Climate change perception, vulnerability and adaptive agricultural practices of the Tharu in the western Tarai of Nepal

Buddhi Ram CHAUDHARY THARU, M.A., M.Sc. Agri.

This thesis is presented for the degree of Doctor of Philosophy of The University of Western Australia

School of Social Sciences; School of Agriculture and Environment

Anthropology and Agricultural Science

2021

THESIS DECLARATION

I, Buddhi Ram CHAUDHARY THARU, certify that:

This thesis has been substantially accomplished during enrolment in this degree.

This thesis does not contain material which has been submitted for the award of any other degree or diploma in my name, in any university or other tertiary institution.

In the future, no part of this thesis will be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of The University of Western Australia and where applicable, any partner institution responsible for the joint-award of this degree.

This thesis does not contain any material previously published or written by another person, except where due reference has been made in the text.

This thesis does not violate or infringe any copyright, trademark, patent, or other rights whatsoever of any person.

The research involving human data reported in this thesis was assessed and approved by The University of Western Australia Human Research Ethics Committee. Approval #: RA/4/20/4133.

Third-party editorial assistance was provided in the preparation of this thesis by Dr Christine Davies, Principal Editor, Tweak Editing, Australia.

This thesis does not contain work that I have published, nor work under review for publication.

Signature: [redacted]

Date: 6 July 2021

ABSTRACT

Agriculture is one of the sectors most impacted by climate change, thereby affecting farming communities and food systems. The Tharu Indigenous people of Nepal have for generations engaged in farming and natural resource usage in the Tarai (plains region) of Nepal. This thesis addresses how they perceive and have responded to the changing climate based on research in two rural villages in the Bardiya district, Thapuwa and Bikri, that have experienced contrasting vulnerability to flooding and drought hazards, respectively. An exploratory sequential mixed-methods research design, involving the collection of quantitative data through household surveys and, later, qualitative data through interviews and participant observation, was used for the six months of fieldwork.

Tharu perceive that temperatures have increased and rainfall has decreased in the recent decades. The increased temperature perceptions is validated with the meteorological data of the area/district whereas the decreased rainfall perceptions could not be validated due to high inter-annual variations. The Tharu prioritised flooding and cold waves as the first- and third-most significant hazards for both villages, whereas in terms of their impact on livelihood and future risks, storm and drought were placed in second position in Thapuwa and Bikri, respectively. The Tharu apply both Indigenous and scientific knowledge to predict the climate and weather, climatic extremes, and crop production and management. However, the application of Indigenous knowledge has decreased, particularly amongst the youth, a consequence of their formal education, the availability of information and communication technology, and increasing household economic needs.

The types of capital linked to livelihood determine the adaptive capacity of individuals and communities, which varies with space, gender, and social/cultural factors. The village location determines the accessibility of markets and services, and the sensitivity to hazards, which was comparatively higher in Thapuwa than Bikri. Land ownership, education and services significantly affect adaptive capacity; therefore, smallholder tenants and women had consistently lower adaptive capacity than did large landholders and men. However, women had a better position with regard to certain forms of livelihood capital, such as social and financial capital, mainly due to social networking and cash saving for adaptation measures. Tharu farmers use Indigenous and local knowledge in agriculture in many ways to adapt to and mitigate the effects of climate change, including for crop production (e.g. relay sowing, mixed cropping, crop landraces), crop protection (non-chemical measures), and storage of produce. Local farming practices are resilient to climate and emit low levels of greenhouse gases, but yields are mostly lower than modern agricultural practices. The adoption of high-yielding improved and hybrid seeds in major staple crops (rice, maize, wheat) has increased, along with irrigation technology and chemical inputs, to meet the increasing demand for household food security and economic needs. However, traditional methods continue to be used for lentil and other minor crops. In the future, local agriculture practices will require a competitive yield and profit advantage for smallholders to adapt to and mitigate climate change.

Keywords: vulnerability, adaptation, mitigation, climate resilience, climate-smart agriculture

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACKNOWLEDGMENTS

This research was supported by an Australian Government Research Training Programme (RTP) Scholarship.

The second round of fieldwork was part funded by UWA Convocation Postgraduate Research Travel Award in 2018.

Technical assistance was kindly provided by Prakash Chaudhary and Mangal Khunha for the household survey and focus group discussions, respectively, as described in the research methodology.

I express my deepest gratitude to all for their support and contribution during my candidature. This thesis is the product of coordinated, combined, and sustained efforts of many people throughout my PhD journey.

First, my sincere thanks go to my advisers, Dr Greg Acciaioli and Professor William Erskine, for their ongoing discussions, feedback, and assistance to shape me as a scholar. I am thankful to Associate Professor Katie Glaskin for helping me reach the end of my PhD candidature as coordinating supervisor in the final months. Thank you, Dr Pashupati Chaudhary, Nepal field supervisor, for your advice and support during the Nepal fieldwork and early chapter drafts. I would like to thank the Graduate Research School (GRS), UWA for technical and administrative support throughout my PhD candidature.

I also express my appreciation to the people of Thapuwa and Bikri villages who coordinated and participated in my research through interviews, group discussions, and surveys. My appreciation is extended to the *Barghar* (village head), *Guruwa* (Tharu shaman), and *Chaukidar* (watchman) in each village for their cooperation, support and care throughout my studies.

Finally, I am grateful to my father, Shalik Ram Tharu, and all my relatives and friends for their encouragement during the fieldwork and making my stay wonderful. Special thanks go to my wife, Laxmi Chaudhary, and son, Pranjal, who have filled my life with joy.

[redacted]

Buddhi Ram Chaudhary Tharu

6 July 2021

ABBREVIATIONS AND ACRONYMS

ADS	Agriculture Development Strategy
AFOLU	Agriculture, Forestry and Other Land Use
APP	Agriculture Perspective Plan
AR4/AR5	Fourth/Fifth Assessment Report of IPCC
CA	Conservation Agriculture
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon dioxide
COP	Conference of Parties
CVCA	Climate Vulnerability and Capacity Analysis
DHM	Department of Hydrology and Meteorology
DLSO	District Livestock Service Office
DSR	Direct-seeded Rice
FAO	Food and Agriculture Organization of the United Nations
FMIS	Farmers Managed Irrigation System
G/RCM	General/Regional Circulation Model
GHG	Greenhouse Gases
Gt CO_2 -eq/yr	Gigatonne of CO_2 -eqivalent per year
GWP	Global Warming Potential
ha	hectare
hh	household
hhh	household head
I/NGO	International/Non-government Organisation

IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IPR	Intellectual Property Rights
ITPGRFA	International Treaty on Plant Genetic Resources for FAO
IUCN	International Union for Conservation of Nature
Kg	Kilogram
km	kilometre
LAPA	Local Adaptation Plan of Action
LDC	Least Developed Countries
m	meter
mm	millimetre
m asl	m above sea level
N_2O	Nitrous oxide
NAPA	National Adaptation Plan of Actions
NPK	Nitrogen, Phosphorus, and Potash
NPR/Rs	Nepali Rupees
NT	No-tillage
^oC	degree centigrade
OECD	Organisation for Economic Co-operation and Development
PAR	Photosynthetically Active Radiation
ppm	parts per million
RCP	Representative Concentration Pathway
REDD+	Reducing Emission from Forest Deforestation and Degradation
SAR	Second Assessment Report of IPCC
SLF	Sustainable Livelihood Framework

SRES	Special Report on Emission Scenarios based on the Third Assessment Report of IPCC
SREX	Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation of the IPCC
t/mt	ton/metric ton
TAR	Third Assessment Report of the IPCC
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	The United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
UWA	The University of Western Australia
V2R	Vulnerability to Resilience
VBS	Vikram Samvat. Approx. 56 years ahead than AD
WG (I, II, III)	Working Group of the IPCC: I– physical sciences, II– adaptation, III– mitigation
ZT	Zero-tillage

GLOSSARY AND TERMS

Tharu word	Nepali word	English word/ meaning
Months		
Baisakh	Baisakh	April–May
Jeth	Jesth	May–June
Asar	Asar	June–July
Saun	Shrawan	July–August
Bhadau	Bhadra	August–September
Kuwar	Asoj	September–October
Katik	Kartik	October–November
Aghan	Mangsir	November–December
Pus	Paush	December–January
Magh	Magh	January–February
Fagun	Falgun	February–March
Chait	Chaitra	March–April
Seasons, climate and weather		
Badri	Badal	Cloud
Bahiya/Barh	Badhi	Flooding
Barkha mahina	Barkha mahina	Rainy months
Bundibunda pani	Phatphut pani	Rain droplets
Charcharwa gham	Charko gham	Intense/hard sunlight
Gaiya berhna	–	Rainmaking ritual event
Gham mahina	Garmi mahina	Summer months
Hawapani	Jalbau	Climate
Hewat	Sit lahar	Winter rain

Jar mahina	Jado mahina	Winter months
Jhammak pani	Jhammak pani	Heavy rain
Jhimjhim pani	Simsime pani	Light rain
Kuhira	Kuhiro/Tuwalo	Fog
Laram gham	Nyano/Parilo gham	Soft sunlight
Magha lotna	–	Rainmaking ritual event
Mausam	Mausam	Weather
Pala	Tusaro	Frost
Ragga	–	Rainfall gap during the rainy season
Sailaf	Bhisan badhi	Disastrous flooding
Sukkha	Sukha	Drought
Land and natural resources		
Ailani	Ailani	Unregistered land
Asami	Haliya	Tillers
Baggarwa/Baggar	Bagar	Riverbed
Bansapti	Bandevi	Forest deity
Bari	Karesabari	Home garden
Bataiya	–	Sharecropping
Burhan	Naya Muluk	New Territory (Banke, Bardiya, Kailali and Kanchanpur districts)
Dihwa/Dadwa	Bari	Upland
Gharauri/gharbas	Ghaderi	Residential land
Jabda	Gairikhet	Lowland paddy field
Janglad	Janglad	Forestland
Jimidar/Jamindar	Jamindar	Landlord

Kamaiya	–	Bondage labour system in agriculture
Kanbhara	–	Payment (cash/kind) by *Asami* to *Jimidar* to leave the village
Khetwa/khet	Khet	Paddy field
Mahut	Mahute	Elephant trainer and carer
Oenra	Garha	Terrace plot of rice field
Parti	Banjho	Uncultivated agricultural land
Phata	Phant	Grassland
Tarai	Terai/Madhesh	Plainland

Agriculture and farming

Adhiya bataiya	Adhiya	Sharecropping where the tenant pays 50% of production to the landowner
Atwa	Machan	Watchtower
Baggar/ Ghari	Goth	Cattle shed
Bakhari	Bhakari	Grain storage made from bamboo/grass
Begari	Samuhik Sramadan	Compulsory free labour contribution mostly in community work
Bharwa	Bhari	Traditional methods of carrying weight by people such as carrying/shoulder pole
Buwari	Chhita dhan	Rice sowing in the puddled field
Chhirwa	Goth	A house open on both sides
Danta Kilwahi	Dante	Raking
Dehari	–	Large earthen bin in the Tharu community
Dharrha	Ghas	Herbaceous grass

Dhuriya	Banjho jotai	First-time tillage of upland field (*dihwa/bari*) before the season starts
Gejar	Dosro jotai	First tillage during the rice puddling process and left for 1–2 weeks to decay the weeds
Har	Halo	Plough
Henga Sarawan	Samyaune	Levelling
Jhukka	Bukhyacha	Scarecrow
Kamda	–	Small hut at the farm for rest
Kharhi	Khali	Pile of harvested crop
Khenhwa/ Kharenhwa	Khalyan	Yard prepared for threshing and cleaning agricultural produce
Lewa	Hilyaune	Puddling of wet rice field
Nihna	Melo	A row of harvested crops
Odra	Khalde paso	Deadfall trap
Ofar/Chir	Banjho jotai	First tillage of rice field before season starts
Food and beverages		
Basi	Bihanko khaja	Breakfast
Kalwa	Bihanko khana	Lunch
Mijhni	Arni/Nasta	Day-snacks and food
Beri	Sanjhko khana	Dinner
Maar	Maad	Boiled rice with plenty of soup to drink in the summer
Jaar	Chhyang	Rice beer
Chichar	Andi ko bhat	Sticky rice cooked in steam
Daru/Maad	Raksi	Local liquor

Ghonghi	Ghongi	Water snail
Mus	Musa	Field rat
Machhi	Machha	Fish
Deities and worship		
Auli	–	A special event performed at the start and end of rice harvesting
Bandhup	Dhup	Unique essence prepared by *guruwa* and offered to deities during worship by firing on charcoal fire
Barka kalwa	–	Lunch at the start of rice transplantation where the *Bagha* deity is worshipped to protect bullocks and tillers
Bhutwa/deuta	Devata	Deity
Bramathan/Thanhwa/Marwa	Mandir	Village shrine
Chiraki	–	Assistant of *guruwa* and *kesauka*
Darbandhi	–	Ritual to protect the village through sealing four corners of a village
Desbandhya/Pathrathiya gurwa	Gau pujari	Shaman who serve village shrine and selected by the villagers
Deuhrar	Puja kotha	Divinity room
Dhuriya	–	Ritual ceremony to protect livestock and people in the village

Gandhi hakna	–	Gandhi bug removal process from the rice field
Ghar guruwa	Ghar pujari	Shaman who serve within family and group/clan (*jat*)
Gurbaba	–	First Tharu god who created earth and life
Guruwa/Gurau	Dhami/ Jhakri	Shaman cum healer
Hardahwa	–	Ceremony for completion of rice transplantation
Hareri	–	Ritual performed to keep crop green and productive
Harot lena	–	Worshipping the plough and bullock to ensure good crop production
Lawangi	–	First tasting of new products of the season
Mantar	Mantra	Spiritual songs of *guruwa* to treat and control spirits
Nikasi	–	Sending deities from village to rest in forest and Patan (India)
Pata	Singhasan	Special place for deities on ground in the divinity room
Pendia	–	Celebration of completion of rice threshing
Suswaina	Dhami/Jhakri khelne	Shaking the body by *guruwa* through the shamanistic power
Sakhya naach	–	A long dance of more than a month before and during the *Dashya* festival
Mangar	–	A special song sung during marriage

Institutions

Baidawa	Baidya	Traditional healer
Barghar/Mahtawa	Mukhiya	Village leader/head in the Tharu village
Chaukidar	Pale/Chaukidar	Watchman/messenger
Kachehri/Khayala	Baithak	Community/village meeting under the *barghar* system
Sorihnya	Sudheni	Traditional birth attender

CHAPTER 1. INTRODUCTION

1.1 Background and rationale for the research

Climate change is a serious global threat impacting multiple sectors and thus human life. Temperature increases due to the increased concentration of greenhouse gases (GHG), predominantly carbon dioxide (CO_2) from anthropogenic intervention, are a major concern. Agriculture is one of the sectors that is heavily impacted by climate change, challenging global food systems and the livelihoods of dependents. Agriculture is an important GHG emitter (5.0–5.8 gigatonne of CO_2-equivalent per year, Gt CO_2 -eq/yr), contributing 10–12% of global anthropogenic emissions (Smith et al., 2014). Methane (CH_4) and nitrous oxide (N_2O) are two important gases emitted by agriculture, mainly from wet rice, inorganic fertiliser and cattle (IPCC, 2014b; Smith et al., 2014).

There is an established relationship between climate change and natural disasters (IPCC, 2012). Global temperatures have increased by 0.78°C since the pre-industrial era (pre-1850) and are predicted to increase by 2°C by the end of the 21st century (IPCC, 2014c). Changes in temperature and precipitation patterns lead to extreme events, such as flooding, droughts and severe heat/cold waves, which have a severe impact on farming and livelihoods. Nepal is one of the most vulnerable countries to climate change, where changes in climate variability have been fast and unpredictable. An analysis of 24 years of data (1971–1994) showed that the average temperature has increased by 0.03°C/year in the Tarai region and 0.06–0.12°C/year in the mountain and the Himalaya regions (Shrestha, Wake, Mayewski, & Dibb, 1999). Similarly, a climatic analysis of data from 1976–2005 showed that the maximum and minimum temperatures in Nepal have increased by 0.05°C and 0.03°C per year (Practical Action, 2009). Projected temperature increments for Nepal are higher than global temperature trends, with the mean annual temperature predicted to increase by 1.2°C by 2030, 1.7°C by

2050 and 3.0°C by 2100 using General Circulation Models (GCM) and Special Report on Emission Scenarios (SRES B2[1]) (MoE, 2010a). Changes in rainfall pattern are less well-defined than those for temperature, but inter-seasonal rainfall variation has increased, along with rainfall in the post-monsoon period. Various sources have also showed a decline in winter rainfall (MoE, 2010a; Practical Action, 2009; Shrestha et al., 1999).

Within Nepal, exposure to climate change and its impact varies with geographical region and the sociocultural context of individual families. Natural resource-dependent and farming communities/households in developing countries are more vulnerable than non-farming communities and households in developed countries, which is mainly due to their different adaptive capacities in adjusting to the changing climate scenario. Various types of livelihood capital or assets (social/cultural, economic, natural, physical, and financial), including institutions and the governance system, determine the adaptive capacity in regard to climate change of an individual or a community (Deressa, Hassan, & Ringler, 2008; Gentle & Maraseni, 2012; Porter et al., 2014).

Globally, Indigenous people have limited livelihood options and are heavily dependent on natural resources. They are among the first to observe, experience and respond to a changing climate (Galloway McLean, 2009). This study focuses on the Tharu of the western Tarai[2] of Nepal who have been, for generations, dependent on agriculture, with limited engagement in services, business and foreign labour (Bista, 1972; Chaudhary, 2008; Guneratne, 2002). This study is based in the Bardiya district, so it mainly represents the *naya muluk* (new territory: Banke, Bardiya, Kailali, and Kanchanpur districts), including the Dang district of western

[1] The Third Report (TAR, 2000) of the IPCC published four storyline and scenario families for SRES scenarios (A1, A2, B1 and B2), where B2 is envisioned local solutions for economic, social and environmental sustainability, with increasing population and moderate economic growth (Nakicenovic et al., 2000).
[2] Tarai is the southern plain region of Nepal. It is also described as foothills in many publications. Tarai and Terai are interchangeably used in the literature, but here we use Tarai, as the spelling Terai has connotations of the usage of the East India Company during the British colonial era.

