Having livestock or not; Edu- Household's head level of education; Age- Age of household's head; Active- Total households' member (age

	Land	Income	Met	House	Livestock	Edu	Age	Active	Sex	Health	Health PerC	Cope	Days	PerC	Stress	Work
Income	0.16	1														
Met	0.09	0.26	1													
House	-0.12	-0.17	0.09	1												
Livestock	0.17	0.07	-0.05	-0.02	1											
Edu	0.25	0.21	0.28	-0.06	-0.03	1										
Age	-0.08	-0.09	-0.14	0.05	0.102	-0.49	1									
Active	0.54	0.23	0.06	0.05	0.22	0.16	-0.03	1								
Sex	0.12	-0.02	-0.01	0.03	0.07	0.12	0.3	0.17	1							
Health	0.12	0.05	0.28	0.08	0.04	0.17	-0.14	0.03	-0.01	1						
Health PerC	0.01	0.21	0.22	-0.16	0	0.06	-0.1	-0.08	-0.19	0.11	1					
Cope	0.03	0.4	-0.06	-0.11	0.12	0.17	-0.07	0.02	-0.12	0.01	0.36	1				
Days	0.1	-0.39	-0.03	0.21	0	-0.07	0.09	0.05	0.14	-0.04	-0.5	-0.56	1			
PerC	-0.06	0.4	0.29	-0.02	-0.06	-0.01	0.02	0.02	0.01	-0.18	0.16	0.15	-0.26	1		
Stress	0.03	0.18	-0.07	-0.04	0.17	0.06	0.04	0.002	-0.01	0.04	0.12	0.34	-0.22	0.11	1	
Work	0.04	-0.04	0.02	0.07	0.05	-0.01	0.004	0.04	0.01	0.08	-0.12	-0.04	0.12	-0.19	-0.1	1
Urban	0.12	0.16	0.12	-0.18	0.12	0.12	-0.11	-0.06	-0.14	0.12	0.35	0.15	-0.19	-0.04	0.21	-0.13

Appendix B.7: Correlations matrix of determinants of perceived labour productivity loss from cold stress (N=350).

Note: Land: Household land size; Income: Annual household Income; Met: Access to weather information; House: Type of house; Livestock: Having livestock or not; Edu: Household's head level of education; Age: Age of household's head; Active: Total households' member between 15 - 59); Sex- Sex of the household's head; Health- Existing health status; Health PerC- Numbers of heat/cold-related illness; Cope- Numbers of implemented heatwave/cold spells adaptation measures; Days- Numbers of working days during summer/winter seasons; PerC- Perception of heatwaves/cold spells; Stress- Perceived level of heat (cold) stress during summer (winter); Work- Level of work satisfaction working in agriculture; Urban- Urban or rural areas.

(age between 15: 59); Sex: Sex of the household's head; Health: Existing health status; Health PerC: Numbers of heat/cold-related illness; Cope: Numbers of implemented heatwave/cold spells adaptation measures; Days: Numbers of working days during summer/winter seasons; PerC: Perception of heatwaves/cold spells; Stress: Perceived level of heat (cold) stress during summer (winter); Work: Level of work satisfaction working in agriculture; Urban: Urban or rural areas.

Appendix B.8: Impacts of the level of income and level of heat and cold stress on different coping strategies related to heat and cold by bivariate analysis(N=350).

	Impact on heat wave response strategies				
	Hats/umbrella	***Resting in shade / slowing down work***	***Stopping work***	***Reschedule working times***	***Cooling techniques***
Level of perceived heat stress (1 to 3)	$\chi^2(2) = 0.049$ $p = 0.9758$	$\chi^2(2) = 0.007$ $p = 0.9970$	$\chi^2(2) = 5.035$ $p = 0.0807$	$\chi^2(2) = 10.39$ $p = 0.0055$	$\chi^2(2) = 1.801$ $p = 0.4064$
Annual household's income (1 to 5)	$\chi^2(4) = 24.82$ $p = 0.0001$	$\chi^2(4) = 9.282$ $p = 0.0544$	$\chi^2(4) = 46.77$ $p = 0.0001$	$\chi^2(4) = 9.968$ $p = 0.0426$	$\chi^2(4) = 18.15$ $p = 0.0012$
	Impact on cold spells response strategies				
	Warm clothes	***Stopping work/ resting to warm up***	***Reschedule working times***	***Drinking hot***	***Others***
Level of perceived cold Stress (1 to 3)	$\chi^2(2)= 2.088$ $p = 0.3520$	$\chi^2(2) = 30.56$ $p = 0.0001$	$\chi^2(2) = 7.556$ $p = 0.0229$	$\chi^2(2) = 75.35$ $p = 0.0001$	
Annual household's income (NRP)(1 to 5)	$\chi^2(4) = 0.913$ $p = 0.9227$	$\chi^2(4) = 40.50$ $p = 0.001$	$\chi^2(4)=61.94$ $p = 0.001$	$\chi^2(4)= 59.06$ $p = 0.0001$	

Appendix B.9: Definitions and coding of key variables used in structural equation model.

Variables	**Descriptions**	**Coding**
Threat appraisal/risk perception: Perceived probability – production damage	Respondents' estimate that agricultural production will be affected negatively by floods/heat waves/cold spell in the next 10 years	1 = very unlikely; 2 = quite unlikely; 3 = quite likely; 4 = very likely
Threat appraisal/risk perception: Perceived probability – personal damage	Respondents' estimate that they and their families will be negatively affected by floods/heat waves/cold spells in the next 10 years	1 = very unlikely; 2 = quite unlikely; 3 = quite likely; 4 = very likely
Threat appraisal/risk perception: Perceived probability – infrastructure damage	Respondents' estimate that their housing and farm equipment will suffer physical damages in the next 10 years because of floods/heat waves/cold spells	1 = very unlikely; 2 = quite unlikely; 3 = quite likely; 4 = very likely
Threat appraisal /risk appraisal: Perceived severity	Respondents' perception of the increment of the magnitude and frequency of floods/heat waves/ cold spells in the future	1 = very unlikely; 2 = quite unlikely; 3 = quite likely; 4 = very likely
Coping appraisal: Perceived self-efficacy	The belief that the respondent is able to adapt to the impacts of natural disasters, asked as follows: "To what extent do you agree with the following statement: I believe that I am able to avoid the negative consequences of floods/heat waves/cold spells on my household and my farm."	1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree
Coping appraisal: Perceived responsibility	Respondents' believe that personal responsibility is important in reducing exposures to floods/heat waves/cold spells, asked as follows: "To what extent do you believe that personal responsibility is important in reducing exposures to floods/heat waves/cold spells?"	1 = not important at all; 2 = rather unimportant; 3 = important; 4 = very important
Coping appraisal: Response cost	Respondents' evaluation of the overall cost to carry out the potential adaptation strategies to reduce the impacts of floods/heat waves/cold spells.	1 = very cheap; 2 = cheap; 3 = expensive; 4 = very expensive
Intended adaptation strategies	Measurement of respondent's preparedness and capacity to cope and adapt, asked as follows: "If there are more and heavier floods/heat waves/cold spells in the future, what would be your potential future adaptation strategies to minimise the risk for your farm and your family?"	Continuous (numbers of potential adaptations)
Previous experience	Respondents' evaluation of previous damage from floods/heat waves/cold spells on agricultural production in the lasts 10 years	1 = minimal damage; 2 = slight damage; 3 = bad damage; 4 = severe damage

Variables	Descriptions	Coding
Reliance on public protection (Trust)	Respondents' satisfaction with the public management of floods/heat waves/cold spells in their areas	1 = very unsatisfied; 2 = unsatisfied; 3 = satisfied; 4 = very satisfied
Concern	Concerned about the risks of the floods/heat waves/ cold spell in your community	1 = not at all concerned; 2 = a bit concerned; 3 = concerned; 4 = highly concerned

Note: All the questions were asked separately for flood, heat waves, and cold spells models.

Table B10: Sampling design

Districts (Municipality)	Ward number	Household number	Sample size
Banke (Rapti Sonari)	5	782	31
	8	1027	33
	12	1786	105
Bardiya (Gulariya)	3	1142	44
	4	1571	89
	5	1501	48

Appendix B.11: Goodness of fit statistics, Amos SEM outputs.

Models	Cold Spells	Heat Wave	Floods
Analysis	Multivariate mediation model	Multivariate mediation model	Multivariate mediation model

Mediators	1	1	1
x^2	113.4	102.8	67.7
df	35	37	38
$\frac{x^2}{df}$	3.23	2.78	1.70
RMSEA	0.08	0.07	0.04
CFI	0.93	0.93	0.98
SRMR	0.04	0.04	0.03
TLI	0.81	0.83	0.94

Note: x^2 *= chi-square statistics,* df *= degree of freedom,* $\frac{x^2}{df}$ *= Relative chi-square, RMSEA = Root mean square error of approximation, CFI = Comparative fit index, SRMR = Standardised root mean squared residual, TLI = Tucker Lewis index.*

Table B12: Validity of measurement model

Latent variables	Observed variables	Factor loading	AVE	CR
Risk perception of flood	Perceived risk damage to household agriculture by flood	0.72	0.51	0.8
	Perceived personal risk probability of flood	0.84		
	Perceived risk damage to farm infrastructure by flood	0.68		
	Perceived severity of flood	0.6		
Risk perception of heat wave	Perceived risk damage to household agriculture by heat wave	0.7	0.48	0.74
	Perceived personal risk probability of heat wave	0.68		
	Perceived risk damage to farm infrastructure by heat wave	0.61		

	Perceived severity of heat wave	0.6		
Risk perception of cold spell	Perceived risk damage to household agriculture of cold Spell	0.77	0.49	0.78
	Perceived personal risk probability of cold spell	0.67		
	Perceived risk damage to farm infrastructure of cold spell	0.6		
	Perceived severity of cold spell	0.7		

Note: AVE: Average Variance extracted, CR: Composite Reliability

Appendix B.13: Definitions of key explanatory variables and their coding used for Poisson and Multinomial regression models of three extreme weather events (heatwaves, cold spells, floods) intended adaptation strategies.

Explanatory variables	**Descriptions**	**Coding**
Perceived farm probability	Respondents' estimate that agricultural production will be affected negatively by floods/heat waves/cold spell in the next 10 years	1 very unlikely; 2 quite unlikely; 3 quite likely; 4 very likely
Perceived probability personal	Respondents' estimate that yourself and your family will be affected negatively by floods/heat waves/cold spells in the next 10 years	1 very unlikely; 2 quite unlikely; 3 quite likely; 4 very likely
Perceived consequences infrastructure	Respondents' estimate that your housing and farm equipment will suffer physical damages in the next 10 years because of the floods/heat waves/cold spells	1 very unlikely; 2 quite unlikely; 3 quite likely; 4 very likely
Anxiety	Worried about the risks of the floods/heat waves/ cold spell in your community	1 not at all; 2 a bit worried; 3 worried; 4 a lot
Perceived self-efficacy	To what extent do you agree with the following statement: "I believe that I am able to avoid the consequences of the floods/heat wave/cold spells to my household and my farm"	1 strongly disagree; 2 disagree; 3 agree; 4 strongly agree
Perceived response efficacy	The mean score of implemented floods/heat wave/cold spells strategies	4 very effective; 3 quite effective; 2 quite ineffective; 1 very ineffective
Perceived responsibility	Respondents' extent of believe that personal responsibility is important in reducing exposures to floods/heat wave/cold spell	1 not important at all; 2 rather unimportant; 3 important; 4 very important
Previous damage experiences of EWEs	Respondents' overall evaluation of previous experiences of damages of floods/heat wave/cold spells on agricultural production in the lasts 10 years	1 minimal damage; 2 slight damage; 3 bad damage; 4 severe damage
Reliance on public protection	Respondents' satisfaction with the public management of floods/heat waves/ cold spell in your areas	1 very unsatisfied; 2 unsatisfied; 3 satisfied; 4 very satisfied
Perceived severity	Respondents' perception on increment of the magnitude and frequency of the floods/heat waves/ cold spells events in the future	1 very unlikely; 2 unlikely; 3 likely; 4 very unlikely
Response cost	How do you evaluate the overall response cost to carry out the potential adaptation strategies	1 no costly at all; 2 slightly costly; 3 very

Explanatory variables	Descriptions	Coding
	to reduce the impacts of the following EWEs in the futures?	costly; 4 extremely costly
Ex ante perception	Respondents' perceive that there will be more floods/heat wave/cold spell in the next five years	1 definitely not; 2 Probably not; 3 probably yes; 4 definitely yes
Experience	Respondents' experience of changes in more floods/extreme heat/extreme cold during last 10 years	1 if experienced changes 0 otherwise
Education	Respondents' level of education	1 no formal education; 2 completed primary school; 3 completed high school; 4 10+2 completed; 5 graduate and above
Income	Total households income	1 Less than 50000; 2 50000-100000; 3 100000-200000; 4 200000-300000; 5 more than 300000
Extension Service	Access to extension services	1 yes; 2 no
Credit	Access to credit facilities	1 yes; 2 no
Community organization	Household's member association with any community organizations	1 yes; 2 no

Note: The same questions were asked separately for flood, heat waves and cold spells model.

Appendix B.14: Socio-economics characteristics.

Variables	Frequency (%)	Mean (median)	Std. Dev.
Age (years)		38.72	12.9
Gender		1.37	.48
Male	62		
Female	38		
Household's size		7.82	5.29
Education		2.24	1.22
No formal education	32.5		
Primary	35.7		
High school	14.8		
Secondary	8.5		
Undergraduate and above	8.5		
Land Holding (ha)	0.96		1.22
Annual household's income(NPR)			
<50000	10.2		

50,000-100,000	22.5		
100,000-200,000	23.7		
200,000-300,000	21.7		
>300000	21.6		
Access to Agricultural credit			
Yes	50.8		
No	49.2		
Access to extension Services			
Yes	39.4		
No	60.6		
Association with any community organization			
Yes	72.5		
No	27.4		
Number of implemented flood adaptation strategies (0-9)		3.06(3)	1.93
Number of implemented heat wave adaptation strategies (0-8)		3.10(3)	1.98
Number of implemented cold adaptation strategies (0-8)		3.23(3)	1.83
Number of planned flood adaptation strategies (0-7)		3.77(4)	1.53
Number of planned heat wave adaptation strategies (0-8)		3.21(3)	1.77
Number of planned cold adaptation strategies (0-8)		3.42(3)	1.92

Appendix B.15: Poisson regression of intended adaptation to the impacts of future floods, heat waves and cold spells.