Nepal. The Tarai of Nepal, particularly central and western, comprised forested land with a high risk of malaria infections before malaria was eradicated during the American Malaria Eradication Project in the late 1950s. The Tharu in the Tarai were the only frontier group who continuously settled and supported Nepali rulers. As a consequence of adaptation in long-term settlement, the Tharu became genetically resistant to malaria (Modiano et al., 1991). After the eradication of malaria, hill and mountain people were encouraged to migrate and resettle in the Tarai, keeping the Tharu economically, socially and politically marginalised and suffering from an identity crisis (Guneratne, 1998 & 2002; Müller-Böker, 1997; Müller-Böker, 1999a).

The concept of indigeneity—a type of first-order of connection between groups and locale—can be clearly seen based on their continuous and distinct relationship with the locality that differentiates Tharu from others in the Tarai. As described by Merlan (2009:304), an expanded meaning of indigeneity includes the criterion of "peoples who have great moral claims on nation-states and international society, often because of inhumane, unequal and exclusionary treatment." The Tharu were liberated from slavery bondage labour (*kamaiya* system) only at the beginning of the 21st century and are still subjected to exclusion, exploitation, and social inequality by dominant, upper-caste groups. In Nepal, Tharu are recognised as an *aadibasi janjati*[3] (Indigenous nationality); they live mainly in the Tarai of Nepal[4] and the northern region (Bihar, Uttar Pradesh, and Uttaranchal) of India[5]. Despite their significant population size, they experience marginalisation, exploitation and identity crisis in modern Nepal (Dalzell, 2015).

[3] The National Foundation for Development of Indigenous Nationalities (NFDIN) Act 2002 legally recognised 59 Indigenous nationalities in Nepal. As the NFDIN Act 2002 of Nepal defines the term, "Indigenous Nationalities means a tribe or a community as mentioned in the schedule having its own mother language and traditional rites and customs, distinct cultural identity, distinct social structure, and written or unwritten history."

[4] According to the Central Bureau of Statistics/CBS (2011a), the Tharu are the second largest Indigenous nationality after the Magar. The largest population group is the Chhetri (16.6%) followed by Brahmin hill (12.2%) and Magar (7.1%). The total population of Indigenous people in Nepal is 35%.

[5] In India, the Tharu are classified under scheduled tribe status, meaning that they are historically disadvantaged Indigenous people. Their population is 453,000 (JOSHUA Project, 2018).

Indigenous people's knowledge of climate change in agriculture raises two major issues: (1) their dependency on natural resources makes Indigenous people more vulnerable than non-Indigenous people; and (2) their understanding of nature, environment, and response to the changed context can reduce the impact and future risks of climate change. Such understanding, as well as the related practices, is called Indigenous knowledge[6]. Three forms of knowledge—Indigenous, traditional and local—are often used interchangeably in the literature; however, there are distinct connotations of these terms. Indigenous knowledge relates to Indigenous people, traditional knowledge implies knowledge in a rural setting, and local knowledge comprises wider observations, experiences and beliefs of local people, irrespective of ethnicity or geographical location (FAO, 2004). These terms and concepts are discussed in subsequent chapters, particularly in the general discussion and conclusions, comparing the three knowledge types in terms of the adaptation to and mitigation of climate change and crop yield and profitability. In the discussion, local knowledge derives in part from and is integrated with modern knowledge and practices in the process of knowledge generation, validation and transmission.

Indigenous knowledge has positive and negative aspects. In the modern world, Indigenous knowledge has proved beneficial when integrated with science. Local practices and Indigenous knowledge have been integrated in climate science and natural resource management in many projects worldwide, such as Inuit knowledge used for exploring snow routes in Canada (Galloway McLean, 2009) and Australian Aboriginal knowledge for controlled bushfire management in Australia (Andersen et al., 2005; Kimber, 1983). Similar examples involve traditional techniques for field contouring in Mali that reduce water runoff

[6] Various Indigenous knowledge terms are used interchangeably in the literature to refer to common characteristics associated with Indigenous and local people, localised understanding, tacit knowledge, generated through generational experiences, transferred orally, dynamic in nature, and usually associated with low levels of technology. Indigenous practices are the actions and implementation of Indigenous knowledge.

by 20–50% and increase yields by up to 30% (Technology Need Assessment, 2017), and shifting cultivation or swidden farming practices used by Indigenous communities in the tropics. However, debate surrounds soil degradation and low production under shifting cultivation, which involves keeping land fallow between crop plantings, crop rotations and slope/contour farming, all of which are useful for improving soil fertility and reducing carbon emissions. Dry rice farming under shifting cultivation by many Indigenous people in Asia uses local resources and reduces soil degradation and nutrient losses (Conklin, 1957, 1980; Sillitoe, 2017). There are diverse local practices in agriculture, mainly for crop production and soil and insect-disease management (Dewalt, 1994; Thurston, 1990; Warren, 1991).

The important role of specific Indigenous knowledge does not mean that all Indigenous and local knowledge is effective and applicable in all contexts (Dewalt, 1994; Sillitoe, 2007). Local knowledge has limitations related to factual information, and can be impacted by a binary ideology of Indigenous knowledge and western science, romanticised concepts, contextual interpretations, and localised applications (Agrawal, 1995; Briggs, 2005, 2013; Ghorbani, Khodamoradi, Bozorgmanesh, & Emami, 2012; Lodhi & Mikulecky, 2010). Sillitoe (2007) reminds us that people make mistakes providing examples of the knowledge of refugees who are often incapable of managing in a new place and often misinterpret the Indigenous knowledge they encounter. Dewalt (1994) describes how scientific knowledge complements Indigenous knowledge; for example, managing locusts by identifying specific species and using scientific control measures when local Indigenous knowledge does not recognise such species at the time and place of the outbreak. There is also an issue surrounding Indigenous knowledge documentation and ownership (Dutfield, 2001). The integration and legitimisation of Indigenous knowledge with formal science could help to develop and scale-up Indigenous knowledge using programmes of bilateral/multilateral agencies (Briggs, 2013). My discussion of knowledge systems is not limited to Indigenous knowledge, traditional and local knowledge, but also covers scientific knowledge and modern agricultural practices to determine the multiple strategies of the Tharu Indigenous people for climate change adaptation and mitigation.

Studies on Tharu knowledge have to-date largely focused on wild food and medicinal plants (Dangol, 2008; Ghimire, Shrestha, Shrestha, & Jha, 2000; Manandhar, 1985; Müller-Böker, 1993; Uprety et al., 2010). Dahit (2008) listed several Indigenous knowledge domains, including farming, fishing and hunting, of the Tharu in western Nepal, but the study focused on medicine, organisations, and food and beverages. Some studies on the western Tharu have exclusively focused on climate change perception, impact and vulnerability (Devkota, Bajracharya, Maraseni, Cockfield, & Upadhyay, 2011; Maharjan, Sigdel, Sthapit, & Regmi, 2011), but studies of Indigenous knowledge and agricultural practices are limited. Current scientific understanding of Tharu knowledge does not extend to what they know about climate, weather and the contribution of agricultural practices for adapting to and mitigating climate change. This study expands the Indigenous knowledge on climate change and adds to the theoretical discourse of traditional agricultural practices for climate-resilient and climate-smart agriculture.

This research is interdisciplinary, incorporating anthropological and agronomic aspects of agriculture. The philosophical ideas, study approach and methods for addressing climate change in agriculture may vary in anthropology and agronomy, but the expected outcomes are overlapping, i.e. reducing the impact of climate change and reducing or preventing emissions for resilient agriculture and farmer wellbeing. This study integrates the knowledge and practices of Tharu Indigenous people, with scientific references, and exposes numerous issues associated with local knowledge and practices for knowledge generation.

1.2 Research questions and scope of the study

The central question of this study was how the knowledge of Tharu contributes to improving resiliency in agriculture in the context of the changing climate. The research question changed from an initial focus on the knowledge of the Tharu to encompass broader consideration of the adoption of techniques that were not traditionally part of Indigenous knowledge. This was partly due to the interdisciplinary research being positioned between anthropology and agricultural science, where most anthropological studies focus on emic (the cultural perspective or insider's view) views of traditional agricultural practices, while agricultural science concentrates to technological advancements and chemical-based agriculture. Further, knowledge is a dynamic concept, and Tharu farmers have adopted many modern agricultural technologies and practices. Nepal's priority is to increase crop production, mainly in the Tarai region because it comprises the only flat land in Nepal, and is considered the *annako bhandar* (food/bread basket) of the nation. This study aims to combine anthropology and agriculture to interpret the knowledge and practices that the Tharu apply in their daily life and agriculture.

Specifically, the research investigates the perceptions, impact and strategies for coping with and adapting to climate change, based on the Indigenous knowledge of Tharu and the adoption of scientific information, technology and practices to reduce their vulnerability. The perceptions of climate change are constructed subjectively through experiences of climate-related hazards and extremes, and influenced by previous experiences and socioeconomic factors (Deressa, Hassan, & Ringler, 2011; Gbetibouo, 2009; Otto-Banaszak, Matczak, Wesseler, & Wechsung, 2011; Piya, Maharjan, & Joshi, 2012b). The adaptive capacity of household and community can be measured by assessing the status of livelihood capital (physical, natural, social/cultural, human and financial) through participatory focus group discussions (van de Sand, 2012).

The specific research questions were:

1. What are the perceptions of the Tharu about vulnerability and the impact of climate variability and weather extremes on their livelihoods?
2. What determines adaptive capacity and what are the strategies of Tharu farmers for coping with climate risks?
3. What knowledge and practices do the Tharu use in agriculture and how are they effective for climate change adaptation and mitigation?

The perceptions of climate change and its impact are important for shaping beliefs and attitudes related to management strategies for adaptation and mitigation (Adger & Kelly, 1999; Arbuckle, Morton, & Hobbs, 2013; Haden, Niles, Lubell, Perlman, & Jackson, 2012). I argue that the beliefs, rituals and traditional practices and technology of Tharu contribute to mitigating climate change through low emissions and resiliency in agriculture. Despite the contributions of traditional agriculture, the adoption of modern and scientific agriculture increase amongst the Tharu leads to what I refer “hybrid knowledge”— a combination of Indigenous, traditional and scientific knowledge and practices in agriculture (Mendoza Zuany, 2009; Thomas & Twyman, (2004).

Tharu Indigenous people have diverse knowledge in ethnobotany, forest/wetland management, traditional institutions, massage and traditional medicines, hunting and gathering, farming, and food and beverages (Dahit, 2008; Khadka, 2016; Müller-Böker, 1993; Müller-Böker, 1999a). This thesis covers some elements of Indigenous knowledge related to farming that focus on the impact of climate change and management strategies. The scope of this study is limited to agricultural crops, particularly their production aspects. This is in order to provide a robust discussion of Indigenous knowledge for adapting to and mitigating climate change in the agricultural sector from an Indigenous people's perspective combined with an ethnoscience interpretation.

1.3 Outline of the thesis

The thesis is divided into eight chapters. Chapter 1 (Introduction) discusses the context of climate change and its impact on agriculture and Indigenous peoples. Scientific evidence illustrates that increase in temperature and precipitation patterns have a negative impact on agriculture. In the absence of adaptation and mitigation strategies, this is projected to worsen in the future. This chapter describes the need of study of Indigenous knowledge for climate-resilient agriculture and improving the livelihood and wellbeing of Indigenous and farming communities. The chapter outlines the research objectives of the study with three specific questions relating to climate change perceptions, adaptation, and Tharu knowledge and agriculture practices.

Chapters 2 and 3 review literature to develop the theoretical foundation of the study. Chapter 2 covers three thematic issues: Indigenous knowledge, Tharu identity and policy discourse. Although traditional and local knowledge have similarities with Indigenous knowledge, but Indigenous knowledge has a connection with the Indigenous people for innovation, conservation and continuation from generations. The Tharu in Nepal are dependent on the forest, water and land and farming is still their primary means of livelihood. However, over many generations they have been systematically displaced from their land and territory, marginalised socio-economically and culturally from national mainstream development. Recent national and international policies related to environment protection, biodiversity conservation and Indigenous people acknowledge traditional knowledge, but the implementation is still limited at local levels.

Chapter 3 focuses on climate change, its impact and various agricultural practices and methods to adapt to climate changes and reduce emissions (mitigation). The chapter illustrates how many traditional agricultural practices, such as conservation agriculture and local measures to manage insect pests, diseases and weeds, use of low external inputs and energy, and adapted in the local environmental contexts. The advancement in agriculture technology (e.g., hybrid seeds) and production technology (e.g., alternate wetting and drying in rice, direct seeding of rice) have shown promising results to reduce agriculture emissions.

Chapter 4 focuses on the methodology used to select and approach field-sites, collect and analyse data collected. The chapter discusses the qualitative methods (in-depth interviews, participant observations and group discussions) used to identify vulnerability and adaption strategies at household levels which complement with quantitative data from the household survey.

Chapters 5–7 constitute the results to specific questions enumerated in the research design. Each chapter focuses on answering a question; however, the concept of perception, vulnerability, and adaption are interlinked and hence a complete answer of either question might be addressed upon reading all the three chapters. I incorporated the broader comments of the theis reviewer to streamline the argumentation of hybrid knowledge through adoption of scientific information, knowledge, and practices for the climate-resilient agriculture. Chapter 5 describes the perceptions of the Tharu to changes in climate variables (temperatures and rainfall) and extreme events (flooding, drought, cold/hot waves) that affect agriculture and livelihood (physical, natural, financial, social/cultural and human capital). The perceptions of increased temperature was validated with the meteorological data of the area; however, a decreasing rainfall could not be validated due to a wide range of year-to-year variation. Flooding, droughts, storms and cold waves were the major climate-induced natural hazards in the village, which the Tharu managed with the adoption of a combination of Indigenous knowledge and scientific technology to reduce vulnerability. The Indigenous knowledge of the Tharu is insufficient due to the increasing frequency and the intensity of hazards. Hence, the Tharu integrate Indigenous and scientific knowledge for weather prediction, hazards management, and agriculture adaptation.

Chapter 6 analyses the adaptive capacity of the Tharu and identifies the influential factor for adaptive capacity and adaptation. The adaptive capacity is determined by various livelihood capital of which land, education and agriculture extension services significantly influence adaptive capacity. The study mainly focuses on climatic change perspective of adoption, where other various factors, such as economic (price of crops), socio-cultural (poverty, education) are not substantially incorporated in analyses and interpretations. Farmers use both farm and off-farm strategies to reduce climatic vulnerability. Agriculture strategies include an adjustment in sowing time, cultivation of hybrid seed, irrigation technology mainly in major cereal crops (rice, maize and wheat) whereas traditional agricultural practices in minor crops (e.g., lentil, pea) including riverbed vegetable farming in a flood-prone area. Income diversification and migration are increasingly becoming important in securing food and financial security and for coping with climatic and economic.

Chapter 7 describes some of the specific Tharu Indigenous knowledge in terms of classification of seasons, land and weeds and rituals in farming. Tharu classify seasons based on temperature and precipitation and organise the agricultural calendar and cultural/ religious activities according to seasons. They also practice various rituals for healthy and productive crop and livestock. However, Indigenous knowledge is integrated into the modern practices in various ways, such as relay sowing, zero-tillage, mixed cropping, and crop protection techniques (scarecrow, deadfall trap and watchtower). The use of Indigenous knowledge for climate/weather forecast and hazards management is decreasing because of the availability of scientific information. Tharu practice a combination of traditional agriculture in many minor crops, and adopt scientific agriculture (seeds, inputs, irrigation) in major cereal crops to increase the crop yield. The integration of different knowledge and practices in agriculture is considered as “hybrid knowledge” throughout this thesis.

Chapter 8 lays out the final discussions and conclusions based on the findings of the study. This chapter discusses and consolidates the major ideas and findings of the study. The main discussion point is yield and income is the deciding factor for adaptation and mitigation, which is normally higher with improved varieties and chemical input, so, the adoption is high and fast in smallholder and commercial farmers. There are three sub-points of discussion. The first is that climate perception of the Tharu match the weather data, which supports the argument that Indigenous knowledge plays an important role in perceptions, adaption, and wellbeing of the Tharu. The second point of discussion is that adaptation to climate change is affected by the adaptive capacity of individual, household and community. The final and third argument is that Indigenous knowledge and practices help Tharu in their adaptation to and mitigation of climate change. The chapter concludes with the complementarity of different knowledge systems (Indigenous, traditional, local and scientific) and its integration (hybrid knowledge/practice) for climate-resilient agriculture and wellbeings.

CHAPTER 2. INDIGENOUS KNOWLEDGE, THE THARU INDIGENOUS PEOPLE AND ASSOCIATED POLICY IN NEPAL

This literature review chapter covers the theoretical understandings of Indigenous knowledgethen proceeds to introduce the Tharu Indigenous people in Nepal and then presents policy frameworks in Nepal related to natural resource management (NRM) and agriculture in the context of climate change.

2.1 Indigenous knowledge and practices

Indigenous knowledge is increasingly appreciated because scientific knowledge alone is recognised as inadequate to deal with the complex global climate crisis (Finucane, 2009). The added value of Indigenous knowledge is due to the rich and diverse experiences of Indigenous people across the world.

The term Indigenous knowledge is often used interchangeably with common popular concepts of traditional and local knowledge despite these having different meanings. The use of Indigenous knowledge depends on the situation, context and field of study. The term Indigenous knowledge covers much of the same ground as traditional ecological/environmental knowledge, farmer knowledge, folk knowledge, and indigenous science or ethnoscience, among other terms. Here, it is important to distinguish between local, traditional and Indigenous knowledge. According to the Food and Agriculture Organization of the United Nations (FAO, 2004), Indigenous knowledge has a close association with “tribal groups” and the “original inhabitants of an area”, while traditional knowledge has the connotation of being “rural, isolated, static and not interacting with other knowledge systems”, and local knowledge is community knowledge of people who may or may not be Indigenous people and may have various sources.

Indigenous knowledge and Indigenous people are united in the discussion; therefore, it is crucial to introduce a general understanding of Indigenous people. There is no universally accepted definition of Indigenous people; no UN bodies have accepted an official definition of Indigenous people due to the vast diversity in culture and history (Nakashima et al., 2012). Nakashima et al. (2012) summarised an operational definition containing at least four criteria: 1) socially and culturally distinct from the dominant community through language, dress, social organisation and spirituality; 2) connection with ancestral land and territories, including other natural resources; 3) self-identification and recognised as a distinct cultural group; and 4) in many cases, historically and/or continuing experience of inequity, exploitation and marginalisation. Indigenous people are known by different names, including Native American (American Indians) in the USA, Aboriginal people in Australia, Maori in New Zealand, tribal people in Africa, *adivasi* (previously, scheduled tribes) in India and Indigenous nationalities (*aadibasi janjati*) in Nepal.