	(1)	**(2)**	**(3)**
Explanatory Variables	**IRR (Floods)**	**IRR (Heat waves)**	**IRR (Cold spells)**
Threat Appraisals			
Perceived probability of damage to farm	1.01(0.04)	0.95(0.03)	0.90***(0.03)
Perceived probability of personal damage	1.03(0.04)	0.88***(0.03)	0.90***(0.03)
Perceived consequences for infrastructure	0.99(0.03)	1.08**(0.03)	1.10***(0.03)
Perceived severity of damage	1.04(0.03)	1.04**(0.02)	1.01(0.03)
Anxiety (worry)	0.90**(0.04)	0.92***(0.02)	1.06**(0.03)
Coping Appraisals			
Perceived response efficacy	1.07***(0.02)	0.88***(0.03)	1.11***(0.04)
Perceived response cost	1.11***(0.03)	1.17***(0.03)	0.98(0.03)
Perceived self-efficacy	1.05**(0.02)	1.03(0.03)	0.94(0.03)
Perceived responsibility	1.07***(0.01)	1.13***(0.03)	1.02(0.03)
Social capital and access to facilities			
Community Organization	0.95(0.03)	0.96(0.05)	1.05(0.05)
Extension Services	1.09**(0.05)	1.10(0.05)	0.97(0.04)

Credit	1.0(0.03)	1.01(0.04)	1.03(0.04)
Threat experience EWEs			
Previous damage experiences of EWEs	1.03(0.03)	1.05*(0.02)	1.02(0.03)
EWEs Experience			
Experience	1.31**(0.15)	1.68***(0.18)	1.3***(0.12)
Ex-ante perception	1.00**(0.001)	1.07**(0.03)	1.10**(0.04)
Reliance on public protection	1.00(0.01)	0.97(0.02)	1.06**(0.02)
Implemented strategies	1.10***(0.01)	1.10***(0.01)	1.17***(0.02)
Socio-economic characteristics			
Education	1.02*(0.01)	1.01(0.01)	1.02(0.2)
Annual income (NPR)	1.00(0.01)	1.04**(0.01)	1.01(0.01)
Constant	0.68**(0.14)	0.72(0.10)	0.75(0.15)

*Robust seeform in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

Appendix B.16: Relative Risk Ratio of multinomial Flood, Heat waves and Cold spells adaptation model.

Variables	Taking out crop insurance			Changes in farm management			Emergency management planning			Awareness raising			Seeking off farm employment		
	F	*HW*	*CS*	*F*	*HW*	*CS*	*F*	*HW*	*CS*	*F*	*HW*	*CS*	*F*	*HW*	*CS*
Threat Appraisals															
Perceived probability of damages to farm	0.92	1.57	0.42	0.69	1.46	0.65	0.37 *	2.29	0.47	0.71	1.92	0.37 *	0.79	0.98	1.78
Perceived probability of personal damage	0.50	0.18 ***	0.98	0.93	0.37 **	0.85	0.80	0.2 **	1.11	0.78	0.44	1.26	1.63	0.35 *	0.46
Perceived consequences for infrastructure	1.95	0.91	0.32 **	1.09	1.39	0.64	1.60	0.61	0.78	1.68	1.89	1.56	1.48	2.37	1.88
Perceived severity of damage	1.71	1.25	0.92	0.74	1.53	1.31	1.13	1.31	1.38	0.67	1.27	1.44	0.44	1.64	1.14
Anxiety (worry)	1.20	0.70	3.22 **	1.27	0.64	0.87	1.32	0.46	0.69	0.30 *	0.86	1.01	0.59	0.57	0.71
Coping Appraisals															
Perceived response efficacy	0.48	0.32 **	0.42	1.05	1.12	1.50	0.85	1.37	0.57	1.17	2.70 **	3.7 ***	1.13	4.9 **	1.02
Perceived response cost	0.30 ***	0.35 **	0.06 ***	1.30	1.70	0.64	0.70	0.82	0.76	1.02	0.56	0.38 **	0.30**	0.65	0.2 ***
Perceived self-efficacy	3.48 ***	1.77	1.00	2 ***	1.81 *	1.42	2.8 **	1.80	1.48	2.3 *	2.00	1.65	2.31 *	2.20	2.63

Variables	Taking out crop insurance			Changes in farm management			Emergency management planning			Awareness raising			Seeking off farm employment		
	F	*HW*	*CS*	*F*	*HW*	*CS*	*F*	*HW*	*CS*	*F*	*HW*	*CS*	*F*	*HW*	*CS*
Perceived responsibility	4.69 ***	3.3 ***	1.66	1.46	1.03	0.60 *	1.98 **	1.80	1.62	0.70	0.46 **	0.4 ***	4.1 ***	2.29 *	5.32 **
Social capital and access to facilities															
Community Organization	3.12	5.39 **	2.26	2.63	1.90	1.34	7.3 **	15 **	5.2 **	5.26	1.64	6.18 **	5.30 *	6.59 **	3.17
Extension Services	0.18 **	0.25	0.24	0.53	1.10	0.58	0.30	0.54	0.23 *	1.20	2.93	0.68	0.30	1.45	0.17 *
Credit	9.1 ***	2.21	2.17	1.99	0.53	0.41 *	1.72	0.57	0.68	1.24	0.59	0.52	2.92	0.97	0.65
Threat experience EWEs															
Previous experiences of EWEs	6.01 ***	2.06 **	0.81	2 **	1.30	0.9	2.16	1.46	0.32 **	3.17*	0.84	0.82	2.28	1.30	0.36 *
EWEs Experience															
Experience EWEs	0.83	6.58 ***	11 ***	1.26	1.51	1.42	0.58	1.69	2.14	1.37	4.4 ***	1.58	0.34*	1.33	0.76
Reliance on public protection	1.20	1.67	4.1 ***	0.91	0.85	0.97	1.32	1.31	1.28	0.71	0.45	1.07	0.78	0.85	1.25
Implemented EWEs strategies	2.23 ***	2.03 ***	4 ***	1.3 **	1.5 **	3.0 ***	1.30	1.7	2.1 ***	1.15	1.64 **	1.32	1.9 ***	2.3 ***	4.1 ***
Socio-economic characteristics															
Education	0.74	0.82	1.57	0.89	0.9	0.92	0.87	1.8 *	1.52	0.81	0.9	1.03	0.95	1.12	2.4 ***
Income	1.35	1.37	1.13	1.17	1.36	1.2	0.95	0.9	1.30	1.17	1.7 **	1.29	0.67	0.72	0.52 *

*** $p<0.01$, ** $p<0.05$, * $p<0.1$; *note: F-Flood, HW: Heat wave, and CS: Cold Spells*

Appendix B.17: Questions.

"To minimize the losses to your crops from the impacts of natural disasters such as floods, drought, cold spells, heat waves, earthquakes, lighting, pests and diseases, the government of Nepal is implementing an area-based yield crop insurance scheme in which a farmer can buy separate insurance coverage for one or more crops and pay separate premiums for each policy. I would like to ask you some questions to assess the market potential of such insurance in your area. In principle, you pay a fixed amount of money per hectare per cropping season to the insurance provider as a premium (75% will be paid by the government, and 25% premium will be paid by the farmer) and in return the losses occur from natural disasters will be compensated after the official recognition of the damages. An average area-based yield per hectare (yield index) will be calculated for the crops based on historical data from the agricultural development office (monetary value of crops as fixed by DADO[24]). An official representative of the insurance provider company will conduct a survey of your agricultural production to identify and quantify the damages and losses to your crops. If the average yield falls below the index up to 90% compensation will be paid out."

SN	Questions	Responses and codes
500	Do you have agriculture or crop insurance?	① Yes ② No
501	Do you know what agricultural or crop insurance is?	① Yes ② No
502	Do your neighbours have agricultural or crop insurance?	① Yes ② No ③ I don't know
503	Do you know anybody who has it?	① Yes ② No
504	Would you like to join yield based crop insurance scheme if introduced?	① Yes ② No
505	If yes in 504, are you willing to pay ------------------- (Initial bid) Rs per kattha of paddy for the yield based crop insurance?	① Yes ② No

[24] District agriculture development office

SN	Questions	Responses and codes
506	If no to 505, are you willing to pay ----------------(lower bid) Rs per kattha of paddy for the yield based crop insurance?	① Yes ② No
507	If yes to 505, are you willing to pay ……………………………(higher bid) Rs per Kattha of paddy for the yield based crop insurance?	① Yes ② No
508	If yes in 507, What is the maximum amount that you are willing to pay to insure a hectare paddy crop land?	① Yes ② No
509	If yes in 504, are you willing to pay ------------------- (Initial bid) Rs per/kattha of wheat farm for the yield based crop insurance?	① Yes ② No
510	If no to 509, are you willing to pay ----------------(lower bid) Rs per/kattha of wheat for the yield based crop insurance?	① Yes ② No
511	If yes to 509, are you willing to pay ……………………………(higher bid) Rs per/kattha of wheat for the yield based crop insurance?	① Yes ② No
512	If yes in 511, What is the maximum amount that you are willing to pay to insure a hectare paddy crop land?	① Yes ② No
513	In what way, you are you willing to pay the premium? ① Cash ② In Kind	① Cash ② In Kind
514	What time are you willing to able to pay the premium? ①Right after harvest ② During land preparation ③ At the time of sowing ④ After sowing ⑤ Others	①Right after harvest ② During land preparation ③ At the time of sowing ④ After sowing ⑤ Others
515	If yes to 504, why would you like to purchase insurance?	
516	If no to 504, why you would not like to purchase insurance?	
517	How important of crop insurance as a coping mechanism for Extreme weather events?	① Very important ② Relatively important ③ Neutral ④ Unnecessary
518	If answered yes to 502 or 503, would your decision to join the insurance scheme be influenced by the fact that your neighbour or somebody you know already participate?	①Yes, very much ②Yes, a bit ③No

Appendix B.18: Single-bound model result.

	Logit coefficients	
Variables	**Paddy rice**	**Wheat**
bid1	-0.012*	
bid3		-0.029***
Caste (dummy)	-0.270*	-0.073
Access to extension services (dummy)	-1.727***	-0.307
Floods in the last 5 years (numbers)	-0.046**	-0.004
Household’s income (categorical)	0.296	-0.020
Family Size(numerical)	-0.042	-0.057
Male(dummy)	-0.195	-0.365
Farm size (numerical)	0.112	0.088
Damage experience of EWEs (categorical) during previous year	0.815**	0.668**
Ex-ante perception of EWEs (categorical)	0.268	0.025
Membership of community organization(dummy)	-0.585	-0.183
Household education(categorical)	0.021	0.281
Banke district(dummy)	0.276	0.282
Agricultural performance (categorical)	-0.580**	-0.116
Distance to the flood sources(numerical)	-0.000	0.001*
Constant	3.921**	2.222
Observations	293	293

Appendix B.19: Descriptive Statistics (n=350).

Variables	**Expected sign**	**Frequency (%)**	**Mean**	**Std. Dev.**
Caste of the respondent (dummy)	+/-		0.78	0.41
1 if Tharu		78.4		
0 if others		21.6		
Age (years)	+/-		38.7	12.96
Family size	+/-		7.86	5.31
Education(1-5)	+		2.24	1.23
No formal education		32.5		
Completed primary		35.7		
Completed high school		14.8		
Completed 10+2		8.5		
Bachelor and above		8.5		
Agriculture Experience (Yrs)	+		21.2	12.61
HHs monthly expense(NPR 000)	-		16.13	18.88
Yearly income (1-5)	+		3.22	1.30
<50000		10.2		
50000-100000		22.5		
100000-200000		23.7		
200000-300000		21.7		
>300000		21.6		
Distances from floods sources(meters)	+		461.52	564.72
Gender(dummy)	+/-		0.62	0.48
1 if male		62.8		
0 otherwise		37.2		
Land Size (Bigga)	-/+		1.42	1.72
Ex-ante perception of EWEs (0-3)	+		2.43	0.46
Ex-post damage experience of EWEs (0-3)	+/-		1.61	0.59
Household received remittances in last 12 months(dummy)	+/-		0.14	0.35
1 if remittances received		85.7		
0 otherwise		14.3		
Access to extension services (dummy)	+	0.39	0.45	
1 if have access to extension services		60		
0 otherwise		40		
Floods in the last 5 years (numbers)			4.6	10.6
Agriculture as main source of earning(dummy)	+			
1 if main source of earning		94.6		
0 otherwise		5.4		

Variables	Expected sign	Frequency (%)	Mean	Std. Dev.
Proportion of agricultural income to the total household annual income(1-4)	+			
Less than 25%		16.8		
25%-50%		30.2		
50%-75%		32		
More than 75%		20.8		

Appendix B.20: Farmers' WTP based on different households characteristics (in NPR).

	Mean WTP	Std. Err.	Z	P>|z|	Lower bound	Upper bound
Average WTP for paddy rice	117.49	31.87	3.61	0.00	52.27	176.7
WTP for paddy rice (income effect)						
< 50000	106.9	39.4	2.70	0.007	29.2	184.6
50000-100000	118.6	40.3	2.94	0.003	39.4	197.7
100000-200000	130.3	41.7	3.12	0.002	48.5	212.1
200000-300000	142.0	43.5	3.26	0.001	56.6	227.4
>300000	153.6	45.9	3.35	0.001	63.7	243.6
WTP for wheat (gender effect)						
Male respondent	87.0	23.7	3.6	0.00	40.4	133.6
Female respondent	96.7	24.5	3.9	0.00	48.6	144.8

Appendix C: Supporting Documents

Appendix C.1: Consent Form for Key Informants Interview.

CONSENT FORM FOR KEY INFORMANTS INTERVIEW

CHARLES DARWIN UNIVERSITY

Ellengowan Drive, Darwin, Northern Territory, 0909

Project Title: Economic and Social Impacts of Extreme Weather Events on the Agricultural Sector in the Lowlands of Nepal

I …..of ....

Hereby consent to participate in a study undertaken by Mr Nanda Kaji Budhathoki (PhD Student) of Charles Darwin University, Australia and I understand the purpose of the research is:

The aim of my study is to assess how farmers in your area affected by extreme weather. There are often flooding and heavy rain, droughts, strings of very hot or cold days and I know that this affect your farming. You probably need to change your farming activities accordingly and I would like to find out how exactly you are affected and how you cope with this extreme weather.

I have read the information provided.

1. Details of procedures and any risks have been explained to my satisfaction.
2. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.
3. I understand that:
   - Upon receipt, my questionnaire will be coded and my name and address will be kept separately from it ·
   - Any information that I provide will not be released in an identified form aggregated results will be used for research purposes and may be reported in scientific and academic journals
   - Individual results will not be released to any person except at my request and on my authorisation ·
   - I am free to withdraw my consent at any time during the study, in which event my participation in the research study will immediately cease, and any information obtained will be returned to me or destroyed at my request

Participant's signature……………………………………Date…………………...

PLAIN LANGUAGE STATEMENT

This document is yours to keep

Project: Economic and Social Impacts of Extreme Weather Events on the Agricultural Sector in the Lowlands of Nepal

Researchers: My name is Nanda Kaji Budhathoki and I am conducting this research as part of my PhD which I pursue at the Charles Darwin University in Australia. My supervisors are Kerstin Zander (Principal supervisor), Jonatan Lassa and Douglas Paton.

Purpose of the study: The aim of my study is to assess how farmers in your area affected by extreme weather. There are often flooding and heavy rain, droughts, strings of very hot or cold days and I know that this affect your farming. You probably need to change your farming activities accordingly and I would like to find out how exactly you are affected and how you cope with this extreme weather.

Benefits of the study: The proposed research will contribute to understand the underlying causes of occurring EWEs. In addition, it will also assess how EWEs are likely to pose increasing risks to life and property in particularly regions in the future. Event specific studies related with climate change can be a tool for informing choices about assessing and managing risk and guiding adaptation strategies to minimize the risks associated with EWEs

What would be expected of you: We are conducting household survey with farming household and key informants' interviews with government officials, village heads in the study areas to discuss current situations of extreme weather events particularly heat waves, floods and cold spells in their areas and its impacts on their agricultural livelihoods, existing coping and mitigation measures to minimize the risks of these events in the recent years and the future suggestions to lower the impacts of these events in next one decade under different circumstances. This project will investigate the impacts of EWEs on agricultural sector by using structured households survey questionnaire and semi-structured stakeholder interview.

Risks/discomfort: There is no specific risk associated with the participations in this research project. Questionnaire is designed such a way that which will reduce you discomfort while answering responses as much as possible. We would be highly grateful to you if you could participate and answer all the questions but you are free to quit the survey anytime you want.