The knowledge of Indigenous people relating to NRM, including agriculture, is important for generational engagement. Warren (1991) described various Indigenous practices, technologies and knowledge in agriculture, such as agronomic practices, crop protection and agrobiodiversity conservation, which are dynamic in nature (exhibiting continuity and change); changes are not random, but rather are intended to solve local issues. Similarly, the World Bank (2004, p. 42) reported that Indigenous knowledge is usually tacit knowledge[7], and often guarded jealously, hence the saying that "each time an elder dies, it is as if a library has burned down." So, from the above various concepts and definitions it can be summarised that Indigenous knowledge represents knowledge associated with Indigenous (tribal/ethnic) people,

[7] Every knowledge has personal and tacit elements and tacit knowledge cannot be made fully explicit because skill-based knowledge requires focused observations for transfer that depend on the observance of sets of rules. He clarifies, "the tacit cooperates with the explicit, the personal with the formal" (Polanyi, 1958, p. 87). Later, Nonaka & Takeuchi (1995) described tacit knowledge is subjective, intuition, and hunches, which is learned through the experience. It is sometimes hard to express in words and prove it.

developed through continuous practical experience, transferred orally across the generations, and is important for local decision making.

Various characteristics distinguish Indigenous knowledge from other knowledge systems. Agrawal (1995) explicitly distinguished Indigenous knowledge and scientific knowledge on three distinct grounds: on a substantive ground, a methodological and epistemological ground, and a contextual ground. The substantive difference is due to its different subject matter, historical evolution, and distinctive characteristics. The methodological difference is related to how problems are viewed and analysed. Indigenous knowledge is considered closed, non-systematic and holistic, rather than open, systematic and analytical as in the scientific knowledge system. The closed characteristics of Indigenous knowledge must be interpreted carefully. While the underlying system of generative principles of Indigenous knowledge may be relatively closed, its empirical range is open. Some of the differences between Indigenous knowledge and scientific knowledge are summarised in Table 2.1.

Table 2.1 Contrasts between traditional and scientific knowledge systems

Indigenous/traditional knowledge	**Scientific knowledge**
Local	Global/universal
Subjective and tacit knowledge	Objective and explicit knowledge
Knowledge of experience (body)	Knowledge of rationality (mind)
Simultaneous knowledge (here and now): taught in the community, so knowledge is not organised in systematic ways	Sequential knowledge (there and then): scientists are taught in institutions for knowledge transmission
Inductive: knowledge gathering with everyday chance experiences	Hypothetico-deductive: specific protocols used for hypothesis testing and assessing constancy in findings

Sources: Adapted from Agrawal (1995), Nonaka & Takeuchi (1995) and Sillitoe (2017)

Although Indigenous knowledge, traditional knowledge and local knowledge are often used interchangeably, in this thesis some important conventions are adopted in terms of Indigenous knowledge. Firstly, the term Indigenous knowledge is exclusively related to Indigenous people and the knowledge practised by them. Secondly, in terms of range, Indigenous knowledge has been used in a wide variety of contexts, relative to traditional and local knowledge, for decades in terms of knowledge of plant diversity, especially in forests and other environments. Thirdly, much (though not all) of Indigenous knowledge is tacit knowledge, which is organic in terms of its application of external resources. Indigenous knowledge differs from traditional knowledge in that it does not necessarily relate only to remote, isolated groups or those with low use of technology. The integration of Indigenous knowledge and traditional knowledge with scientific knowledge creates a "hybrid knowledge" which is considered as local knowledge in this thesis.

The term "best practice" is commonly used in the development field. According to UNESCO's *"Management of Social Transformations Program (MOST)"* programme, best practice is the part of knowledge that describes the most effective, efficient and reliable techniques and practices (UNESCO, 2002). The book *Best Practices on Indigenous Knowledge* describes four characteristics of best practice related to ameliorating poverty and social exclusion: (i) innovative, (ii) brings difference, (iii) sustainable effect, and (iv) potential for replication (UNESCO, 2002). In this study, best practice is related more to local knowledge, being the innovation of local people through their knowledge and experience.

2.1.1 Indigenous agricultural practices

Indigenous agricultural practices are an array of techniques and methods used by Indigenous people in farming. They can be categorised on various bases, including stage of farming activity (land preparation, production, harvesting and storage), type of land used (upland, lowland), availability of water (drought, waterlogging/stagnation) and so on. For simplicity, the notion of Indigenous practices is classified into two farming systems: shifting cultivation and permanent/sedentary farming. Shifting cultivation covers one of the oldest forms of farming, while permanent farming covers various agronomic practices, including the use of inorganic agricultural inputs and farm machinery on a permanent piece of land.

Shifting cultivation/slash-and-burn/swidden agriculture

Shifting cultivation is one of the earliest agricultural practices used by Indigenous people in rural areas where land is not a limiting factor. This practice continues in many parts of the world, particularly in countries in tropical regions such as Brazil, Mexico, Ethiopia, Kenya, Indonesia, the Philippines, India and Nepal. Under this system, after clearing and burning a forest plot, cultivation is practised for several years in one place to exploit the soil nutrient advantage and then moves to the next place; it is also known as slash-and-burn farming or swidden agriculture. The two common types of shifting cultivation involve semi-nomadic people shifting their settlements with shifting cultivation, and people living in permanent village/settlements who practice shifting cultivation (Webster & Wilson, 1966).

The prevalence of swidden farming is declining due to the high demand for food production with the increasing population (Conklin, 1957; Ellen, 2007; Geertz, 1963; Webster & Wilson, 1966). Production in shifting cultivation depends on the fallowing and rotation that determine soil fertility. The cultivation timeframe under shifting cultivation before fallow depends on the population pressure. Webster and Wilson (1966) reported 2–4 years of cultivation with low population pressure, with up to 10 years in Malaya. There are cases in Indonesia, where farmers plant various tree crops after cultivation of 1–2 dry rice crops (G. Acciaioli, personal communication, 29 May 2020). The slash-and-burn practice of shifting cultivation is considered by many governments and agencies to adversely affect forest and bushland and degrade soil. Swidden farming has a relatively light carbon footprint with low population pressure. However, as the fallow cycles shorten and population pressure increases, increasing food demand and affecting fertility restoration, the carbon footprint increases. Indeed, a shift from swidden to permanent farming comparatively increases the carbon footprint. Van Vliet et al. (2012) analysed 157 cases across the globe in swidden agriculture to find that the transition from swidden to intensive agriculture often leads to permanent deforestation, increased weed invasion, decreased soil fertility and increased soil erosion. In terms of climate mitigation, shifting from swidden to intensive monocropping significantly reduces carbon stock above ground (by more than 90%) and in the soil (by 10–40%) (Bruun, De Neergaard, Lawrence, & Ziegler, 2009). Slash-and-burn practices in shifting cultivation produce off-site air pollution and can contribute to soil erosion and land degradation as fallow cycles shorten.

The literature shows two distinct ideological perspectives, with some arguing that shifting cultivation is no longer appropriate with increasing population and food demands, while others—particularly anthropological and ethnoecological researchers—advocating in favour of shifting/swidden cultivation where a non-expansive, steady-state equilibrium is possible. Their general logic points to the use of low inputs, forest regeneration, and minimum tillage. It offers higher production with low forest and soil degradation, as well as protecting from forest fires through forest management and controlled bushfires. There is concern about carbon emissions from slash-and-burn cultivation, but satellite imagery indicates that the regional haze problem in archipelagic Southeast Asia each year is primarily caused by large-scale oil palm plantations, not smallholder farmers burning swidden plots. In the Indonesian context, government bureaucrats consider the persistence of swidden farming as a failure of the agricultural Green Revolution (Ellen, 2007; Geertz, 1963). Hence, governments and funding agencies often view shifting cultivation as destructive farming.

Shifting cultivation is decreasing worldwide with government policies directed towards intensive agriculture, an increasing market demand for cash crops, and land scarcity. However, the practice continues to be valued in specific niches, in terms of shifts in climate and uncertainty, where forest/land is sufficient and population pressure remains low (Van Vliet et al., 2012). While swidden agriculture has low energy consumption and greenhouse gas emissions, the geographical range of its use continues to decline; however, the important techniques of the practice, including land fallowing, rotation, and slope farming techniques, contribute to sustainable agricultural practices in the contemporary debate on climate change. As shifting cultivation has been such an important aspect of the agricultural knowledge and practices of Indigenous peoples, it provides baseline for considering the deployment of Indigenous and local knowledge in agricultural practices among the Tharu as an Indigenous people. Shifting cultivation is a basis of contemporary agricultural development as well. It is widely practiced by with the Indigenous and tribal people throughout globe, and thus must be treated to contextualize how Indigenous knowledge interfaces with agriculture.

Sedentary/permanent agriculture

Sedentary agriculture is a broad term that covers various agricultural practices on specific fixed land in contrast to shifting cultivation (Webster & Wilson, 1966). Many small-scale swidden farmers also maintain sedentary plots (e.g. fruit trees, rubber stands, oil palm). Many different farming systems are based on the technology and use of agricultural inputs, including traditional, conventional and improved agriculture. Though the terms traditional and conventional agriculture are used interchangeably in the literature, a distinction can be made. Traditional agriculture is generally understood to be low production with low inputs and technology; as the term indicates, it is part of the tradition and culture of communities, and such communities are often Indigenous people. Conventional agriculture involves existing farming practices and technologies whereby crop intensification, monocropping in rotation, and heavy tillage are common.

It is hard to distinguish cleanly between traditional and modern scientific practices in agriculture. For example, crop rotation and mixed cropping are strategies that are pursued both in traditional agriculture practices and modern scientific agricultural practices. Many labelled traditional practices are, in fact, already hybrid, incorporating sceitific knowledge. Various agricultural practices have evolved from the knowledge and experience of Indigenous people. In modern agriculture, such traditional practices are either given a new name or improved through scientific knowledge. Examples include conservation agriculture (minimum soil disturbance, mulching, and crop rotation), organic agriculture (low inorganic fertiliser and pesticide use), direct seeding (relay sowing of lentil into paddy rice), and integrated farming (rice–duck, rice–fish, agroforestry), which protect the environment, improve soil health, increase yield and help with climate change adaptation and mitigation (Bhattacharyya et al., 2013; Sapkota, Jat, Aryal, Jat, & Khatri-Chhetri, 2015). The practices used by the Tharu are discussed in chapter 6 in the sections on climate change adaptation and mitigation.

In summary, sedentary agriculture has higher productivity than shifting cultivation. Irrigation requirement is prerequisite common including rainfed farming, and higher levels of inputs and management are often used. Therefore, alternatives that reduce production costs, care for the environment, and use natural resources sustainably—conservation agriculture and organic farming—are discussed. These practices are often associated with low input and energy use, thereby supporting the environment and reducing greenhouse gas emissions.

2.1.2 Debate and challenges in Indigenous knowledge

Historically, Europeans have used Indigenous knowledge, mainly for medicinal plant properties during colonisation in the 17th and 18th centuries (Nakashima et al., 2012). While

Indigenous knowledge is recognised as the basis of biodiversity conservation and sustainable NRM, there is ongoing debate about these concepts, ownership and conservation. In this context, western knowledge recognises some aspects of Indigenous knowledge as unscientific, while advocates of Indigenous ecological knowledge claim that western science is based on traditional knowledge (Dutfield, 2001; Woytek, 1998).

There are two major challenges surrounding the debate on Indigenous knowledge: scaling up and property rights. Scaling up refers to its use and application in the larger community and geographical regions, which is constrained by its localised nature, contextual use, factual limitation and binary ideology (Briggs, 2005). Many theorists are in favour of *ex-situ* Indigenous knowledge archives, being the identification, isolation, documentation and storage in national, regional and international archives. However, Agrawal (1995) argued that *ex-situ* archiving would be fatal due to (1) the local nature of Indigenous knowledge, so the *ex-situ* archives ultimately foster inappropriate practices among end-users in other locales; and (2) the dynamic nature of Indigenous knowledge, which can be modified and even changed over time, rendering the stored information not applicable or useful in future contexts.

The issue of ownership of Indigenous knowledge in the form of Intellectual Property Rights (IPR) under Trade-Related Aspects of Intellectual Property Rights (TRIPS) is considered problematic due to copyrights, patents and/or trade secrets (Dutfield, 2001; Ganguli, 2001) since Indigenous knowledge is generated over generations and transferred orally in public domains (Dutfield, 2001).

2.2 Tharu Indigenous people of Nepal

Indigenous people are the conservators of much of the global biological, mineral and other natural resources; they manage 11% of forest resources and 22% of the land surface and conserve 80% of the world’s biodiversity (Galloway McLean, 2009). Many Indigenous people in the rural landscape depend on nature not only for their livelihoods but also for their cultural and spiritual identity (Nakashima et al., 2012; Sillitoe, 2017) Agriculture forms part of the cultural identity of many Indigenous people, such as the Tharu in Nepal (Bista, 1972; Chaudhary, 2008; Rajaure, 1981a). Therefore, it is important to explore Tharu Indigenous knowledge and their traditional farming practices for robust discussion of their knowledge system in agriculture. Accordingly, this section reviews the Tharu Indigenous people of Nepal and their relationship and engagement with land and farming.

2.2.1 Demography of the Tharu

Asia is part of the most culturally diverse region worldwide—the Asia–Pacific region—where 60–80% of Indigenous people live (Galloway McLean, 2009). The Tharu live in the northern part of India and southern part of Nepal known as the Tarai. Most Tharu reside in Nepal, being about 75% of the total Tharu population of 2,121,000 (JOSHUA Project, 2018). In India, the Tharu are found in Bihar, Uttar Pradesh and Uttaranchal Pradesh with concentrations in Champaran, Gorakhpur, Gonda and Nainital districts; there are ~449,000 Tharu in India (JOSHUA Project, 2018). Figure 2.1 shows the distribution of the Tharu in Nepal and India.

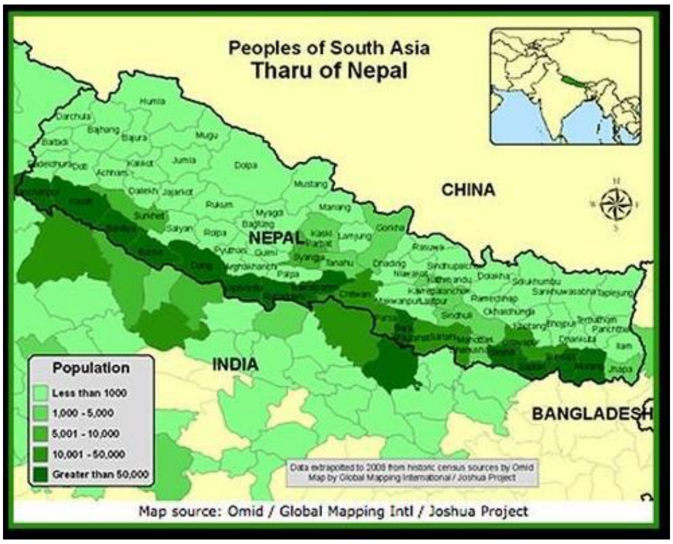


Figure 2.1 Distribution of Tharu in Nepal and India

Source: JOSHUA Project (2018)

In Nepal, most Tharu live in 23 districts of the Nepalese Tarai from east Jhapa to west Kanchanpur. The Tharu are the second-largest Indigenous nationality after the Magar in Nepal, with a total population of Tharu in Nepal of ~1,737,470 (6.6% of national population—26.5 million) (CBS, 2011a). Appendix 1 shows the Tharu population from various censuses in Nepal. The Tharu in Nepal are often known by the place/region where they live, such as Kochila Tharu (across the Koshi River), Lamphuchhiya/Morangia Tharu (Morang, Sunsari, Jhapa), Lampuchwa Tharu (Parsa), Chitaune Tharu (Chitwan) and Dangaura Tharu (Dang) (Guneratne, 2002). In western Tarai, four main sub-groups/castes—Dangaura, Desauri, Kathariya, and Rana—are inhabitants. Dangaura migrated from Dang-Deokhuri during the 20th century, whereas Rana and Kathariya Tharu were along the border of Nepal and India before the Dangaura (Chaudhary, 2008; Guneratne, 2002; Srivastava, 1999). There is little information on the Desauri Tharu. Some consider them as a social group of Dangaura, whereas others consider them as ancient settlers of the Tarai similar to Kathariya and Rana Tharu. Tharu are only one endogamous group in terms of ethnic recognition in Nepal and India (Guneratne, 2002).

It is difficult to trace Indo-Nepal transmigration due to the open border and historic cultural relationships. Srivastava (1999) reported that prior to cultivation in the *naya muluk*[8] (new territory) of Nepal, there were some Rana Tharu settlements in the Nainital district, and other Tharu in the Champaran and Gorakhpur districts of India, many of whom later migrated to the Kailali and Kanchanpur districts of Nepal. Guneratne (2002) mentioned that there was no evidence of the prior existence[9] of the Tharu in the *naya muluk* of the western Tarai of

[8] The Sugauli Treaty was an official agreement between the British East India Company of India and Rana government of Nepal. Nepal lost its vast area to the British East India Company through this treaty. The geographical span of Nepal before that treaty is called 'The Greater Nepal'. In 1846, a piece of land (Banke, Bardiya, Kailali and Kanchanpur districts) was returned to Nepal as a gift by the East India Company for supporting the suppression of the anti-British uprising at Lucknow, India. The regained land is called the new territory (*naya muluk*).

[9] According to Guneratne (2002), the existence of the Tharu in new territory (*naya muluk*) was only evident from the early/mid-twentieth century. Krauskopff (1995) mentioned that before the mid-twentieth century, studies on

Nepal. He stated that migration into the *naya muluk* increased from 1861 on the return of the territory from the British East India Company. However, there is evidence of migration of the Tharu into India from eastern and western (Dang-Deokhuri district) Nepal, with Panjiyar (2000) recounting that some Tharu *jimidar*[10] moved to Indian territory due to the appointment of new *jimidar* to exploit Tharu in the Tarai of Nepal during the early 19th century. Later the King of Nepal ordered the return of the Chaudhari from India (Rajpur and Gorakhpur), but many did not return. Guneratne (2002) mentioned that the Tharu from Dang-Deokhuri, Nepal, settled in Gorakhpur even after the Sugauli Treaty (1816) by recognising malarial resistance[11] in the Nepalese Tharu. Tharu continue to pay the price for combating malaria—suffering from sickle cell and Thalassemia genetic disorders.

There is evidence of migration of Indian Tharu to Nepalese territories. In the late 19th century, the Nepal government encouraged Indian people to migrate to the Tarai to render the Nepalese Tarai habitable up to the mid-20th century. Guneratne further mentioned a drastic decline in the Tharu population in the Gonda district, India due to their migration to the *naya muluk* in Nepal (Benet 1978 as cited in Guneratne, 2002).

2.2.2 Religious faith of the Tharu

Drone Prasad Rajaure initiated an anthropological study among the western Tharu in Dang during the 1970s and published his work on the economy, passage of life, festivals, tattoos, and women and child-rearing aspects of the Tharu in Dang. Rajaure (1981b) mentioned that the

---

the Tharu mostly focused on the Rana Tharu of India and Nepal, which were undertaken by D.N. Majumdar and his student S.K. Srivastava. Drone Prasad Rajaure first drew attention to the Tharu of Dang (Dangaura) in the 1970s, followed by two French PhD scholars, Christopher McDonaugh and his wife Gisele Krauskopff, in 1984 and 1985, respectively.

[10] *Jimidar* were the local intermediaries to collect land tax from landowners for Nepal’s land revenue office (central government). *Jimidar, Jamindar* and *Zamindar* normally signify the same meaning of ‘land intermediaries and landlords’, but *Zamindar*, a word originating in India, has connotations as landlords while *Jimidar* were essential functionary to collect land taxes (Regmi, 1977).

[11] A malaria eradication campaign started in the 1950s. The disease was almost eradicated in the1970s, enabling possible settlement of non-Tharu in this region of Nepal. The Tharu have seven-fold lower incidence of malaria, resulting in a ten-fold reduction in morbidity due to malaria in the *Tarai* region of Nepal (Modiano et al., 1991).

Tharu are Hindu, but they also have other religious beliefs and practices. Similar to Rajaure, most studies agree that Hinduism is dominant in the Tharu, and it has increased through the state mechanism and social dominance of the high-caste Hindus, such as Brahmins and Chhetri (Chaudhary, 2008; Gellner, 2018; Guneratne, 1998; Letizia, 2014; Maslak, 2003).

Tharu espouse a mixed religious cosmology, with beliefs in Tharu deities and spirits, and Hindu gods and goddesses. They traditionally worship benevolent and malevolent deities and spirits. Tharu deities, such as *Jaggarnathya* (tiger), *Bherwa* (sheep) and *Madua* (drunk), are worshipped as benevolent deities for the betterment of people, whereas evil spirits, such as *Raksha* (demon) and *Churinya* (witch), are worshipped so that they will not terrify the people. Arjun Guneratne mentioned that the deities of the Tharu relate to the forest, whence *gurau* (shamans) acquire supernatural powers and medicinal knowledge (Guneratne, 1999 & 2007). Similarly, Müller-Böker (1999b) mentioned the belief of the Tharu in *ban Dewi* (forest deities). I also found that the Tharu believe that malevolent spirits mostly live in the forest in big trees of particular species, such as *simal* (*Bombax ceiba*), *pipara* (*Ficus religiosa*), *bargad* (*Ficus bengalensis*) and *amli* (*Tamarindus indica*).

The life-cycle passage is one context in which to distinguish the religious faith of the Tharu from Hindu ritual practices. The life rituals of the Tharu during birth, marriage and death differ from Hindu customs. For example, Tharu do not perform *nwaran* (navel falling off ceremonies) and rice feeding. Tharu perform marriage ceremonies in front of the house deities rather than *kanyadan* through the Brahmin ritual process in Hinduism. Death and funeral rituals also differ; for example, the Tharu allow the last breath before someone dies inside the house, whereas, among Hindus, the final breath must be outside the house. The Tharu bury their dead, but Hindus cremate corpses (Rajaure, 1982a). Guneratne (1999) mentioned that Chitwan Tharu traditionally used a Brahman at funerals to settle the *pitri* (dead spirit) to send to *sworgalok* (heaven), even before malaria eradication (pre-1950s), but this practice did not apply in the villages in this study, where Tharu use the Tharu *babhana* (Brahman), known as *Thar babhana*, in the funeral and purification process on the last day of mourning called *din*. *Thar babhana* gives purified oil to mourning households, relatives and villagers to purify the dead spirits of people; *Thar babhana* is also called *Tel babhana* (oil Brahman).

Festival celebrations also differ among communities (Tharu and Brahmin/Chhetri); for example, the *Dashain* (Tharu call *Dashya*) Hindu grow barley for *jamara* (yellowish shoot in the absence of light) and red *tika* (whole rice and red powder), but the Tharu grow maize for *jamara* and white *tika* (rice flour with water). Tharu worship house deities and sacrifice chickens and pigs, whereas the Hindu worship the goddess Durga. Both slaughter *bhunru kwarha* (*Benincasa hispida*) considering the *Maisasur rakshyas* (demon). It is argued that red *tika* and animal sacrificing are linked to the celebration of victory and power in the monarchical system in Nepal, commemorating when Drabya Shah conquered the Indigenous King Khadka Magar in 1559 by cheating in the race of Ligligkot in Gorkha (Hangen, 2013).

The Tharu are not exclusively followers of Hinduism, as evidenced by their various deities in the *deuhrar* (divinity room) and *thanhwa* (village shrine). In the *thanhwa* *Daharchandi* and *Cabahwa* are typical Tharu deities, but there are five *Pandava* of Mahabharata that are linked to the Hindu religion. Furthermore, Rajaure (1982b) states that the songs sung during the *Sakhya naach*[12] are related to the Mahabharata and Krishna *charitra*. Similarly, the *barki maar* (the big song) is about the Mahabharata and *mangar* (a special song sung during marriage) is also connected to the Mahabharata. Hence, Tharu have been influenced by the Hindu religion, but there is no robust historical evidence to trace the adoption of Hinduism (Rajaure, 1982b).

[12] A long dance of more than a month that starts from the birthday of lord Krishna (Astimki festival) and completed at the end of Dashya festival.

There is a firm belief that state polices during different political regimes in Nepal, led by the high-caste Hindus, compelled Indigenous people to follow the Hindu religion, Nepali-Khas language and dress, in the name of state-building and national integration (Guneratne, 1998 & 2010). During the Rana[13] dynasty (1846–1950) and Panchayat[14] period (1960–1990), Tharu intermediaries, such as *jimidar*, *barghar* and influential people, were motivated to promote the Hindu religion to establish a link between Brahman and Chhetri and to uplift the social inferiority of the Tharu (Gellner, 20 January 2018; Guneratne, 1998, 1999, 2010). Rajaure (1982b) has noted specific events in February 1955, organised by the late Parsunarayan Chaudhari (Tharu *jimidar* and influential politician) in his village Gobardiha, Dang-Deokhuri that included invited intellectuals and influential Tharu from all over Nepal and encouraged the Tharu not to eat pork, liquor or chicken. Rajaure (1982b, p. 94) writes:

> [ ] Hindu religion and culture is the religion and culture of the elite, so rich Tharus, while trying to upgrade their social status, have been adopting the Hindu way of religious life. They no longer want to be linked to the tradition of the poor class Tharus. [….] The Tharus from prosperous and educated families try to direct the people under their influence toward change and higher standards.

There is an ongoing movement to revitalise traditional religion and practices among Indigenous people in Nepal. Gellner (2018) describes how the movement to adopt Buddhism among Nepali IP, including Magar and Tharu, is linked to efforts to overturn the exploitation and domination of high-caste Hindu (Brahman and Chhetri). There is a consensus amongst activists that Indigenous people are not Hindu but have other religions, such as Buddhism, nature worship (*Prakritivada*), animism (*Jivavada*) and Bon (pre-Buddhist religion in Tibet).

[13] Rana directly ruled Nepal keeping the Shah King just for symbolic purpose. Rana had the title of 'Shree 3' while the Shah King had 'Shree 5'. Jung Bahadur was the first Rana prime minister who introduced *muluki ain* (the Civil Code) in Nepal that institutionalised caste, slavery, and the untouchability system in Nepal.

[14] Panchayat was the single party system that banned the multi-party democratic system in Nepal through the direct leadership of King Mahendra in Nepal.

It is not easy to detach these from the centuries of practice of Hinduism, which is why the Gurung Indigenous people of Nepal seem in favour of dual religions (Hindu and Buddhism) (Gellner, 2018). Sapkota (2014, p 24) concluded that "identity mind-set is concentrated in upper leadership, but local people would like to reveal their issues and identities relating to class, ethnicity, gender and region." It is true that the immediate concern of Tharu is livelihoods and economic improvement in the community level, but the people who have engagement with the outer community (non-Tharu) are social change agents and obviously they mostly belong to upper leaders in social and political spheres (Chaudhary, 2008; Dahit, 2008).

Most Tharu consider themselves as Hindu despite differences in ritual beliefs and practices. In the Hindu religion, there are several gods and goddesses, and Nepal is a multi-ethnic country, where the deities of Tharu are a part of the pantheon. I do not see any issues with the Hindu religion, but there are problems with caste-based discrimination and the lack of respect for other cultures, beliefs and practices; for example, Brahman and Chhetri never worship Tharu deities. In the Hindu religion, Brahman and Chhetri have exploited and discriminated against other religious and cultural groups; as a result, the oppressed and discriminated have started to turn away from Hinduism. *Dalit* and genous people suffer from discrimination by high-caste Hindus; hence, many *dalit* and ethnic minority groups have converted to Christianity. There is political discussion among the Tharu and other Indigenous people in Nepal to follow the "natural religions" (*Prakritivada*, *Jivavada*, Bon, Kirat and Buddhism), but a consensus is lacking among the Tharu leaders and activists. The constitution of Nepal declares a *dharma nirapekshya* (secular state) that favours the freedom of religion, which Indigenous people fought for within the nation for years. Unfortunately, the adoption of Hindu cultural practices has not stopped in Tharu society; for example, *kanyadan* in marriage and *bhai tika* in the *Tihar* is mostly celebrated by Tharu youth.

2.2.3 Agriculture: a way of life and culture of the Tharu

Tharu have been largely an eco-friendly people with close ties to nature and the environment. Tharu consider land as an *ammar mati* (divine gift) of the *Gurbaba* (first god of the Tharu); therefore, they never consider land as private property (Rajaure, 1982b), which shows how attached the Tharu are to their land. The presence of the Tharu in the Tarai region can be traced back several centuries (earliest evidence 5^{th}–7^{th} century) (Krauskopff, 2000); thereafter, the Tharu resided in and contributed to making the Tarai the *annako bhandar* (food basket) of Nepal (Chaudhary, 2008; Chaudhary, 2003).

Evidence of land ownership and management among the Tharu community occurred at least as early as the unification[15] of Nepal in 1768. The *jimidar* were appointed from among the Tharu by the Sen, Shah and even Rana rulers in the Tarai of Nepal until the 1950s. Panjiyar (2000) mentioned that Tharu enjoyed customary practices of land ownership and management for cultivation. This is some of the strongest evidence of the farming inclination of Tharu. The *Pahari*[16] *jimidar* used to come to the Tarai during winter when the prevalence of malaria was low. They engaged in land management through intermediaries (*patwari, kothari and taula*), but they hardly engaged in farming. In addition, ploughing was not considered respectable by Brahmins and other ruling castes, so the *Pahari jimidar* did not farm the land.

There is agreement that the Tharu cleared the Tarai and started farming—specifically the *naya muluk* (Chaudhary, 2008; Guneratne, 2002). Engagement of the Tharu in the management of elephants—as *mahut*—in Chitwan and Bardiya reflects the traditional

[15] Nepal was unified in 1768 by the Gurkha ruler, Pritihivi Naryan Shah. Before unification, Nepal was ruled by many kings in small kingdoms. From 1768–1846, Nepal was ruled by the Shah; but from 1846–1950 it was ruled by Rana though there were ceremonial Shah Kings. Nepal opened to the Western World from 1951 after the first restoration of democracy in Nepalese history. Political parties were again banned from 1960–1990. In 1990, multiparty democracy was re-established and, in 2006, Nepal entered into the Federal Democratic Republic of Nepal.

[16] *Pahari/Pahariya/Parbati* is the Tharu word for people having origin in the Hills and the Mountains in Nepal. Pahari is derived from *Pahad* means ‘hills’ and *Parbati* is derived from *Parbat* meaning ‘hills and mountains’.

profession as well as skills to manage wildlife. The Mahato post of the Tharu in Chitwan comes from the elephant carer profession (Chaudhary, 2008; Guneratne, 2002; Locke, 2011).

Francis Hamilton was a British colonial medical doctor who spent three years in Nepal between 1802 and 1814, and wrote about Tharu (Hamilton, 1819, p. 169).

> On the plains, the population consists chiefly of Tharus and Aniwars. The great caste on the hills is the Murmi, and this is also the case on the north of the valley of Nepal. About the forts are some Rajputs, many of the spurious breed of Khas, and a good many Magars.

Hamilton (1819, pp. 162-163) further described agriculture in the Tarai:

> [………… In the dry season, the elephants retire to the lower ranges of hills; but in the rainy season they abandon these forests, and are then very destructive to the crops, which, indeed, prevents the natives from being so attentive to the cultivation of rice as they otherwise would be, so that, although the country is best adapted for the culture of this grain, the farmers content themselves chiefly with winter crops of wheat, barley, and mustard. The Raja reserves to himself the sole right of catching the elephants, and annually procures a considerable number.

Dor Bahadur Bista (1967), a renowned Nepali anthropologist, mentioned the Tharu as a purely farming community and the prevalence of a *kamaiya* system (debt bondage labour system) in agriculture in the book *People of Nepal* (Bista, 1972). During the 1970s, Drone Prasad Rajaure studied the Dangaura Tharu in the Dang-Deokhuri valley of western Nepal and mentioned that the Tharu not only depended on agriculture for their livelihoods, but they were unable to diversify their source of livelihood beyond farming and the transport of sacks of agricultural production for non-Tharu to the southern border with India (Koilabas of Dang-Deokhuri) and Nepalgunj of Banke. Tharu were so strongly connected with farming that many engaged in this livelihood even though they did not even own land. They were sharecroppers and rented land to cultivate. Overall, agriculture was the primary occupation of the Tharu people despite land ownership by others (Rajaure, 1981a).

Mahesh Chandra Regmi, a well-known socioeconomist of Nepal, described Tharu land ownership in his book *Landownership in Nepal.* He says that Chaudhari were selected from the local Tharu community to bring land under farming and collect land tax for the central government (Regmi, 1977). Panjiyar (2000) published a book, *The King of Nepal and the Tharu of the Terai* that describes land ownership of the Tharu in the Tarai before the unification of Nepal. Historical artefacts collected by Panjiyar proved that Ranapal Chaudhari was honoured with the title *Shyaha Mohar*[17] by the Sen King, Mahapati Sen, in the Sen Dynasty of Vijayapur (Panjiyar, 2000). He documented that Hem Chaudhari from Saptari received 21 *Lal Mohar* (red seals) during the Shah Dynasty. Guneratne (2002) also wrote that not only were the Chaudhari granted land, authority over customary village practices and judiciary power, but also village priests (*gurau/guruwa*) were recognised by the central authority to protect the village from epidemics, dangerous wild animals, and several other threats in the Tarai. For example, in 1807, Tetu Gurau in Chitwan was granted rights to protect his village and territory from wild animals and evil spirits and to cultivate the land. Similarly, Ganesh Dhami in Udaypur in 1842 and Parsunarayan Chaudhari in Dang-Deokhuri in 1838 were granted land and local authority to manage villages (Guneratne, 2002). Hence, there is robust evidence that the Tharu were the first settlers and farmers of the Tarai of Nepal.

2.3 Climate change policy framework

In the contemporary context the research, development, and promotion of Indigenous knowledge and practices are influenced by national and international policy regimes. In this

[17] The royal seal document is written in black. The red-coloured royal seal order is called *Lal Mohar* (Panjiyar, 2000).

section, I briefly review international and national policies related to climate change, agricultural biodiversity and agriculture for Indigenous people and Indigenous knowledge.

International policies and agreements determine the pathways of climate change adaptation and mitigation. With the formation of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, the world started to act to counter anthropogenic causes of climate change through the Kyoto Protocol. More recently, the Paris Agreement of 2015 is committed to keeping the global temperature rise below 2°C and CO_2 concentration below 350 ppm. However, there are global disagreements and disinclinations among state parties to reduce emissions and pay for pollution. Nepal has developed and is implementing a climate change policy and programs to pay its nationally determined contributions (NDCs[18]) and fulfil its commitments to reducing emissions and adapting to the impacts of climate change.

2.3.1 International policies

The UNFCCC is the international intergovernmental platform to formulate and implement policies related to climate change. There are four important international policies—the Kyoto Protocol, the Paris Agreement, the Convention on Biological Diversity, and the International Treaty on Plant Genetic Resources for Food and Agriculture—related to climate change, agrobiodiversity, Indigenous knowledge and Indigenous people, as summarised in Table 2.2. International policy instruments have not exclusively mentioned Indigenous knowledge, but instead mentioned traditional and local knowledge because Indigenous knowledge has a relationship with particular ethnic/tribal peoples and political connotations (FAO, 2004).

[18] NDCs are the commitments to the Paris Agreement by the state parties to reduce GHG emissions. The state parties must submit NDCs every five years.

Table 2.2 International policies concerning climate change and traditional knowledge

S.N.	Policy	Policy provision	Comment/limitation
1	Kyoto Protocol 1997	Developed (Annex I countries) countries must reduce emissions, and support and cooperate with developing countries; 'polluters pay' for emission trading and the Clean Development Mechanism (CDM).	China and India are non-annexed, but their emission levels are increasing and may exceed those of annexed countries. Promotes planting forests for CO_2 sequestration; provides economic incentives to prevent destruction of wetlands (Shaw, 2002).
2.	Paris Agreement 2015	The agreement seeks to keep the global temperature rise below 2°C, from the pre-industrial level in the 21st century and support the developing and most climate-vulnerable countries to improve adaptive capacity.	The USA had withdrawn its commitments during the period of President Donald Trump, but current President Joe Biden again agreed to commit to this agreement. Criticised for low level of reduction (0.2°C) (Schaefer, 2017).
3.	Convention on Biological Diversity (CBD 1992)	Main objective is conservation and use of biological resources, and share of benefits earned from the use of resources. CBD recognises the importance of traditional knowledge coming from Indigenous and local communities.	Intellectual property rights of the community are complex in the CBD. Costs associated with the collection, conservation and access to germplasm are challenging (CBD, 1992).
4.	International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, 2001)	Access and benefit-sharing, farmers' rights, and sustainable use of plant genetic resources are the main provisions in the treaty. It acknowledges traditional knowledge of farmers for the conservation of plant genetic resources.	Intellectual property rights are challenging; the treaty ensures that property rights are not given to anyone without modification of plant genetic resources. Complexity regarding patent rights to breeders, companies and farmers (FAO, 2001).