What will happen to the information you provide: Information provided by you will keep confidential and will be used for research purposes only. This information will help us to understand and discuss the problems related with EWEs and offer possible solutions to minimize the risks of these EWEs. The output will be published in academic journal.

Oral Consent

If you have any questions about the project, please feel free to contact the researcher,
Nanda Kaji Budhathoki on Phone-------------------------------

Email: nandakaji.budhathoki@cdu.edu.au

Australian Contact

Northern Institute, Charles Darwin University

+61999466689, Northern Territory

Australia

This research has approved from the Charles Darwin University Human Research Ethics Committee. If you have any concerns about the project, you can contact the Ethics team of the Charles Darwin University Human Research Ethics Committee on the toll free number, 1800466215 or by email; ethics@cdu.edu.au

Appendix C.2: Household Survey Questionnaires.

Household Survey Questionnaires

On

Economic and Social Impacts of Extreme Weather Events on the Agricultural Sector in the Lowlands of Nepal

Good day. My name is Nanda Kaji Budhathoki. I am a PhD student in Northern Institute at Charles Darwin University, Australia. We are doing this research for the **Economic and Social Impacts of Extreme Weather Events on the Agricultural Sector in the Lowlands of Nepal** project. This is a household survey being conducted by researchers from the Charles Darwin University to assess how farmers in your area affected by extreme weather. There are often flooding and heavy rain, droughts, strings of very hot or cold days and I know that this affect your farming. You probably need to change your farming activities accordingly and I would like to find out how exactly you are affected and how you cope with this extreme weather.

I am studying the views of household’s head or others adult member in order to learn and discuss about current situations of extreme weather events particularly heat waves, floods and cold spells in your areas and its impacts on their agricultural livelihoods, existing coping and mitigation measures to minimize the risks of these events in the recent years and the future suggestions to lower the impacts of these events in next one decade under different circumstances.

I would like to discuss these issues with a member of your household in an interview. Every person in the area has an equal chance of being included in this study. All information will be kept confidential and will be used in aggregate form. Your household has been chosen by chance. This interview will take about 60 minutes. There is no penalty for refusing to take part. And if you choose to take part, you may stop at any time, or skip any questions if you do not wish to answer.

[If yes] May I please interview this person now?

[If no] Will this person return her at any time today?

[If no] Thank you very much.

[If yes] Please tell this person that I will return for an interview at: [Insert convenient time]

A. Questions on household and farming characteristics

S.N	**Question**	**Response and code**	**Go to**
101	District Name		
102	Village council		
103	Ward No		
104	Village/Tole		
105	Name of the respondent		
106	Caste (self-assessment) (√) ① Dalit ② Ethnic groups (Gurung, rai, limbu, Newar etc), ③ Bramin/chhetri ④ Madhesi ⑤ Others (specify)	① ② ③ ④ ⑤	
107	Age(Completed year)	__________ Years	
108	Sex ① Male ② Female	① ②	
109	Education of household head ① No formal education ② Completed primary school ③ Completed High School ④ 10+2 completed ⑤ Graduate and above	① ② ③ ④ ⑤	
110	Type of house ① Kacha (Khar,Leaves) ② Pakka (Bricks) ③ Tin (corrugated Sheet) ④ Others	① ② ③ ④	
111	What is your main occupation? ①Agriculture ② Salary/Wages ③Non-Agri. Business ④ Remittances ⑤ Others	① ② ③ ④ ⑤	
112	What is your spouse's main occupation? ①Agriculture ② Salary/Wages ③Non-Agri. Business ④ Remittances ⑤ Others	① ② ③ ④ ⑤	
113	Farming experiences	__________ Years	
114	How would you mainly use your agriculture production? ①Household consumption ②To sell in local Market ③ To sell in distance market	① ② ③	
115	How many months per year your self-produced agricultural products sufficient to feed for your family members?	__________ Months	
116	If your farm produce is not sufficient to feed round the year, how do you manage feeding your family rest of the time? ① Buying food from market ②Buying food from the neighbours ③ Smoothing food habit (2 times a day instead of 3) ④ Contribute in others farm in return for food grains	① ② ③ ④	

117	In your opinion, what is the minimum cash amount that a family of your size would normally need on a monthly basis for food, clothes and others basic needs?	Rs___________	

118	Household size		
	a	<15 years	------------------
	b	16-65 years	-----------------
	c	Over 65 years	------------------

119	Drinking Water Sources ① Shallow Tube well ② Deep Tube Well ③Supply Water ④Open sources (river)	① ② ③ ④	
120	Access to different facilities and markets		
	Institutional services	Do you have access to those asked institutional services? ①Yes ② No	What is the sources of those institutional services? ①Own ②Friends/family/neighbours ③Media ④NG0/INGOs ⑤Government agency ⑥Others
A	Agricultural credit	① ②	① ② ③ ④ ⑤ ⑥
B	Marketing of produce	① ②	① ② ③ ④ ⑤ ⑥
C	Extension of crops and livestock	① ②	① ② ③ ④ ⑤ ⑥
D	Crop insurance	① ②	① ② ③ ④ ⑤ ⑥
e	Weather forecast	① ②	① ② ③ ④ ⑤ ⑥
f	Road network	① ②	① ② ③ ④ ⑤ ⑥
121	Select all the assets presently possessed by the household (Multiple responses possible) ①Radio ②Cell phone ③ Computer ④ Motorcycle ⑤ TV ⑥ Cycle ⑦ Tractor ⑧ Four wheelers ⑨ Others		① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

122	Land holdings			
	Irrigation status	Bigga	Kattha	Dhur
a	Irrigated			
b	Non-irrigated			
c	Total			
123	What kind of ownership does your households have on the majority of lands? ① Owned ② Share cropping ③Tenant ④Leased land ⑤ Others			① ② ③ ④ ⑤
124	How many animals (heads) do you possess?			

Types	Cows	Buffalo	Sheep/goats	poultry	Others	Total
Heads						

125	Which of those animals is the most important one for your livelihood?	①Cows ② Buffalo ③ Sheep/goats ④Poultry ⑤ Others
126	Main crops and what land assigned to them (in % of all arable land)?	

Type	Rice	Wheat	maize	Vegetables	Others(Specify)
% of land					
Status of land ①Rain fed ②Irrigated	① ②	① ②	① ②	① ②	① ②

127	Which of those crops is the main one contributing to your livelihood? ① Rice ② Wheat ③ Maize ④ Vegetables ⑤ Others	① ② ③ ④ ⑤
128	How well is your farming enterprise (agriculture) doing compared to 5 years ago? ① Much better ② Better ③ The same ④ Worse ⑤ Much worse ⑥ NA (I was not in Farming 5 year ago)	① ② ③ ④ ⑤ ⑥
130	What is the different sources of Income? (Multiple responses possible) ① Agriculture ② Livestock ③ Remittances ④ employment ⑤ dairy ⑥ Others	① ② ③ ④ ⑤ ⑥
131	How would you split your annual income sources for the entire household?	① Farm work _________ % ② Livestock and Poultry_________ % ③\Financial Remittances_________ ④ Total Non-farm work_________ % ⑤ Total: 100
132	Has this household received remittances in the past 12 months? यो घरधुरीले गत बर्ष बिप्रेसन प्राप्त गर्यो? ① Yes ② No	① ②
133	Annual Households income (Rs) ① Less than 10000 ② 10000-50000 ③ 50000-100000 ④ 100000-200000 ⑤ more than 200000	① ② ③ ④ ⑤
134	Proportions of annual income from agriculture income	
a	Proportion annual crop Income ① Less than 25% ② 26-50% ③ 51-75% ④ More than 75%	① ② ③ ④
b	Proportion annual farm Income ① Less than 25% ② 26-50% ③ 51-75% ④ More than 75%	① ② ③ ④
135	How do you rate your current living standard compared to standard five years ago? ①Better ②Same ③Worse ④ Do not know	① ② ③ ④
136	If your living standard have been changed, what could be the possible reasons behind such changes	
137	How do you rate your living standard compares with that of most others people in your villages? ① Much below average ② below average ③ Average ④ Above average ⑤ Much above average	① ② ③ ④ ⑤