2.3.2 National policies—Nepal

Important policies related to climate change and agriculture in Nepal are summarised in Table 2.3. Other agricultural policies, such as agrobiodiversity, seed vision, and rangeland policies, have considered traditional knowledge and Indigenous peoples in the conservation and protection of biological resources, related skills and benefit sharing, because they are based on international policies (CBD 1992 and ITPGRFA 2001). Overall, Nepal's climate change and related policies are inclusive in terms of gender, caste, ethnicity, and income, clearly mentioning *aadibasi janjati* (Indigenous people) for participation and capacity development, but not mentioning Indigenous knowledge or even traditional knowledge.

Table 2.3 Nepal's policies concerning climate change and Indigenous knowledge

S.N.	Policy	Policy provision	Comment/limitations
1	Climate Change Policy of Nepal 2011	Inclusive of gender, age and marginalised people, including Indigenous people. Ensures flow of at least 80% of climate fund for climate change adaptation and mitigation (MoE, 2011). Duly acknowledges local and Indigenous knowledge, skills and technology for adaptation and mitigation.	Silent in terms of climate fund flow mechanism, roles and responsibilities of institutions and mechanisms (Lamsal, Chaudhary & Bhandari, 2014).
2	National Adaptation Plan of Actions (NAPA 2010)	Classifies the districts of Nepal into various categories based on a vulnerability index. Prioritises adaptation needs (activities). Inclusive and participatory with regard to different social and ethnic groups in Nepal.	The vulnerability index used is more based upon experts' judgements than data driven (MoE, 2010a).
3	Local Adaptation Plan	Action plan for climate adaptation at the local level.	LAPA preparation manual exists at the local level, but

	of Action (LAPA 2011)	Focuses on participatory planning and inclusiveness in terms of vulnerable areas, gender, classes, ethnicity and groups to improve their adaptive capacity (MoE, 2010a, 2010b).	planning and implementation are constrained due to local-level re-structuring.
4	Nepal Reducing Emissions from Deforestation and Degradation of Forests (REDD+) Strategy 2015	Inclusive in terms of gender and social groups, community participation and sharing benefits from carbon trading. Gives due attention to poor and forest-dependent people and communities (MoFSC, 2015).	Complex in terms of its procedures and qualifying criteria and conditions for the community to receive financial benefits (Helvetas Nepal, 2011).
5	Renewable Energy Subsidy Policy 2016	Implements public–private partnership modality. Subsidies for the cost of renewable energy (generally 40% from government, 30% from financial institutions and 30% individual investment (MoPE, 2016).	No criticisms in the literature
6	National Environment Policy 2019	Controls different types of pollution, manages sewage and garbage, and expands park and greenery through public participation and environmental justice strategy with inclusiveness strategies (MoFE, 2019a).	No criticisms in the literature
7	Agriculture Development Strategy of Nepal (ADS 2015–2035)	Plans to double the annual agriculture growth rate (from 3% in 2010 to 6% by 2035). Envisions doubling land and labour productivity by 2035 (MoAD, 2015). Emphasises climate-resilient agriculture, environmental protection and biodiversity conservation.	Only mentions ‘good practices’; document suggests that traditional subsistence agriculture is the main hindering factor for agricultural development.

2.4 Conclusion

A much of the Indigenous knowledge of Tharu and Indigenous people relates to tacit knowledge, such knowledge created in the community is practised, refined and transformed orally in unwritten form. Therefore, it is difficult to distinguish the knowledge and practices of the Tharu from those of other groups in the region. Indigenous knowledge of particular Tharu is also practised by local non-Tharu in the area and even across different regions in the world. Therefore, the term local knowledge indicates an amended version of Indigenous knowledge by incorporating scientific knowledge which is also described as "hybrid knowledge", though it is also found beyond any one particular Indigenous people in a locality. However, there are some specific agricultural practices and technology of the Tharu that are associated with their rituals, culture, and tradition in the Tarai region of Nepal can be considered as the Tharu Indigenous knowledge that will be discussed in more detail in chapter 7. Indigenous knowledge and traditional agriculture practice are not just to respond to climate change, but also associated with culture, tradition, and practices of the Tharu. The adoption of modern agriculture is increasing due to the higher crop yield and income. There is an integration of knowledge and practices to overcome the local challenges including climate change, hence, Indigenous and scientific knowledge and practices complements each other rather than the competitions.

The Tharu Indigenous people, living in the lowland of the Indo-Nepal border, are considered *adibasi* in India and *aadibasi janjati* (Indigenous Nationalities) in Nepal. The Tarai is the homeland region of the Tharu, who converted the malarial, tropical, densely forested marshland into Nepal's most prosperous region today. Regardless of land ownership, Tharu never left farming and continue to be involved in farming. Despite the ongoing priority to develop agriculture, Tharu still practise traditional agriculture with low external inputs, using Indigenous knowledge and local resources.

International communities have accepted Indigenous knowledge in the form of traditional knowledge through different international policies and mechanisms. The IPCC has incorporated the role of Indigenous knowledge and practices for adaptation and mitigation in agriculture and NRM. Similarly, the CBD and ITPGRFA have acknowledged the skills, knowledge and practices of Indigenous and local communities for biodiversity conservation, utilisation, and benefit-sharing.

In Nepal, climate change policy and sectoral policies supporting climate change adaptation and mitigation are inclusive in terms of gender, caste, ethnicity and income to benefit and empower Indigenous people, but ignore the knowledge, skills, and practices of Indigenous people to manage the forests, irrigation, land and territories, biodiversity conservation and environmental protection. Thus, the policy itself is progressive in terms of supporting and benefiting marginalised and Indigenous people. However, the ADS—the primary agriculture program policy document—exclusively focuses on efforts to commercialise and modernise agriculture to double agricultural growth, labour and land productivity, without considering traditional and Indigenous knowledge.

CHAPTER 3. CLIMATE CHANGE: VULNERABILITY AND ADAPTATION

Climate change is a serious global threat affecting natural resources and, thus, humans. The use of natural resources such as land, water, and energy to meet increasing food demands is influenced by climate variability and change. Agriculture not only produces food, but is also a major source of global warming and climate change and, therefore, must be resilient to climate change without compromising production. The Intergovernmental Panel on Climate Change (IPCC) Working Group II (WG II) of the Fourth Assessment Report (AR4) 2007 defined climate change as, "Any change in climate over time, whether due to natural variability or as a result of human activity", whereas the United Nations Framework Convention on Climate Change (UNFCCC) is more concerned about anthropogenic causes of climate change. It defined climate change as, "[a] change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods" (IPCC, 2007, p. 6).

This section begins by outlining climate change scenarios and observed/predicted climate variables (temperature, rainfall, and CO_2), followed by a discussion of the vulnerability and impact of climate change on agriculture, both globally and locally, and climate change adaptations in agriculture at global, national and local levels. The impacts of such changes, particularly in agriculture, are considered from both observed and future climate scenarios, with a focus on local Tarai staple crops (rice, maize, wheat and legumes).

3.1 Climate change scenarios

3.1.1 Global climate change scenario

Physical science has proved that the climate is changing more rapidly than in the pre-industrial era (pre-1850). According to the IPCC Fifth Assessment Report (AR5) 2014, temperature (atmospheric and ocean) and sea level are increasing, while snowfall and ice cover are decreasing. For example, the global temperature (land and ocean) increased by 0.78°C from

1850 to 2012, which was mainly due to anthropogenic interventions (IPCC, 2014c). Carbon dioxide (CO_2) is the most emitted (76%) greenhouse gas (GHG), followed by methane (CH_4, 16%), nitrous oxide (N_2O, 6.2%) and F-gases (2%) (IPCC, 2014c). At the global level, Agriculture, Forestry and Other Land Use (AFOLU) only contributes one-fourth of total GHG emissions, but is the main source of GHG emissions in many developing countries.

Increased temperature and CO_2 concentration have a direct effect on water resources (for irrigation), crops, livestock and fisheries. Future projections of temperature are based on various GHG emission scenarios. According to the Representative Concentration Pathway (RCP2.6) scenario, the increase in global temperature rise will be less than 2°C, relative to pre-industrial temperatures (1850–1900), by the end of the 21st century (IPCC, 2014c). Precipitation patterns and regional distribution may change, and related extreme hazards and disasters will result in unevenly distributed climatic risks. The response and adaptation to such changes are determined by the sociocultural, economic and political condition of people and nations across regions and within countries (IPCC, 2014c).

3.1.2 Climate change scenario in Nepal

Nepal is highly diverse in terms of climate, geography, and biodiversity, in addition to its sociocultural diversity. Nepal is divided into five physiographic zones (High Himalaya, High Mountain, Middle Mountain, Siwalik and Tarai). The physiographic zones are categorised into three ecological belts—Mountain (High Himalaya and High Mountain with altitude >3000 m asl), Hill (Middle Mountain, 1300–3000 m asl) and Tarai (*Churiya*, 60–1300 m asl) (MoE, 2010a; Shrestha, Pandey, Chanamai, & Ghosh, 2013). Nepal's climate is divided into four seasons—pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–November) and winter (December–February) (DHM, 2015 & 2017).

Temperature

Temperature varies with altitude and season. The Tarai region has the highest temperatures (mean annual max >30°C), which gradually decline towards the Northern Himalaya. The pre-monsoon period (April–May) is the hottest season, while winter (December–February) is the coldest (Practical Action, 2009).

Changes in climate variability are fast and unpredictable in Nepal. A study conducted by Shrestha et al. (1999), which analysed climatic data from 1971–1994, showed that incremental temperature varied with altitude and season. The annual average temperature increased by 0.03°C/year in the Tarai (low elevation) and 0.06°C/year in the Mountains (high elevation). The post-monsoon season (October–November) had the highest warming rate (0.08°C/year) and the pre-monsoon season (March–May) had the lowest (0.03°C/year) (Shrestha et al., 1999). Another climatic analysis spanning 1976–2005 showed that maximum and minimum annual temperatures increased by 0.05°C and 0.03°C, respectively (Practical Action, 2009).

The projections for temperature increases in Nepal are alarming and vary spatially by elevation and season. Greater temperature increases will occur in winter than in the monsoon season, and in the western and central regions than in eastern Nepal (MoE, 2010a). The General Circulation Model (GCM) with SRES B2 scenario showed that the maximum annual temperature will increase by 1.2°C by 2030, 1.7°C by 2050 and 3°C by 2100 (MoE, 2010a). The General and Regional Circulation Model (G/RCM) predicted that the mean annual temperature will increase by 1.4°C by 2030, 2.8°C by 2060 and 4.7°C by 2090 (MoE, 2010a) Most recently, Ministry of Forest and Environment (MoFE, 2019b) predicted the average annual mean temperature will increase by 0.9–1.1°C in the 2030s and by 1.3–1.8°C in the 2050s.

Precipitation

The rainfall trend in Nepal is less clear than that for temperature. There is large inter-annual variation in rainfall, particularly monsoon rainfall. From 1976–2005, rainfall increased by 4 mm/year in an analysis of 166 weather stations across the country (Practical Action, 2009). In general, pre-monsoon and monsoon rainfall has declined and post-monsoon rainfall has increased in mid- and far-western Nepal, relative to most parts of central and eastern Nepal (Practical Action, 2009). Monsoon rainfall decreases from east to west, whereas winter rainfall decreases from north-west to south-east. The average annual rainfall in Nepal is 1800 mm with the highest precipitation in the mid-hills of western (Pokhara) and central Nepal (east of Kathmandu valley) (Practical Action, 2009).

As mentioned earlier, precipitation projections for Nepal are unclear. According to NAPA 2010, the Regional Circulation Model (RCM) predicted both increases and decreases in rainfall variation. However, in terms of spatial distribution, the eastern and central regions will receive more monsoon and post-monsoon rainfall than western Nepal. There is a projection that rainfall will increase by 2–6% in the 2030s and 8–12% by in the 2050s (MoFE, 2019b). Overall, total annual rainfall seems to increase specially in the post-monsoon season, but decreasing rainfall in the pre-monsoon and the winter season (MoE, 2010a; MoFE, 2019b).

3.2 Perceptions of climate change

In general, the perception of climate change discussed here is what individuals or the community feel and realise in terms of changes in climatic variability (temperature, rainfall). An individual perceives changes in climatic variables when it becomes measurable and/or extreme (too hot, too cold). Perception is a psychological process of realising the changes (Wachinger et al., 2010), and is influenced by many factors, including sociocultural factors (Nhemachena & Hassan, 2008) and knowledge imparted by agricultural extension services (Gbetibouo, 2009). Indigenous knowledge is an important tool for local people to verify perceptions of climate change. Various plants, animals, insects and non-climatic indicators are reported as indicators of climate change, including changes in flowering and the fruiting times of fruit and tree species, the disappearance of some Indigenous plants, birds, insects and wildlife, and the emergence of new weeds, insects, and diseases (Chaudhary & Bawa, 2011; MoE, 2010a).

The sectoral working group for Nepal (MoE, 2010a) walked transects of different ecological belts in Nepal and traced the climate change perceptions held by local people in different regions. People's perceptions were diverse and varied between ecological and geographical regions. In general, people perceived the increase in temperature, upward-shift of agro-ecological regions, changes in rainfall pattern, and increased frequency and impact of climate-induced disasters. Irrespective of regions, people perceived increased temperatures, particularly in summer (June–October), delayed monsoon seasons and more rainfall in the latter part of the monsoon season (September–October). Scarcity of irrigation water and drought were mostly perceived in spring and before the monsoon (February–May), which affected crop yield. Furthermore, the Nepal National Adaption Programme of Actions (NAPA) pointed out that due to land degradation and erosion in the *Churiya* (hills) of Nepal, resultant flash floods, flood disasters, river course changes, and inundations are affecting livelihoods and farming in the Tarai. Similarly, climate-induced disasters, such as cold, fires (forest and house), landslides and floods, have increased in the last 5–10 years (MoE, 2010a, 2011).

3.3 Impact and vulnerability to climate change

The impact of climate change has interactive effects of vulnerability, exposure and hazards on natural and human systems due to the extreme weather and climate events (IPCC, 2014a). Exposure is the situation of people and their livelihoods located in areas prone to adverse conditions. Hazards are those physical events related to climate that cause physical impact. Climate change has physical, socioeconomic, cultural, health, ecosystem, and livelihood impacts. Vulnerability covers the concepts of sensitivity/susceptibility, exposure and capacity to cope and adapt (IPCC, 2014a). The Second Assessment Report (SAR) 1996 of the IPCC defines vulnerability as “the extent to which climate change may damage or harm a system.” The SAR states that developing countries are more vulnerable than developed countries due to their less favourable economic and institutional mechanisms (IPCC, 1996). Similarly, the IPCC Third Assessment Report (TAR) 2001 defines vulnerability as, “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.” Furthermore, “vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity” (IPCC, 2001, p. 21). The Fourth Assessment Report (AR4) 2007 of the IPCC follows the same definition as TAR. In the Fifth Assessment Report (AR5) 2014, vulnerability is described as “the propensity or predisposition to be adversely affected” (IPCC, 2014a, p. 39). In short, vulnerability to climate change is susceptibility due to the inability to manage the adverse impacts of climate change. Vulnerability, adaptation, mitigation and resiliency are interrelated and interlinked within climate change.

There are two school of thoughts prevalent in the study of vulnerability—the human ecology school and the structural view. The core element of the human ecology perspective is “human adjustment to natural hazards”, where adjustment depends on “resource utilisation” in the given magnitude–frequency patterns of natural process (Hufschmidt, 2011, p. 623). The philosophy behind this school of thought is that “[n]atural hazards and natural disaters are generated by false human adaptation rather than by natural forces only.” Therfore, adaptation is rrequired for reducing vulnerability from natural hazards (Hufschmidt, 2011, p. 624). Furthermore, Hufschmidt (2011) categorised vulnerability into threetypes: climate change and global environmental change; development and livelihood; and human ecology. The first category considers vulnerability as a function of exposure, sensitivity, and adaptive capacity/

resilience. The development and livelihood category considers vulnerability as a function of (external) exposure and (internal) capability to cope as well as potentiality (resilience), whereas the human ecology view considers vulnerability as the degree to which a system is susceptible to injury or change. Adaptation, capability and adjustment are the key strategies for reducing vulnerability under above first, second and third categories, respectively. Human ecology considers mitigation as a part of adaptation, whereas the climate change perspective deals separately with adaptation and mitigation.

This review focuses on vulnerability that is governed by both climatic and non-climatic (mostly sociocultural) factors. Climatic factors result in exposure to extreme events, hazards and disasters increase vulnerability. Non-climatic factors, such as physical geography, social, economic, gender and institutional factors, also contribute to vulnerability.

3.3.1 Approaches to studying vulnerability

The two main approaches to studying climatic vulnerability are biophysical and social, whereas an integrated approach endeavours to capture the advantages of both (Deressa et al., 2008; Nelson, Kokic, Crimp, Meinke, & Howden, 2010).

Biophysical approach

The biophysical approach, also known as the impact or risks/hazards-based approach, measures the physical damage to social and environmental systems, such as production, income, human death and other factors, to express the level of vulnerability (Adger, 1999; Adger & Kelly, 1999; Deressa et al., 2008). It is also known as the “end-point”, as it measures the impact of hazards as the end result. It has been criticised for excluding the socioeconomic dimensions of vulnerability.

Socioeconomic approach

The socioeconomic approach considers vulnerability as a “starting point” and assesses the socioeconomic and political aspects of individuals and society to assess vulnerability. This approach asserts that vulnerability is socially constructed due to changes in economic and institutional paradigms in society, but is often criticised for not considering biophysical aspects (Deressa et al., 2008). Entitlement and livelihood options are vital to determine the vulnerability of individuals or groups/communities as access to and control of natural resources is crucial to food security and poverty (Adger, 1999; Adger & Kelly, 1999). The IPCC is shifting the concept of vulnerability from hard biophysical to soft social vulnerability, considering vulnerability as the outcome of human–environment interactions. The AR5 2014 has also made a distinction between “contextual vulnerability” (starting point) and “outcome vulnerability” (end-point). Outcome vulnerability is the same as mentioned earlier, whereas contextual vulnerability is an inability in the current situation to cope with the changing climate or external pressure (IPCC, 2014a).

Integrated approach

An integrated approach of vulnerability assessment is a combination of the biophysical and social approaches (Nelson et al., 2010) and is arguably the best approach to overcoming the limitations of the two approaches treated above (Deressa et al., 2008). Piya, Joshi, and Maharjan (2016) argue that social vulnerability should consider hazards—physical events impacting life and livelihoods—as vulnerability is hazard-specific; therefore, they urge the use of an integrated approach to analyse vulnerability.

3.3.2 Impact and vulnerability in agriculture

Climate change has direct effects on soil, water, crop and animal production. Increases in temperature trigger the physiological processes of crops and influence soil, moisture and nutrients. In water-stressed or drought conditions, the physiological changes in crops ultimately affect yield. Extreme climatic events, such as very high/low temperatures, little/heavy rainfall, wind speed and related hazards also directly affect agriculture. This section explores the observed impact of climate change and its future vulnerability and risks in agriculture.

There are limited benefits and substantial negative impacts of increased temperatures and CO_2 concentrations upon agriculture. A high concentration of CO_2 enhances the growth of C_4 plants (e.g. maize, sorghum and sugarcane), especially under water stress, by increasing photosynthesis and thus improving crop water use efficiency (Porter et al., 2014). However, increased temperatures shorten the growing season, reduce grain set, increase water stress, and stimulate the emergence and ecology of insects, diseases and weeds (Chakraborty, Tiedemann, & Teng, 2000; McDonald, Riha, DiTommaso, & DeGaetano, 2009; Porter et al., 2014). Temperature is critical to crop production. In rice and wheat, 32–34°C temperatures at flowering increase senescence, resulting in low grain set, and temperatures exceeding 40°C result in total crop losses (Porter et al., 2014; Wheeler, 2017).

Climate change has had a negative effect on the yield of major crops in South Asia above 30 ^{o}C temperature (Jagadish, Craufurd, & Wheeler, 2007; Lal, 2011; Lobell et al., 2012). Net cereal production is projected to decrease by 4–10% in South Asia by the end of this century with increase in temperature by 3 ^{o}C (Lal, 2011). Similarly, in India, reductions in rice yield are projected to be higher under irrigated (–10%) than rainfed (–2.5%) conditions by 2080 (Soora et al., 2013). In contrast, yields of rice and wheat were higher with increasing CO_2 and temperatures (+6°C) in a study at the Nepal Agricultural Research Council (NARC) (Malla, 2009), where average temperatures were 27.4°C and 20.6°C, respectively, during the rice and wheat growing seasons. However, further increases in temperatures are expected to reduce crop yields in the Tarai because the temperature has reached maximum threshold levels (30–34°C) (Karna, 2014; Poudel & Kotani, 2013).

Impact on major cereal crops

The effect of increased temperatures on crop yields is well-studied (Jagadish et al., 2007; Peng et al., 2004; Porter et al., 2014; Zhang, Zhu, & Wassmann, 2010). The upper temperature limit where crops persistently thrive with good yields is not clear. The effect of temperature differs with crop type, stage of growth, and day and night temperatures. It has been broadly concluded that temperatures above 30 adversely affect the yield of major crops, such as wheat, rice and maize (Howden et al., 2007; Lobell et al., 2013; Lobell, Sibley, & Ortiz-Monasterio, 2012; Schlenker & Roberts, 2009). A yield impact analysis of major cereal crops from 66 studies (meta-analysis) showed that 1–2°C of local warming begins to reduce wheat and maize yields in the tropics, with significant yield reductions with 3–5°C warming (Porter et al., 2014). Crop yield vulnerability and risk are projected to increase in the absence of measuring adaptation. A meta-analysis by the IPCC on wheat, maize and rice showed that adaptation will increase the yield equivalent by 15–18% more than without adaptation until the 2080s (Porter et al., 2014). Various adaptation and mitigation strategies in agriculture are discussed in subsequent sections.

Various projection models (usually GCM and RCM) are used to predict the impact of climate change on crop yield. Crop modelling has shown varying levels of climate change impact on yields, most of which are negative (yield reductions). A 4°C rise in temperature will have a negative effect on yield without adaptation, with further negative effects beyond the 2080s, regardless of adaptation and emission scenarios (Porter et al., 2014).

The effect of temperature on cereals (rice, wheat and maize) in Nepal is in line with global trends and findings. Karna (2014) reported that rice has reached the maximum temperature threshold (30°C during flowering and fruiting) in the Tarai. Rice yields are projected to decrease with further increases in temperature (4.2% yield reduction with 1.6°C rise by 2100). Similarly, using a crop simulation model, Poudel and Kotani (2013) reported that rice and wheat yields are impacted negatively by increased temperature in all regions of Nepal, but the impact varies with crop type and altitude. A 1°C increase adversely affects rice yield in all regions, but has a positive effect on wheat yield at low altitudes, and negative effect at mid/high altitudes (Poudel & Kotani, 2013).

Malla (2009) reported that rice yields increased by 17.1% and 26.6% with temperature increases of 6.2°C and 7.4°C, respectively, in experimental research of the Nepal Agriculture Research Council. With ambient temperatures >30°C during the study (2001–2005), an additional 6–7°C exceeded the temperature threshold of 32–34°C. Such findings are at odds with the global literature, which reports that temperatures above 34°C are detrimental to cereals and reduce yields. A crop simulation model (DSSAT) showed that a temperature increase of 4–7°C and doubling of CO_2 increased the yields of rice, wheat and maize in all regions (Tarai, Hill and Mountain), except for maize in the Tarai (negative effect) (Malla, 2009).

Impact on horticultural crops

Increased temperatures are projected to negatively impact some fruit crops due to insufficient chilling temperature and chilling hours required for crops such as grapes and apples (Luedeling, Girvetz, Semenov, & Brown, 2011; Wolfe et al., 2008). Early flowering and maturity have been reported in response to higher temperatures in grapes in Australia (Webb, Whetton, & Barlow, 2011) and apples in Japan (Fujisawa & Kobayashi, 2010) and South Africa (Grab & Craparo, 2011). Early budburst and flowering in several tree species (e.g. *Magnolia sp. Michelia champaca*, *Rhododendron spp.*, *Prunus persica*), and the emergence of insects and diseases, including mosquitoes, were reported by Chaudhary & Bawa (2011) in the eastern hills of Nepal and Darjeeling, West Bengal of India.

Impact on insects, diseases and weeds

The impact of climate change on insects varies. Temperature is critical for flower blossoming, pollinators and natural predators in insect ecology. Potts et al. (2010) reported that climate change is one of various potential drivers (agrochemical, pathogens, alien species, climate change, and interaction among them) that affect wild and domesticated pollinators. Most studies have shown that an increase in temperature and CO_2 increases an insect's growth rate, over-wintering, migration and expansion of geographical range, and diversifies host plants (Cannon, 1998; Porter, Parry, & Carter, 1991). For example, the USA has witnessed greater infestations of Japanese beetles (*Popillia japonica*) in early cultivated soybean due to high carbon: nitrogen (C: N) ratios and sugar contents in plant leaves (Hamilton et al., 2005), the UK has reported increased aphid severity due to elevated CO_2 (Cannon, 1998).

Change in climate variability influences pathogen-host interactions, pathogenicity and the rate of disease development (Coakley, Scherm, & Chakraborty, 1999; Chakraborty et al., 2000). Three possible effects of change in climate variables on plant diseases are reduced yields, decreased efficiency of disease management and change in geographical distribution (Coakley et al., 1999).

Weeds are favoured with increased temperatures and CO_2 concentrations in future higher emission scenarios (McDonald et al., 2009; Wolfe et al., 2008), such that weed composition and competitiveness changes, where minor weeds can become major weeds and vice-versa (McDonald et al., 2009; Ziska & Goins, 2006) Herbicide resistance and effectiveness is less likely with elevated CO_2 (Manea, Leishman, & Downey, 2011). McDonald, Riha, and Ditommaso (2010) suggested where crop–weed height differences during early growth indicate the appropriate timing to apply post-emergence herbicides

3.3.3 Climate change, disaster and vulnerability nexus

Natural hazards are physical phenomena that occur naturally and are influenced by the onset of events related to geophysical (e.g. landslides), hydrological (e.g. floods), climatological (e.g. extreme temperature, droughts), meteorological (e.g. storm), or biological (e.g. insects, disease and weeds) factors (IFRC, 2018). The IPCC AR5 2014 defined a natural hazard as the "occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources" (IPCC, 2014c). It is believed that the natural cycle and pattern of natural hazards are altered due to changes in the climate system (Anderson & Bausch, 2006). Such changes in climatic pattern and anthropogenic interventions increase the possibilities of extreme events, such as floods, landslides, heat/cold waves, and crop failures (Anderson & Bausch, 2006; IPCC, 2012). Natural hazards cause human death, damage to physical property, economic losses and changes in social dynamics. The impact of natural hazards depends on the geographical area, and the adaptive capacity and level of preparedness of people.

Extreme climatic events have a direct impact on agricultural production systems and other natural resources, thereby increasing vulnerability and risk. Increasing temperatures will accelerate evapotranspiration, thereby increasing water requirements, and cause drought in combination with low rainfall. Similarly, the frequency of extreme rainfall is expected to increase in the 21st century, causing flooding (IPCC, 2012).

The relationship between natural disasters and climate change is well-known (Anderson & Bausch, 2006; IPCC, 2012; Lal, 2003). The Special Report of the Intergovernmental Panel on Climate Change (SREX) (IPCC, 2012) established the relationship of anthropogenic climate change and natural climatic variability to climate extremes and other climate and weather events that lead to disaster risks[19]. Anderson & Bausch (2006) found a relationship between climate change and extreme events in Europe, with increased heat waves, increased rainfall severity and intensity, and a shift in rainfall pattern related to climate change. Intense rainfall caused immediate flash floods and as well as drought at other times due to low rainfall. Further increases in heatwaves, flooding, and strong windstorms are predicted for the 21st century in Europe (Anderson & Bausch, 2006).

Nepal is one of the most vulnerable countries to natural disasters due to its rugged topography, young and steep mountains, and concentrated heavy rainfall (Pradhan, 2007). According to the United Nations Office for Disaster Risk Reduction (UNISDR), flooding is the number one hazard in Nepal based on an analysis of 43 years (1971–2013). Fires, earthquakes, and landslides are ranked second, third and fourth, respectively, based on the number of people affected and physical property damaged. However, epidemics are the number one cause in terms of human deaths (DesInventar, 2018). Nepal's Tarai is particularly vulnerable to floods and fire, whereas hills and mountains are liable to landslides and soil erosion. Drought is problematic throughout the country (MoHA & DPNet-Nepal, 2015). Similarly, both heatwaves, coldwaves and occasional windstorms are exerting enormous pressure on human life and livelihoods, including agriculture.

Flooding is a devastating disaster globally. According to the World Bank, one-third of the world's land area is flood-prone, and about 82% of the world population is affected by floods (Dilley et al., 2005). The duration and intensity of rainfall lead to flash floods, landslides and soil erosion that have direct implications on farming, including human and physical safety.

---

[19] Disaster risk (r) is a function of probability (p) and consequences (c) ($r = p \times c$), where p is the chance of occurrence of a particular disaster in a certain period of time, and c is the impact/severity of the disaster (IPCC, 2012).

In Nepal, river floods in 1993, 2008 (Koshi flood[20], mid and far-western floods[21]), and 2014 (Kailali and the Babai River flood[22]) have been notable flood disasters that not only caused physical and economic damage but also claimed lives (MoHA & DPNet-Nepal, 2015; Practical Action, 2017).

Agriculture in Nepal is largely dependent on monsoon rainfall; drought, both in summer and winter, persistently affects agricultural yield. Summer drought is caused by the El Niño Southern Oscillation (Sigdel & Ikeda, 2010), and winter drought is influenced by the warming Indian Ocean and Arctic Oscillation (Sigdel & Ikeda, 2010; Wang, Yoon, Gillies, & Cho, 2013).

Drought is more serious than other hazards in terms of its greater outreach and impact (Wilhite, 2000). According to Wilhite (2000), drought mainly occurs from low precipitation, but is aggravated by high temperatures, strong winds and low relative humidity. The term drought[23] refers to the unavailability of adequate water due to the failure of rain, insufficient storage in the soil surface and sub-surface region, and low storage in the root zone (Lal, 2011). Drought severely impacts crop production in Nepal. For example, the western Nepal drought in 2008/2009 reduced wheat and barley yields more than 50%, compared with the previous year (Wang et al., 2013).

[20] On 18 August 2008, the embankment of the Koshi River breached; 493 lives were lost, 3500 were reported missing and 575 ha of agricultural land was deposited with silt and sand (Practical Action, 2017).
[21] From 19–21 September 2008, intense rainfall in the mid- and far-western regions of Nepal (Banke, Bardiya, Kailali and Kanchanpur districts) resulted in flash flooding. In Kailali, 15 people died. The floods affected 23,660 households and the event was recorded as the deadliest flood in 25 years.
[22] On 15 August 2014, floods in the Babai River and the Karnali Rivers affected people in the Surkhet, Dang, Bardiya and Kailali districts of mid- and far-western regions of Nepal; 53 people were confirmed dead, 34,760 families were affected and 5,936 families were displaced (Practical Action, 2017).
[23] There are three types of drought—meteorological, hydrological, and agronomic. Meteorological drought is due to a decline in rainfall over a long period. Hydrological drought is due to an extended period of reduced surface runoff and depleted groundwater reserves. Agronomic drought refers to the unavailability of soil moisture in the crop root zone due to water losses through runoff and evaporation (Lal, 2011).

It is clear that climate change has already impacted lives and livelihoods, including agriculture. The agricultural impact is not uniform and varies according to region, crop type, and crop growth stage. In general, temperatures above 30°C reduce crop yields, while temperatures above 34°C cause flower senescence and pollen sterility that may lead to complete crop failure. Despite the uncertainty, it is generally understood that increasing temperatures will cause further damaging effects without adaptation. The impact on insects requires more measures to protect pollinators and predators. Increased temperatures and CO_2 favour diseases and weed growth, competitiveness and shifts in agroecological range. Extreme climatic events and hazards/disasters, such as floods, droughts, fires, and landslides, have increased with human interventions and climate change.

3.4 Adaptation to climate change

This section discusses adaptation strategies in agriculture to reduce the impact of and future vulnerability to climate change. The concept of adaptation has gained prominence since the TAR (2001). The IPCC in the TAR considered adaptation as "adjustment to climatic stimuli or effect." Simply, adaptation to climate change is reducing vulnerability or enhancing resilience[24] against observed and expected extreme weather risks and climate variability. Similarly, the Fifth Assessment Report (AR5) 2014 (IPCC, 2014c, p. 118) defines adaptive capacity as, "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences."

The AR5 of the IPCC projected that adaptation is important, being most effective within moderate changes in temperature (1–2°C in temperate regions and 1.5–3°C in tropical regions) by delaying the potential negative impact of climate change for several decades (Howden et

[24] In general, resilience is the ability of a system to cope/resist stress and disturbances, but also reduce vulnerability and risks for the future.

al., 2007; Porter et al., 2014). Adaptation is an option that need to be undertaken immediately; without it, the impact of climate change may increase (Porter et al., 2014).

3.4.1 Types of adaptation

There are many ways to classify adaptation. Adger et al. (2007) in the IPCC AR4 classified adaptation practices according to sector (agriculture, forestry, water), actor (government, non-government, private), and spatial (local, national, regional, global) categories. However, anticipatory, autonomous, and planned adaptation are the most discussed categories (IPCC, 2001, 2007).

Anticipatory adaptation

Anticipatory adaptation, also known as proactive or ex-ante adaptation, includes measures that take place before any observed impact of climate change. Adaptation that takes place after the observed impact of climate change is called ex post facto or reactive adaptation (IPCC, 2001, 2007).

Autonomous adaptation

Autonomous adaptation, or spontaneous adaptation, is an immediate response and/or action to cope with the changing climate and extreme weather events. Autonomous adaptation comes naturally through local community efforts after climatic stimuli, hazards or disasters through voluntary welfare contributions, without any intervention by public agencies (IPCC, 2001).

Planned adaptation

Planned adaptation is well-planned, long-term strategic action to adjust or transform the system through the leadership of public institutions. It consists of institutional arrangements and policy formulation, with practical implementation, and is often realised for effective adaptation (IPCC, 2001).

3.4.2 Approaches to studying adaptation

Two basic approaches to studying adaptation are found in the literature: (1) enhancing adaptive capacity by reducing vulnerability (the vulnerability approach); and (2) the transformational approach. The AR4 of the IPCC used the vulnerability approach to assess adaptive capacity. It concludes with some generic and specific indicators relating to vulnerability and adaptive capacity. Generic indicators include education, income and health. The specific indicators of climate impact include damage or loss caused by floods or droughts, knowledge, technologies, and institutions. All these factors have varying degrees of influence to determine the adaptive capacity of a system (Adger et al., 2007).

The IPCC SREX 2012 and the AR5 2014 used a risk-based framework for adaptation, incorporating concepts of vulnerability, risk and climate adaptation. Typically, the concept of risk includes dimensions of probability and uncertainty related to social responses and threats (Noble et al., 2014). The risk-based framework has three levels of risk: acceptable risk, tolerable risk, and intolerable risk. Acceptable risk frequently happens, and its impact is low, so it does not need adaptation action. Tolerable risks are important in terms of adaptation, as they should be maintained within a reasonable level. Intolerable risks are either beyond the capacity of adaptation or not efficient and economical for reducing climate change impact. Under the tolerable risks, "incremental adaptation"[25] can be useful, but for intolerable risks, transformational change may be necessary. The transformational adaptation (paradigm shift) approach seeks to change the attributes of system thinking, perception and action to climate change, and includes activities such as changing livelihood options and migration and relocation to new places (Noble et al., 2014. In some frameworks transformation and adaptation are counterposed, rather than transformation being used as an approach to adaptation.

---

[25] Incremental adaptation refers to maintaining the existing system of technology, governance, institution, and value systems though adjustments, such as changing cropping patterns (planting date adjustment, varieties) or more efficient use of the irrigation system.