B. Questions on risk perception of extreme weather events and adaptation practices

201. What are the most important risks you are facing with your farming at the moment? Please tick those risks and rank these accordingly

Farmers' Risks	**Tick (√)**	**Rank (1,2,3,4 and 5) 1st important 2: 2nd important, 3: 3rd Important, 4: 4th important, 5: 5th Important**
Environmental risks		
Drought		
Heat wave		
Cold weather		
Floods		
Excessive rainfall		
Biological risks		
Diseases		
Soil degradation		
Pest/insects		
Weeds		
Financial and market risks		
Low prices for agricultural products		
Market supply and demand volatility		
Lack of market		
High price of inputs		
Lack of inputs		
Human Resources risk		
Illness/Injuries		
Lacks of labourers		
Policy and institutional risks		
Disruption of markets		
No credits available		
Unrest		
Regulatory changes		

Extreme weather events	
202. Have you observed changes in the following weather and environmental parameters in the last 10 years?	① Yes ② No
203. If yes 202, Do you think these changes have affected on agricultural production?	① Yes ② No
204. If yes, how did they affect your farming activities?	(Specify…)
205. Adaptation measures	1. Changing crop varieties 2. Changed crop type 3. Changing planting date 4. Changed fertilizer 5. Increased irrigation 6. Migrate to urban areas for off farm

	employment 7. Rented out crop land 8. Crop diversification (mix-crop) 9. Planted shaded trees in field 10. Others (specify…)			
Extreme heat	① ②	① ②		
Excessive cold	① ②	① ②		
Longer dry spells (drought)	① ②	① ②		
More floods	① ②	① ②		
More extreme rain	① ②	① ②		
Increased frequency of hailstorm	① ②	① ②		

206	If you have observed heat wave (yes in 202), then ask followings	Responses
a	When there was last heat waves?	-----------
b	How many days was it remained?	………………days
c	What was the highest day-time temperatures during the last heat wave?	
d	How many heat waves were there during last year?	……………..numbers
E	How many heat waves were there on average during last five years?	
F	Do you think that there will be more heat waves in the future? ① Definitely yes ② Probably yes ③ Probably not ④ Definitely not	① ② ③ ④
G	If there was heat wave last year, did the heat waves affect the household' livelihoods? ① Not affected ② Moderately affected ③ Highly affected	① ② ③
H	How the heat wave have affected the household' livelihoods last year? [Multiple answer possible] ① Crop production ② Food prices ③ Livestock ④ Fishing ⑤ Houses/assets	① ② ③ ④ ⑤
I	How damaging were the last year heat waves to your household agricultural crop? ① No damage ② Minor damage ③ Some damages ④ Fairly damage ⑤ Extremely damage	① ② ③ ④ ⑤
J	How many animals were killed due to heat waves during last year?	
K	What did you do to cope with these adverse effect of heat wave on livelihoods? ① Looked for extra income ② Sales of properties ③Rely on help from government ④ Rely on help from others ⑤ Others	① ② ③ ④ ⑤
207	If you have observed cold spells (yes in 202), then ask followings	responses
a	When there was last cold spells?	-----------
b	How many days was it remained?	………………days
c	What was the lowest day-time temperatures during the last cold spells?	
d	How many cold spells were there during last year?	……………..numbers
E	How many cold spells were there on average during last five years?	
F	Do you think that there will be more cold spells in the future? ① Definitely yes ② Probably yes ③ Probably not ④ Definitely not	① ② ③ ④
G	If there was cold spells last year, did the cold spells affect the household' livelihoods?	① ② ③

	① Not affected ② Moderately affected ③ Highly affected	
H	How the cold spells have affected the household' livelihoods last year? [Multiple answer possible] ① Crop production ② Food prices ③ Livestock ④ Fishing ⑤ Houses/assets	① ② ③ ④ ⑤
I	How damaging were the last year cold spells to your household agricultural crop? ① No damage ② Minor damage ③ Some damages ④ Fairly damage ⑤ Extremely damage	① ② ③ ④ ⑤
J	How many animals were killed due to cold spells during last year?	
K	What did you do to cope with these adverse effect of cold spells on livelihoods? ① Looked for extra income ② Sales of properties ③Rely on help from government ④ Rely on help from others ⑤ Others	① ② ③ ④ ⑤
208	If you have observed floods (yes in 202), then ask the followings	responses
a	When there was last floods in your areas?	-----------
b	How many days was it remained?	………………days
c	Depth of the last flood	---------------feets
d	How far is the river/stream from your house?	---------------meter
e	How many floods were there during last year?	……………..numbers
E	How many floods were there on average during last five years?	
F	Do you think that there will be more floods in the future? ① Definitely yes ② Probably yes ③ Probably not ④ Definitely not	① ② ③ ④
G	If there was floods last year, did the floods affect the household' livelihoods? ① Not affected ② Moderately affected ③ Highly affected	① ② ③
H	How the floods have affected the household' livelihoods last year? [Multiple answer possible] ① Crop production ② Food prices ③ Livestock ④ Fishing ⑤ Houses/assets	① ② ③ ④ ⑤
I	How damaging were the last year flood to your household agricultural crop? ① No damage ② Minor damage ③ Some damages ④ Fairly damage ⑤ Extremely damage	① ② ③ ④ ⑤
J	How many animals were killed due to floods during last year?	
K	What did you do to cope with these adverse effect of floods on livelihoods? ① Looked for extra income ② Sales of properties ③Rely on help from government ④ Rely on help from others ⑤ Others	① ② ③ ④ ⑤
209	Have you changed/shifted your planting seasons in the last 5 years? ① Yes ② No	① ②
210	If Yes in 209, please explain why do you shift/change planting seasons?	

211. How likely do you think your agricultural production will be affected negatively by floods, heat waves, and cold spells in the next 10 years? [**Perceived probability farm]**

EWEs	**Very likely(4)**	**Quite likely(3)**	**Quite unlikely(2)**	**Very unlikely(1)**
Floods				
Heat waves				
Cold spells				

212. How do you assess the seriousness of the consequences of floods, heat wave and cold spells for your agricultural production? [**Threat experience Appraisal]**

EWEs	**Very seriousness (4)**	**Quite seriousness (3)**	**Not very seriousness (2)**	**Not at all seriousness (1)**
Floods				
Heat waves				
Cold spells				

213. What are the direct and indirect [damage] cost in household level due to following extreme weather events during last year?

SN	**Direct and indirect costs**	**Floods**	**Heat wave**	**Cold spells**
a	Income loss[Absence from work](Days*Wages]			
b	Amount spent to repair and rebuild damage structure[			
c	Cost of illness[Money spent to treat from illness due to sickness from these events]			
d	Losses due to damages to household appliances[TV, fridge etc]			
e	Losses due to damages to household assets[Furniture and utensils]			
f	Losses due to damages to vehicles			
g	Livestock losses			
h	Crop losses			
i	Evacuation and temporary houses			

j	Clean up cost			

214. How likely do you think yourself and your family will be affected negatively by floods, heat waves and cold spells in the next 10 years? [**Perceived probability personal]**

SN	EWEs	Very likely(4)	Quite likely(3)	Quite unlikely(2)	Very unlikely(1)
a	Floods				
b	Heat waves				
c	Cold spells				

215. How likely do you think the crop yield of your seasonal crops will decline in the next 10 years because of the following EWEs? [**Perceived consequences crops]**

	EWEs	Very likely (4)	Quite likely(3)	Quite unlikely(2)	Very unlikely(1)
a	Floods				
b	Heat waves				
c	Cold spells				

216. How likely do you think your housing and farm equipment will suffer physical damages in the next 10 years because of the following EWEs? [**Perceived consequences infrastructure]**

	EWEs	Very likely (4)	Quite likely(3)	Quite unlikely(2)	Very unlikely(1)
a	Floods				
b	Heat waves				
c	Cold spells				

217. Are you worried about the risks of the following EWEs (Floods, heat wave and cold spells) in your community? [**Worry**]

	EWEs	Not at all (1)	A bit worried(2)	Worried(3)	A lot (4)
a	Floods				
b	Heat wave				
c	Cold spells				

218. To what extent do you agree with the following statement: “I do not believe that I am able to avoid the consequences of the following EWEs to my household and my farm”? [**Perceived self-efficacy]**

	EWEs	**Strongly agree (4)**	**Agree (3)**	**Disagree (2)**	**Strongly disagree (1)**
A	Floods				
B	Heat waves				
C	Cold spells				

219. Perceived responsibility: To what extent do you believe that personal responsibility is important in reducing exposures to EWEs?