Adaptation refers to enhancing actions to meet challenges while staying on already existing pathways, whereas transformation refers to changes that initiate new pathways (as the term paradigm shift also implies). So, the term transformational adaptation is intended to indicate that both types of pathway change can be operative in complex responses.3.4.3 Agricultural adoption relating to adaptation

The concept of adoption originates from sociology, which is associated with the discrete choice of an individual to opt for an innovation. Adoption is the part of innovation that inquires who adopts and in what time frame to new technology/ideas (Zilberman, Zhao, & Heiman, 2012). Adoption focuses on the pattern of adoption, profile of adopters, timing of adoption, and impact of the adoption. The concept of adoption is generally introduced for innovations and new technologies that often require policies and institutional arrangements. The major objective of adoption is often to increase profits. The term adoption is widely used in academia and has been used in parallel with and sometimes even interchangeably with adaptation in the context of climate change.

Adopters of innovations in agriculture can be grouped into five categories: innovators, early adopters, early majority, late majority, and laggards. Rogers (1958) categorised adoption based on the time and scale of adoption. The time of adoption represents the best measure of the diffusion of agricultural innovation practices. In general, there are fewer farmers in the innovators and early adopter categories—due to the newness of the technology and low risk-bearing capacity of farmers—than the early majority and late majority categories, and a lower frequency in the laggard category, such that the adoption curve has a symmetric bell-shape (Rogers, 1958). Profit margins, associated risks, and structural and behavioural characteristics of individuals determine adoption. The relative speed of adoption of agricultural practices between innovators and early adopters not only differs with structural characteristics (such as age, land size, market access), but also behavioural characteristics (external information analysis, innovative ideas, and cooperation) (Diederen, Van Meijl, Wolters, & Bijak, 2003).

The concept of adaptation comes from biology and deals with the response to shocks, such as flooding hazards due to climate change. Responses to climatic shocks after the event may be called reactive (ex-post) adaptation, whereas planned responses to future shocks are called proactive (ex-ante) adaptation. The proactive response includes mitigation aspects, such as migration, reassessment, and innovation (Zilberman et al., 2012). Adaptation is a broad concept that incorporates adoption, such as the adoption of new agriculture technology, inputs and extension services to enhance climate change adaptation. Adaptation emphasises historical evidence, and requires a longer time frame to obtain evidence for adaptation knowledge and practices. The adaptation can be completely new knowledge, technology and practices that follow upon the process of adoption.

Adoption itself is an adaptation strategy to climate change in agriculture. The motive to adopt any technology is primarily for profit; however, adoption is an important strategy for adaptation to climate change, since many agricultural technologies are developed to reduce the effects of biotic and abiotic stresses in agriculture. Adoption can be a quick way to respond to shocks and hazards, but adaptation may also encompass a long-term approach based on historical evidence of farmers' continuous experiences, experimentation and adjustments to climate variability.

3.4.4 Adaptation practices in agriculture

Adaptation options in agriculture can be categorised into four groups: technological, agronomic, sociocultural and institutional (Noble et al., 2014). Technological adaptation covers the technological aspects of crop improvement, as well as those related to irrigation and climate information. Agronomic adaptation includes various crop production strategies, such as seed selection, sowing date adjustments, and crop protection and management. Sociocultural adaptation options relate to education, local knowledge, extension services, and behavioural changes. Institutional options concern economic and financial incentives, laws and regulations, and government policies and programmes relating to adaptation and mitigation. The selection and use of adaptation depend on the availability of adaptation options and opportunities. However, incremental adaptation is more common than the transformative approach to adaptation.

This review focuses on the adoption of agronomic practices, such as crop genetic diversity, farmer-managed irrigation systems, tillage methods, crop rotations, crop residue and manure management, and production systems. Most agronomic practices have implications for both adaptation and mitigation. The specific agricultural practices related to mitigation are discussed in the mitigation section. Local agricultural adaptation practices are diverse; this review focuses on rice–wheat/legume systems, particularly in South Asia.

Conservation agriculture

Conservation agriculture (CA) is based on minimum soil disturbance, continuous soil cover, and diversified crop rotations, and often viewed as a viable option for reducing GHG emissions in agriculture (Lal, 2016). Conservation agriculture reduces soil erosion, conserves soil moisture, sequesters soil organic carbon, and reduces input use, and can be synergistic with forestry (in the early stage of plantations) and integrated livestock farming (Lal, 2016). A non-puddled technique of land preparation (strip method) and rice transplantation by using machine decrease fuel and labour costs, increase the yield of rice grain and subsequent crops (lentil, wheat), the effectiveness of herbicides, and improves soil quality in long-run as well as reduce greenhouse gas emissions (Alam, Bell, & Biswas, 2019; Alam, Biswas, & Bell, 2016; Bell et al., 2019). A meta-analysis of 700 cases of CA in Sub-Saharan Africa showed that CA produced higher maize yields than conventional farming under drought and high-temperature conditions due to better soil water infiltration (Steward et al., 2018).

Conservation tillage,[26] such as zero-tillage, no-tillage or minimum tillage, in rice–wheat systems produces similar or higher yields, particularly of rice, than conventional tillage. Most studies on CA and conservation tillage report similar or higher crop yields than a conventional tillage system, along with lower production costs (mostly through reduced labour), increased water productivity and reduced GHG emissions, thereby contributing to the mitigation of climate change (Gathala et al., 2015; Jat et al., 2014; Ladha et al., 2016; Sapkota et al., 2015). Conservation agriculture reduces emissions (mostly CO_2, CH_4, N_2O), but often increases N_2O depending on agronomic practices and the use of residue/organic matter (Jat et al., 2014; Mishra & Singh, 2012; Phillips, Thomas, Blevins, Frye, & Phillips, 1980; Zhao et al., 2016). Some studies have reported reduced yields under CA but reduced CH_4, N_2O and CO_2 emissions, relative to conventional practices, e.g., in a short-term experiment on pigeon pea (Pratibha et al., 2016). However, zero-tillage generally increases crop yields and reduces emissions over the medium- and long-term (Jat et al., 2014; Sapkota et al., 2015). Gathala et al. (2015) reported that CA-based tillage (ridge and strip tillage) did not increase yields in a rice–rice system, but increased yields and profitability in a rice (*kharif)*–maize (*rabi*) system in Bangladesh.

Few studies have related conservation tillage to climate change mitigation, as many believe that no-tillage does not play a significant role in mitigation due to the small amount of soil carbon deposition, which is often emitted during latter tillage. Some researchers argue that

[26] Conservation tillage is a broad term used to cover various types of tillage methods (zero-tillage, reduced tillage, minimum tillage etc.), which involve fewer soil disturbances and greater addition of crop residues (at least 30%) than conventional tillage (Reicosky, 2015).

the mitigation role of CA has been over-emphasised (Powlson, Stirling, Thierfelder, White, & Jat, 2016; Wolf, Herrera, Tomich, & Scow, 2017).

The major challenge of CA is that farmers want to see immediate results in terms of yield, but it usually takes 4–5 years, and the reductions in production costs mostly from family labour are not often considered by small farmers (Jat et al., 2014; Sustainnet EA, 2010). Another challenge of CA is the need for crop residues to cover the soil, but these are also used as animal fodder.

Direct-seeded rice

Direct-seeded rice (DSR) is viewed as an alternative to paddy rice that avoids permanent flooding. It not only reduces the GHG emissions (CH_4 and N_2O), but also the cost of production by cutting labour and tillage costs. There are three DSR techniques: dry-seeding, wet-seeding, and water-seeding (Farooq et al., 2011), in which pre-germinated seeds are sown in dry, puddled, or puddled with standing water fields, respectively. Seed vigour is important in DSR for rapid germination, seedling anchoring and nutrient uptake under dry and water-deficit conditions (Yamane et al., 2018). From an adaptation point of view, farmers use DSR for low rainfall, late-season sowing in case the earlier transplanted rice is damaged by flooding or other causes. Swidden agriculture is an excellent example of DSR practised by many Indigenous people in the highlands. There is broad consensus that DSR reduces GHG emissions, saves labour and tillage costs, and may increase yield, relative to conventional continuous flooded rice farming, but yields vary under different contexts (Bhushan et al., 2007; Chakraborty et al., 2017; Kumar & Ladha, 2011; Mishra, Khanal, & Pede, 2017).

In contrast, Zhang et al. (2018) reported lower yields from DSR due to weed problems, which mainly occur in dry-DSR (Chakraborty et al., 2017; Farooq et al., 2011; Kumar & Ladha, 2011; Rao, Johnson, Sivaprasad, Ladha, & Mortimer, 2007). Chemical weed control is the best option to eliminate weeds (Farooq et al., 2011), though hand weeding is an immediate option for smallholders (Rao et al., 2007).

Organic agriculture

Organic agriculture is a nature-based production system, where crop species/varieties and techniques are used continuously to adjust to the agroecology and local environment. Organic agriculture is about soil and environmental protection and the provision of healthy and nutritious food with no use of chemicals. Organic agriculture has enormous potential for GHG mitigation due to the low external inputs and financial requirements (Müller, 2009). However, low yields are always a concern in organic farming, and may require deforestation to meet food demands (Trewavas, 2001). Seufert, Ramankutty, and Foley (2012) found that organic agriculture results in 5–34% lower yields than conventional agriculture, depending on the level of management. Organic agriculture contributes to adaptation and mitigation through the low use of inorganic fertiliser and other energy sources (Scialabba & Mller-Lindenlauf, 2010). Organic carbon deposition in soil with minimum tillage, and hence sequestration, is also higher under organic agriculture than non-organic systems (Wolf et al., 2017). Therefore, organic agriculture may have higher global warming potential (GWP) per unit of production than modern agriculture. Hence, there is a need for further research to quantify the mitigation and adaptation potential of organic agriculture. Furthermore, GWP (CO_2e) is found calculating both per ton of production (yield-scaled GWP or life-cycle GHG emissions) as well as per ha. The latter one can be ultimately converted into CO_2 –eq/ton (Ladha et al., 2016).

Adaptation has mostly positive outcomes; however, in some cases, presumed adaptation measures exhibit undesirable effects, or "maladaptation". As defined by the IPCC (2014a), "maladaptation refers to adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future." Some examples of maladaptation were seen in the Green Revolution, which increased productivity and food security in Asia, at the expense of the soil, farming diversity, and dependency on seeds and fertiliser (Ellen, 2007). Another example is in Palca, Bolivia, where smallholder farmers practised intensive farming and cash cropping. The community has realised the impact of climate change and intensive monocropping, which has increased farmer vulnerability (IPCC, 2014a) compared to earlier integrated farming systems. Maladaptation can be both temporal and spatial. Particular adaptations can benefit one group or sector, but disadvantage another group and sector. Agricultural commercialisation and modernisation policies and programs provide short-term farmer profit, but reduce agrobiodiversity and increase sensitivity and vulnerability to climate change in the long-term (Noble et al., 2014).

3.4.5 Limits and constraints/ barriers of adaptation

Adaptation is a means, not the end to solve problems. Adaptation has its limits, to the point where adaptation practices are effective and applicable for reducing the impact of climate change, beyond which adaptation cannot be secured from "intolerable risks". Adaptation limits are not static; they can change over time with investment, regulatory policies, and social or political attitudes (Noble et al., 2014). Some adaptations are intolerable at certain times, but tolerable at other times; this phenomenon is called the "soft adaptation limit". A hard adaptation limit is when no available adaptation actions are available to avoid an intolerable risk (Noble et al., 2014).

While the terms adaptation constraints, barriers and limits are often used interchangeably, even in IPCC Assessment Reports, there is some conceptual differentiation. Klein et al. (2014, p. 907) defined adaptation constraints as "factors that make it harder to plan and implement adaptation actions" by reducing adaptation options, their effectiveness and adaptation costs.

The adaptation constraints/barriers under the five different types of livelihood capital and their potential adaptation opportunities are listed in Table 3.1.

Table 3.1 Constraints and opportunities for adaptation in agriculture

Constraints/barriers to adaptation	**Description**	**Adaptation opportunity**	**References**
Natural capital			
Ecological barriers Land Plants and animals	Availability of agricultural land, soil type, irrigation source Yield potential of crops/varieties/breeds	Low external agricultural inputs, local crop landraces Agricultural intensification Irrigation technology Improved, resistant and high-yielding varieties	AIPP (2012) Caritas (2016) Swiderska, Song, Li, Reid, and Mutta (2011) Technology Need Assessment (2017)
Physical capital			
Infrastructure Information and communication technology (ICT)	Geographical remoteness, inaccessibility, extension services, information technologies	Digital/mobile telecommunication Technological innovation Infrastructure efficiencies Early warning systems	Chhetri, Chaudhary, Tiwari, and Yadaw (2012) Marvin et al. (2013) Lenton, Livina, Dakos, Van Nes, and Scheffer (2012)
Social/cultural capital			
Sociocultural factors Cognitive behaviour Normative behaviour Institutions and governance	Demography (age, sex, gender, class, caste system) Psychology of perception Rigid in traditional beliefs Participation and representation in social and political institutions	Development of social capital	Adger et al. (2007) Adger, Barnett, Brown, Marshall, and O'Brien (2013) Deressa et al. (2011) Deressa, Hassan, Ringler, Alemu, and Yesuf (2009) Jones and Boyd (2011)

Human resource capital			
Knowledge, awareness, network and leadership	Education-related training and exposure, profession/job, social/political networks	Development of human capital	Bowen, Cochrane, and Fankhauser (2012) Lemos et al. (2013)
Financial capital			
Access to credit Savings	Job, income Bank account, savings, credit access	Resource provision	Ayers and Huq (2009) Klein (2010)

3.5 Mitigation of climate change

The IPCC defined mitigation as human interventions to reduce emissions and improve GHG sinks. Agriculture, Forestry and Other Land Uses (AFOLUs) are both the source and sink of GHG emissions. The AFOLU sector is the second-largest economic sector contributing 24% to total GHGs after energy (electricity and heat, 25%) (IPCC, 2014b). Other important sectors are industry, transport, building and others (IPCC, 2014b). Agriculture alone contributes 5–5.88 $GtCO_2$-eq/year or ~50% of the total AFOLU emissions (10–12 $GtCO_2$-eq/year). The highest percentages of GHG emitted from agriculture occur in Asia, Africa and Latin America. In the absence of mitigation, adaptation to climate change will be hard, and adaptation practices may not work due to their limitations. The impact of climate change may be irreversible if only adaptation is used; therefore, mitigation is equally important for sustainable agricultural development.

There are three main strategies for mitigation: reducing/preventing emissions from the sources, sequestering GHG to sinks, and substituting fossil fuel-based products with biological products (Smith et al., 2014). Livestock and manure, inorganic fertiliser and wet rice cultivation management are important to reduce CH_4 and N_2O emissions from agriculture. Increasing the carbon sink capacity of either the soil or plant biomass is important for carbon sequestration.

Crop and minimal land tillage systems sequester CO_2 from the atmosphere and restore it into biomass and the soil, respectively. Crops, particularly fruit trees, have enormous potential to store carbon as biomass (Smith et al., 2014). Peatlands and mangroves are other important carbon sinks, with water drainage and their conversion to other forms of land use significantly increasing GHG emissions to the atmosphere (Smith et al., 2014).

3.5.1 Agricultural practices for mitigation to climate change

As stated earlier, adaptation and mitigation are interrelated. In rice–wheat/legume cropping systems, CH_4 emissions from paddy and livestock and N_2O emissions from manure, residues and inorganic fertiliser are important. Some of the measures to reduce water demand in rice have been discussed—direct seeding in dry beds and reducing tillage. This section focuses on practices that help to reduce emissions, mainly from paddy rice fields. This is important because rice is the main food source in Asia, and most rice is cultivated under flooded conditions. Livestock and manure are integral components of farm power and manure for smallholder farmers. Therefore, reducing emissions from these two sources is important for mitigation.

Mitigation can be grouped into supply- and demand-related options. Smith et al. (2014) reviewed various technologies, practices and behavioural aspects to manage crop, pasture, forage, and livestock production for reducing/preventing GHG emissions. Supply-side mitigation options include the use of improved varieties, efficient and effective fertilisers, reduced tillage, crop rotations, relay sowing of pulses such as lentil, cover crops, effective water management, rice management and biochar. Options to reduce CH_4 production in livestock include grazing and pasture management, livestock raising, feeding and breeding improvements, and urine and manure management. These practices are used both for adaptation and mitigation.

Demand-side options involve transforming the food system to reduce food losses by (1) reducing post-harvest losses, (2) substituting animal-based proteins and (3) fossil fuel-based goods with low GHG-intensive and renewable goods (Smith et al., 2014). Post-harvest losses are high in developing countries due to the lack of the appropriate technologies and facilities, whereas food losses from the dining table are high in developed countries (Godfray et al., 2010; Hodges, Buzby, & Bennett, 2011). Human diets that are predominantly based on high emission-based foods (animal-based protein) can be substituted with less emission-intensive foods (plant-based protein) to reduce GHG emissions (Bellarby et al., 2013; Berners-Lee, Hoolohan, Cammack, & Hewitt, 2012; Pathak, Jain, Bhatia, Patel, & Aggarwal, 2010). Among animal-based proteins, beef protein is more GHG-intensive than pork, chicken, and dairy proteins (de Vries & de Boer, 2010). Changing human diets is more cultural and a matter of individual preference than technical, such as the acceptance and consumption of meat and fish substitutes. Substituting fossil fuel-intensive goods, such as brick, concrete, iron and aluminium with sustainably produced timber will reduce energy use and emissions. Timber remains as a carbon sink unless it burns since it stores carbon in the wood biomass (Smith et al., 2014).

Methane and nitrous oxide reduction from paddy

Methane (CH_4) and nitrous oxide (N_2O) are the dominant GHG emitted from agriculture. Alternate wetting and drying of rice paddies rather than continuous flooding is a recommended technique to mitigate CH_4 emissions (Islam, van Groenigen, Jensen, Sander, & de Neergaard, 2018; Kesheng & Zhen, 1997; Li et al., 2002; Oo et al., 2018). However, Pandey et al. (2014) reported that alternate wetting and drying did not contribute to total mitigation in Vietnam, as farmyard manure, plant residues and biochar increased N_2O emissions. In general, intermittent irrigation helps to reduce CH_4 emissions from rice fields, but alternate wetting and drying increases N_2O emissions; total emissions are less in terms of the global warming potential (GWP[27]) of N_2O (Hou, Peng, Xu, Yang, & Mao, 2012; Yang, Peng, Xu, Luo, & Li, 2012).