	EWEs	**Very important (4)**	**Important (3)**	**Rather unimportant (2)**	**Not important at all (1)**
A	Floods				
B	Heat waves				
C	Cold spells				

220. Overall evaluation of previous experiences of damages of floods, heat waves and cold spells on agricultural production in the lasts 5 years? [**Previous experiences of EWEs]**

	EWEs	**Minimal damage (1)**	**Slight damage (2)**	**Bad damage (3)**	**Severe damage (4)**
A	Floods				
B	Heat waves				
C	Cold spells				

221. How effective do you think the following adaptation strategies will be in preventing the negative consequences of floods, heat wave and cold spells on your agricultural production?**[Perceived efficacy of measures]**

a. Floods preventing measures	Very effective (4)	Quite effective (3)	Quite ineffective (2)	Very ineffective (1))
Crop varieties change				
Rising dykes				
Shifts from crops to animals				
Flood tolerant varieties				
Proper drainage				
Residue management (Such as mulching)				
b. Cold spells preventing measures	**Very effective (4)**	**Quite effective (3)**	**Quite ineffective (2)**	**Very ineffective (1))**
Crop varieties change				
Using pesticides				
Changing cropping pattern				
Cold tolerant varieties				
C. Heat Wave preventing measures	**Very effective (4)**	**Quite effective (3)**	**Quite ineffective (2)**	**Very ineffective (1))**
Crop varieties change				
Using pesticides				
Changing cropping pattern				
Deep boring				
Canal irrigation				

222. Are you satisfied with the public management of EWEs (floods, heat waves and cold spells) in your areas? **[Reliance on public protection]**

	EWEs	Very satisfied (4)	Satisfied (3)	Unsatisfied (2)	Very unsatisfied (1)
A	Floods				
B	Heat wave				
C	Cold waves				

223. How likely to be increased the magnitude and frequency of the following extreme weather events in the future?

	EWEs	Very likely(4)	likely (3)	Unlikely(2)	Very unlikely (1)
A	Floods				
B	Heat wave				
C	Cold waves				

224. If there is likely to be increased extreme weather events in the future as shown in the 223, what could be the potential future adaptation strategies to mitigate/minimise the risk of extreme weather events at the individual farm household level?

	EWEs	**Potential adaptation Strategies**
a	Floods ① Buying Insurance ②Reducing the assets exposure ③preparing emergent facilities ④ Improving communication campaign ⑤providing financial incentives ⑤ Making more efficient early warning system ⑥ Others (Specify)………………………..	① ② ③ ④ ⑤ ⑥
b	Heat wave ① Buying Insurance ②Reducing the assets exposure ③preparing emergent facilities ④ Improving communication campaign ⑤providing financial incentives ⑤ Making more efficient early warning system ⑥ Others (Specify)………………………..	① ② ③ ④ ⑤ ⑥
c	Cold waves ① Buying Insurance ②Reducing the assets exposure ③preparing emergent facilities ④ Improving communication campaign ⑤providing financial incentives ⑤ Making more efficient early warning system ⑥ Others (Specify)………………………..	① ② ③ ④ ⑤ ⑥

225. How do you evaluate the overall response cost to carry out the potential adaptation measures to reduce the impacts of the following EWEs in the futures?

	EWEs	**Not costly at all(4)**	**Slightly costly(3)**	**Very costly (2)**	**Extremely costly(1)**
a	Floods				
b	Heat wave				
c	Cold waves				

C. Subjective Wellbeing

300. All things, considered, how satisfied are you with your life in general at the present time in the following dimensions as compared to last five years?	Not at all satisfied (1)	Not very satisfied(2)	Fairly Satisfied(3)	Very satisfied(4)
1.Environmental condition in your area				
2. Financial and economic conditions				
3.Your health				
4.Your social connections and relationships to family and friends				
5.Work conditions/productivity				
Leisure activities				

301. Have following extreme weather phenomenon affected your health and the health of your family in the last five years? ① Definitely yes ② Probably Yes ③ Probably not ④ Definitely not	Responses
a. Floods	① ② ③ ④
b. Heat waves	① ② ③ ④
c. Cold spells	① ② ③ ④

302. If yes in 301, how the following EWEs have affected your and family health over the last five years?	Responses
a. Floods	**Direct health impact:** ☐ Drowning ☐ Injuries ☐ Hypothermia ☐ Mental distress ☐ Snakes bites ☐ Others (Specify)…………………. Indirect health impact: ☐ Risk associated with displacement of disabled, sick, senior people ☐ Communicable diseases (water borne diseases/vector borne diseases ☐ Malnutrition due to poverty ☐ Others (Specify)…………….
b. Heat waves	☐ Heat rash ☐ Dizziness ☐ Confusion ☐ Fatigues ☐ Headache ☐ Nausea ☐ Loss of concentration ☐ Fainting ☐ Heat Strokes ☐ others (specify)
c. Cold spells	☐ Cold related diseases ☐ Joint pain- respiratory problems ☐ Indigestion

303. Have the following extreme weather phenomenon affected your environmental condition in your areas during the last five years? ① Definitely yes ② Probably Yes ③ Probably not ④ Definitely not	Responses
a. Floods	① ② ③ ④
b. Heat waves	① ② ③ ④
c. Cold spells	① ② ③ ④

304. If yes in 303, how the following extreme weather events (Heat waves, cold spells and floods) have affected your environmental condition nearby your locality?	Responses
a. Floods	
b. Heat waves	
c. Cold spells	

305. Have the following extreme weather phenomenon affected your economic and financial condition of your households in your areas during the last five years? **① Definitely yes ② Probably Yes ③ Probably not ④ Definitely not**	**Responses**
a. Floods	① ② ③ ④
b. Heat waves	① ② ③ ④
c. Cold spells	① ② ③ ④

306. If yes in 305, how the following extreme weather events have affected your economic and financial condition of your households?	**Responses**
a. Floods	
b. Heat waves	
c. Cold spells	

307. Have following extreme weather phenomenon affected social connectedness with your family and neighbourhood during the last five years? **① Definitely yes ② Probably Yes ③ Probably not ④ Definitely not**	**Responses**
a. Floods	① ② ③ ④
b. Heat waves	① ② ③ ④
c. Cold spells	① ② ③ ④

308. If yes in 307, how the following extreme weather events (Heat waves, cold spells and floods) have affected your social connectedness with your family and neighbourhood?	**Responses**
a. Floods	
b. Heat waves	
c. Cold spells	

309. Have following extreme weather phenomenon affected working condition including labour productivity and leisure during the last five years? **① Definitely yes ② Probably Yes ③ Probably not ④ Definitely not**	**Responses**
a. Floods	① ② ③ ④
b. Heat waves	① ② ③ ④
c. Cold spells	① ② ③ ④

310. If yes 309, how the following extreme weather events (Heat waves, cold spells and floods) have affected your working condition including labour productivity and leisure?	**Responses**
a. Floods	
b. Heat waves	
c. Cold spells	

D. Labour productivity loss problems due to heat and cold spells

SN	Questions	Responses and codes	Go to
401	Did you feel heat stress while you involve in agricultural activities last year? ① No, not at all ② Yes, rarely ③ Sometimes ⑤ often ⑥ very often	① ② ③ ④ ⑤ ⑥	
402	If you felt heat stress, did you find yourself less productive due to heat stress while you worked in agricultural fields? ① No, not at all ② Yes, rarely ③ Sometimes ⑤ often ⑥ very often	① ② ③ ④ ⑤ ⑥	
403	Since heat waves are common in the dry season (summer season) how much of the time did you find difficult to work on agricultural field as a result of the heat waves last year? ① All the time (100 %) ② Most of the time (75 %) ③ Half of the time ④ Some of the time ⑤ None of the time	① ② ③ ④ ⑤	
404	How many more hours will you be willing to work to compensate the labour productivity loss as a result these extreme weather events (heat waves) per day? ① 1 hour ② 2 hour ③ 3-4 hours	① ② ③	
405	What preventative measures do you currently adopt to avoid heat related stress in the agricultural fields? ① Broad brimmed hats ② Resting in shade ③ Stop working if temp is too hot ④ Rescheduling work time/shift in working hours ⑤ Provision of cool ⑥ Others (Specify)…………	① ② ③ ④ ⑤ ⑥	If response is ② in 405, ask next 406, 407 and if response is ④, ask 408
406	If resting in shade, how many times per day? ① One or two times ② 3 or 4 times ③ More than 4 times	① ② ③	
407	How long rest do you normally take per hour during a hot day? ① 1 to 5 minutes ② 6-10 minutes ③ 11-15 minutes ④ > 15 minutes	① ② ③ ④	
408	If you shift in working hours, what is the shift? ① start early and finish early ② Start late and finish late ③ Both	① ② ③	
409	Do you change your work plan while you work during hot days? E.g. to work inside, instead of working on the farm? ① No, not at all ② Yes, rarely ③ Sometimes ⑤ often ⑥ very often	① ② ③ ④ ⑤ ⑥	
410	Do you have a means to cool down when it is very hot during farm work? ① Yes ② No	① ②	If yes ask next 412, otherwise skip
411	If yes, how?		
412	Do you hire more labourers to get the work done on very hot days? ① Yes ② No	① ②	
413	Have you experienced your labourers to be less productive of very hot days? ① Yes ② No	① ②	

414	How much time do you normally work in the field in the summer season?	☐ Summer season: ☐ Average days per season: ☐ Working hour/days:
415	How many days on average were you and your household members were not able to work/unemployed due to cold waves?	
416	Did you feel cold spells while you involve in agricultural activities last year? ① No, not at all ② Yes, rarely ③ Sometimes ⑤ often ⑥ very often	① ② ③ ④ ⑤ ⑥
417	If you felt cold spells, did you find yourself less productive due to cold spells while you worked in agricultural fields? ① No, not at all ② Yes, rarely ③ Sometimes ⑤ often ⑥ very often	① ② ③ ④ ⑤ ⑥
418	Since cold spells are common in the winter season, how much of the time did you find difficult to work on agricultural field as a result of the heat waves last year? ① All the time (100 %) ② Most of the time (75 %) ③ Half of the time ④ Some of the time ⑤ None of the time	① ② ③ ④ ⑤
419	How many more hours will you be willing to work to compensate the labour productivity loss as a result these extreme weather events (heat waves) per day? ① 1 hour ② 2 hour ③ 3-4 hours	① ② ③
420	What preventative measures do you currently adopt to avoid heat related stress in the agricultural fields? ① Wearing warm cloths ② Stop working if temp is too cold/resting to warm up/fires ③ Rescheduling work time/shift in working hours ➍ Drinking tea ➎ Others (Specify)…………	① ② ③ ④ ⑤
421	If resting to warm up, how many times per day? ① One or two times ② 3 or 4 times ③ More than 4 times	① ② ③
422	How long rest do you normally take per hour during a cold day? ① 1 to 5 minutes ② 6-10 minutes ③ 11-15 minutes ④ > 15 minutes	① ② ③ ④
423	If you shift in working hours, what is the shift? ① start early and finish early ② Start late and finish late ③ Both	① ② ③
424	Do you change your work plan while you work during cold days? E.g. to work inside, instead of working on the farm? ① No, not at all ② Yes, rarely ③ Sometimes ⑤ often ⑥ very often	① ② ③ ④ ⑤ ⑥
425	How much time do you normally work in the field in the winter season?	☐ Winter seasons: ☐ Average days per season: ☐ Working hour/days:
426	How is your health in general? Would you say it is? ① Very good ② Good ③ Fair ④ Bad ⑤ Very bad	① ② ③ ④ ⑤
427	How many days on average were you and your household members were not able to work/unemployed due to cold waves?	

E. Agricultural insurance

In order to minimise the losses to your crops due to natural disasters; Floods, drought, cold wave, heat waves and others disaster, government of Nepal is implementing yield based crop insurance program, in which a farmer can buy separate insurance coverage for one or more crops and pay separate premium for each policy. On that background, I would like to ask you some questions to assess the market potential yield based crop insurance program in your areas. In principle, you pay a fixed amount of money per hectare per cropping season to the insurance provider company as a premium (75 percent will be paid by the government and 25 percent premium will be paid by the farmers) and in return the losses you suffer due to future natural disasters which will be compensated after the official recognition of the damages. Average area yield per hectare (yield index) will be prepared for the crops of the insured units based on the historical data as declared by the agricultural development office. An official representative of the insurance provider company will conduct a survey of your agricultural field to identify and quantify the damages and losses to your crops. If average yields fall below the index up to 90 percent compensation will be given on the basis of amount by which actual average yield (monetary value of crops as fixed by DADO) by falls short of the index.

SN	Questions	Responses and codes	Go to
500	Do you have agriculture or crop insurance? ① Yes ② No	① ②	
501	Do you know what agricultural or crop insurance is? ① Yes ② No	① ②	
502	Would you like to join yield based crop insurance scheme if introduced? ① Yes ② No	① ②	
503	Are you willing to pay ------------------(Initial bid) Rs per hectare of paddy farm for the yield based crop insurance? ① Yes ② No	① ②	
504	If No to 503, are you willing to pay ---------------(lower bid) Rs per hectare of paddy for the yield based crop insurance? ① Yes ② No	① ②	

505	If yes to 503, are you willing to pay ……………………………(higher bid) Rs per hectare of paddy for the yield based crop insurance? ① Yes ② No	① ②	
506	If yes in 505, What is the maximum amount that you are willing to pay to insure a hectare paddy crop land?		
507	Are you willing to pay -------------------(Initial bid) Rs per/hectare of wheat farm for the yield based crop insurance? ① Yes ② No	① ②	
508	If No to 507, are you willing to pay ----------------(lower bid) Rs per/hectare of wheat for the yield based crop insurance? ① Yes ② No	① ②	
509	If yes to 507, are you willing to pay ……………………………(higher bid) Rs per/hectare of wheat for the yield based crop insurance? ① Yes ② No	① ②	
510	If yes in 509, What is the maximum amount that you are willing to pay to insure a hectare paddy crop land?		
511	In what way, you are you willing to pay the premium? ① Cash ② In Kind	① ②	
512	What time are you willing to able to pay the premium? ①Right after harvest ② During land preparation ③ At the time of sowing ④ After sowing ⑤ Others	① ② ③ ④ ⑤	
513	If yes to 502, why would you like to purchase insurance?		
514	If no to 502, why you would not like to purchase insurance?		
515	How important of agricultural insurance as a coping mechanism for Extreme weather events? ① Very important ② Relatively important ③ Neutral ④ Unnecessary	① ② ③ ④	