During alternate wetting and drying rice cultivation, most of the N_2O (> three quarters, 78–85) is emitted after 8–10 days of fertilization during the soil drying period after the water is drained. Hence, it is suggested that the water should be drained in the early- and mid-season of rice cultivation (Islam et al., 2018) and fertiliser applied within 10 days of re-irrigation when the soil pores remain filled with water (Peng et al., 2011) for the effective mitigation of CH_4 as well as N_2O in rice paddy fields. Fertiliser containing a combination of nitrogen, phosphorous and potash (NPK), such as ammonium sulphate, emits less N_2O than nitrogenous fertilisers, such as urea (Datta, Santra, & Adhya, 2013; Kesheng & Zhen, 1997). Similarly, slow-release fertiliser and the spreading of manure and crop residues before paddy cultivation (off-season) help to reduce N_2O emissions.

CH_4 and N_2O reduction from farm manure

The release of CH_4 from the enteric fermentation of ruminants is the main cause of GHG emissions in agriculture. Various strategies and methods have been recommended to reduce emissions from livestock, but this is beyond the scope of this study. However, farmyard manure, an important source of CH_4 and N_2O, is crucial for soil fertility management and reducing inorganic fertiliser use in smallholder farming.

In terms of manure management, anaerobic decomposition in piles, heaps and tanks produces N_2O through denitrification[28]. Therefore, it is recommended that manure slurry and chicken manure are spread during winter or spring. Winter has lower N_2O emissions than

[27] "It is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of CO_2." A higher GWP means more warming to the earth as compared to CO_2 for the given period of time. CO_2, CH_4, and N_2O have 1, 28–36, and 265–298 times GWP, respectively, over 100 years (EPA, n.d.).
[28] Nitrification is the biological process of oxidization of ammonium that releases nitrate, whereas the denitrification process converts nitrate into nitrous oxide and nitrogen gas.

warmer seasons due to the slower denitrification rate (Bates, Brophy, Harfoot, & Webb, 2009). Anaerobic digestion technology decomposes organic materials in a closed vessel under high temperatures to produce CH_4 (65%) and CO_2 (35%). The methane can be used for cooking (biogas) and light (Bates et al., 2009).

3.5.2 Interrelationship between adaptation and mitigation

There are at least four ways that mitigation and adaptation influence each other and determine climate resilience: (1) adaptation that has consequences for mitigation; (2) mitigation that has consequences for adaptation; (3) decisions that have trade-offs and synergies to adaptation and mitigation; and (4) via a process that affects both adaptation and mitigation (IPCC, 2007).

Adaptation affecting mitigation

Adaptation measures can have both negative and positive effects on mitigation. Adaptation measures, such as direct-seeded rice and conservation tillage (e.g. no-tillage and zero-tillage) complement mitigation to reduce emissions. Other adaptation practices, such as water pumping for irrigation, directly consume energy (IPCC, 2007). Infrastructure for adaptation in agriculture, such as warehouses, greenhouses and cold stores, increases material and energy consumption. Similarly, the use of inorganic fertiliser increases N_2O, and other inputs (pesticides, herbicides) increase direct energy inputs (IPCC, 2007).

Mitigation affecting adaptation

Mitigation has both positive and negative effects on adaptation. As discussed earlier, mitigation either reduces/prevents emissions from sources or sequesters CO_2 into sinks. Afforestation/reforestation is considered one of the best mitigation options. However, the significance of increased forest cover is determined by tree species, geographic location and climate characteristics (IPCC, 2007). Afforestation in regions with intense rainfall and an extended dry period can increase water availability, but in semi-arid regions, afforestation can reduce water availability (UK FRP, 2005 as cited in IPCC, 2007). Afforestation and reforestation are significant contributors to biodiversity conservation. Incremental temperatures increase evapotranspiration from plants, which is an important source of rainfall (at least 40%) (Ellison et al., 2017). Smart-ways to conserve ground water could include the gradual replacement of water-inefficient trees with water-efficient trees, considering the native bush and trees in the local forest ecosystem (IPCC, 2007; Murgueitio, Calle, Uribe, Calle, & Solorio, 2011). In agriculture, converting forest or virgin land (peatland, mangroves) into farming or changing from a horticultural land use system to cereal-based farming has severe negative consequences for GHG emissions (IPCC, 2007).

Decisions and processes affecting mitigation and adaptation

Decisions and processes related to mitigation and adaptation have synergetic and trade-off relationships, which are determined by international conventions, treaties and agreements, and the implementation of institutional mechanisms in terms of funding, planning, and setting mitigation targets (IPCC, 2007).

In summary, adaptation and mitigation are interrelated, but the interrelationship is not well understood. Adaptation is often an immediate option, and actions are localised, whereas mitigation is a long-term strategic action incurring costs individually, but sharing effects universally. The integrated study of mitigation and adaptation has been limited (IPCC, 2007).

3.6 Resilience to climate change

The concept of resilience is complex, but it is generally understood as the ability of a system to deal with stresses (Speranza, 2010). Resilience is not only the ability to manage current impacts, but to mitigate future risks. The AR5 of the IPCC comprehensively defined resilience as “the capacity of social, economic and environmental systems to cope with a hazardous event for trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation" (IPCC, 2014c, p. 127). The Resilience Alliance (2018) described three characteristics of resilience: maintaining structure and function, self-organisation, and the capacity to learn and adapt. The resilience index (RI) is used to measure resilience, which is expressed as the capacity to cope with stress minus vulnerability (Shrestha, 2014).

Resilience and vulnerability are closely interrelated. Vulnerability focuses on the negative effects on systems, whereas resilience seeks to make systems more robust (Adger, 2006). Folke (2006) described resilience as an *'antonym'* of vulnerability. Vulnerability and resilience approaches that measure the impact of climate change are considered alternatives to impact-based climate assessments.

Adger (2000) described two types of resilience: *social* and *ecological*. Social resilience is with people, communities and groups, as determined by social, political and environmental factors, whereas ecological resilience is the ability of an ecosystem to overcome stresses and manage disturbances. Jordan (2009) cited multi-layered resilience at societal (individual, group and community), and spatial levels (national, regional and global).

3.6.1 Contribution of Indigenous knowledge to resilience

This literature review has enlisted and differentiated Indigenous and local agricultural practices with western scientific practices that contribute to minimising the impacts of climate change through adaptation and mitigation. There are no clear-cut boundaries to categorise Indigenous knowledge-based practices and modern science-based agricultural practices.

Farmers have made significant contributions to the modernisation of agriculture, being the "first scientists" to improve crops through the selection and conservation of local landraces. Farmers have also contributed to irrigation management, soil fertility management (crop rotation, residues incorporation), and local techniques of crop protection and storage, which are the basis of many modern technological innovations.

Agronomic practices cover a range of husbandry activities from crop selection, sowing date adjustment, switching land/crop, specific production and management, crop protection, and post-harvest and utilisation. Many Indigenous and local agricultural practices emit low carbon and are adapted to local ecosystems and environments. Mixed cropping of maize and legumes is one of the oldest practices to improve soil, production, and the adaptive capacity of farmers (Willey & Osiru, 1972). Conservation agriculture and direct-seeded rice are alternative options to conventional rice–wheat farming to mitigate and adapt to climate change (Jat et al., 2014; Sustainnet EA, 2010). Both practices have been used for centuries by farmers, mostly smallholder and Indigenous farmers, in Latin America and South Asia.

Studies concerning Indigenous knowledge of climate change are complicated due to political relationships between knowledge and identity that often exist in these contexts; however, some common understandings and agreements can be drawn. First is the acknowledgment of Indigenous knowledge and practices by the scientific world; for example, Indigenous knowledge is included in the IPCC's reports in AR4 (2007) and AR5 (2014). Second, Indigenous people and activists have realised that Indigenous knowledge alone might not be sufficient to feed the increasing population, as evidenced by the rural poor and Indigenous people facing food insecurity, hunger and poverty. The integration of Indigenous knowledge and scientific knowledge started after decades of discussion in the 1980s (Agrawal, 1995; Sterrett, 2011). Third, and most importantly, is that the conceptual debate concerning supremacy between Indigenous knowledge and scientific knowledge is over. The role and prospects of science will increase in agriculture, whereas Indigenous knowledge remains a source of knowledge for modern science, and a way of life for many rural farmers in developing countries.

3.7 Conclusion

Global warming and climate change have had a serious impact on human, environmental and natural resources. Climate change induces and accelerates natural disasters, which have an enormous impact on human life and livelihoods. The increasing temperatures and changing rainfall patterns have a direct effect on crop yields, shifting agro-ecological zones and the prevalence of insects, diseases and weeds. High temperatures (>30°C) reduce crop yields—higher temperatures (>34°C) can lead to complete crop failure—which is aggravated by drought and the lack of irrigation. Temperature is also critical to determine insect populations and behaviour, including pollinators and predators, which affect crop yields. High temperature, carbon dioxide concentration, and relative humidity favour diseases and weeds. Traditional agricultural practices mostly associated with Indigenous people, such as shifting cultivation, were adapted to local environments with lower emissions; however, these practices are diminishing due to limited land availability and increased food demands. Many Indigenous and local agricultural practices are adaptable in the changing climate context, which prevent emissions and are energy efficient, such as direct seeding of rice, broadcasting legumes in standing rice fields, growing multiple crops together, and incorporating crop residues in fields.

Resilience in agriculture is the interconnectedness of adaptation and mitigation. The adoption of scientific agricultural technologies, methods and technical services are as important for climate-resilient agriculture as Indigenous, traditional and local agricultural practices. Agricultural practices, such as conservation agriculture and zero-tillage, alternate wetting and drying rice cultivation, and the efficient use of inorganic fertilisers are some promising adaptive agriculture practices to reduce emissions in agriculture.

CHAPTER 4. RESEARCH DESIGN, THEORY AND METHODOLOGY

This chapter describes the research design and methodology used to conduct the fieldwork and analyse the data that support the objectives of the study.

4.1 Introduction: Fieldwork and community

4.1.1 Fieldwork area

The study was based in two rural villages, Thapuwa and Bikri, in the Bardiya District of Nepal (Figure 4.1). These two Tharu villages were selected for their contrasting climatic hazards, i.e. flooding and drought vulnerabilities. Despite their proximity to the Babai River basin system and the predominance of Tharu ethnicity, the villages are relatively distinct in terms of climatic hazards. Thapuwa is closer to the river and more vulnerable to flooding than Bikri, though Bikri is also subject to floods from the Babai River. There is no canal irrigation system at Thapuwa, so it was more drought-prone than Bikri before the introduction of electricity and pumps. Thapuwa is close to the district capital (Gulariya, 5 km away), providing opportunities for labour and business. Thapuwa villagers do not have access to forests, so they have planted trees and orchards for firewood. The Tharu have been living in this village for generations.

Bikri was settled in 1967 by immigrants from Dang-Deokhuri, which is more than 100 km east. Many Tharu migrated to *naya muluk* (Banke, Bardiya, Kailali and Kanchanpur districts) in the 1950s onward. They live close to the forest; many even moved to the forest to escape the floods that resulted in landslides and siltation of their land. In 2010, the traditional irrigation system was upgraded to a modern irrigation system from the Babai Irrigation Project; however, the timely availability and quantity of irrigation water is an issue because the villagers are the end-tail users. Like Thapuwa, Bikri is rural and has small landholdings, but it is further from the city (Gulariya, 9 km).

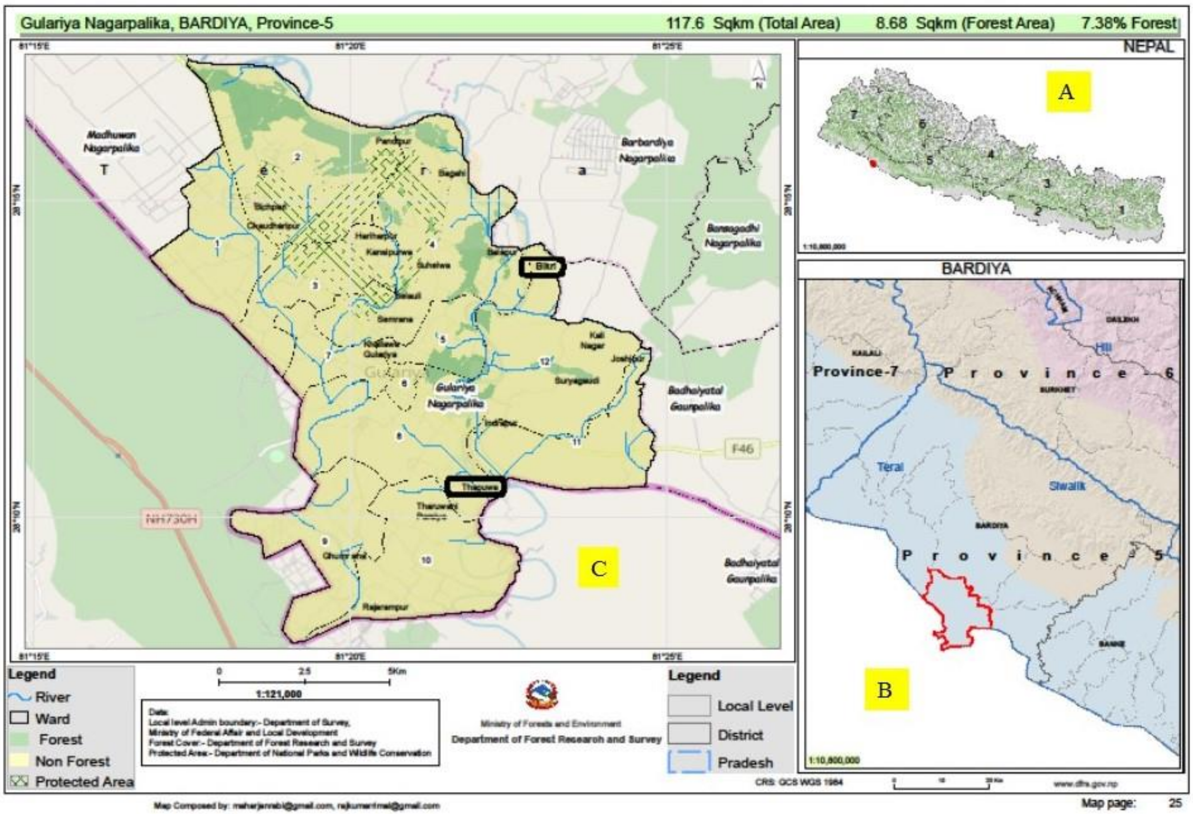


Figure 4.1 Map showing fieldwork sites

The map labelled "A" is map of Nepal with the Bardiya district indicated in red; "B" is district map showing the Gulariya municipality. "C" is of Gulariya municipality where two study villages, Thapuwa and Bikri, are marked.

Source: DoFRS (2019)

Gulariya lies on latitude 28° 13' 21.93" N, longitude 81° 19' 44.19" E, at 215 m above sea level (m asl). It is about 400 km west of Kathmandu (capital of Nepal). The district is politically divided into eight administrative units (six municipalities and two rural municipalities[29]). It shares a border with India in the south. The total area of the district is 2,025 km^2, of which two-thirds are plains (69%), with the remainder being Siwalik (*Churiya)* hills up to 1,300 m asl. Much of the district (48%) comprises the Bardiya National Park. The plains have a tropical climate, while the *Churiya* is subtropical. The summer season is hot and humid on the plains, with monthly mean temperatures up to 39.8°C in May/June and as low as 9.6°C

[29] Rural municipalities are less populated and more rural than municipalities

in December/January. The average annual rainfall total is 1118 mm, with 2050 mm the highest recorded rainfall (DDC Bardiya, 2013). Bardiya district is one of the least developed in Nepal in terms of the Human Development Index (HDI, 0.466) (Government of Nepal & UNDP, 2014) and road networks, with the national road network only connected in the 1990s.

Bardiya district is rural with agriculture as the main source of livelihood. The Rajapur area is famous for rice production due to its alluvial land and farmer-managed irrigation system. The district is self-sufficient and exports food to other parts of Nepal (DADO Bardiya, 2015). The Babai and Geruwa/Karnali are the two large river systems that flow through the district and on south to India.

4.1.2 Research community: the Tharu

There is a significant presence of Tharu (53%, ~226,089) in the Bardiya district (CBS, 2014b). In both study villages, Tharu predominate among the households. There is one non-Tharu household out of 86 in Bikri and seven non-Tharu households out of 143 in Thapuwa. There is a slight difference in language dialect and dress in the two villages, but they both believe in spiritual power and *barghar* and *guruwa/gurau* customary practices for village governance and judicial functions; however, many local practices have been superseded with by law and policies (Khadka, 2016).

4.1.3 Starting the fieldwork

The fieldwork was conducted over a total of six months—March–June 2018 focused on rapport building, household surveys and focus group discussions, while November–December 2018 concentrated on in-depth interviews.

Initially I visited Thapuwa regularly to familiarise myself with the people and the area. I spent several hours at the village tea shop, where I had the opportunity to meet and interact with many people. Many people suspected and even asked me if I was an NGO worker. They were surprised to learn about my PhD candidacy, and some even questioned, “Can someone be a student at your age?” It took several days and many attempts to establish relationships with the *barghar* (village head) and receive support for my research from village functionaries, such as *chaukidar* (village watchman) and *guruwa* (shaman). I conducted several transect walks and bike rides in and around my fieldwork villages. When I entered the villages, it was harvest time for pea, lentil, and mustard, allowing me to witness gender-differentiated practice in agricultural labour. Women carry crops on their heads, whereas men use a *bharwa* (carrying/shoulder pole).

Bikri village is familiar to me as it is my birthplace, and where I completed my primary school education and carried out my Master’s research. Bikri was challenging, as many parents asked me to find jobs for their sons and daughters. This was a real-life example of one of the disadvantages of long-term ethnographic research, where the maintenance of neutrality is advised (Sandstrom & Sandstrom, 2011). Avoiding welcome drinks (*Jaar*—a locally prepared rice beer) and food was another challenge when working closely with people in a familiar area. I had the advantage of being able to collect sound information through the household survey and the focus group discussion as I belong to Bikri village. Both wives and husbands unanimously participated in the household survey, as compared to Thapuwa village. Furthermore, people from Bikri supported my research through participation in extended hours of group discussions. The inhabitants of Bikri responded openly during household survey and particpants observation because of my familiarity with them; however it took me a month for rapport building in Thapuwa. Academically, I am trained in agriculture science and have subsequently integrated anthropology into my disciplinary background in order to understand the complementarity and contradictions in concepts, ideas and world views of both disciplines for climate adaptation and mitigation in agriculture. My observations, interviews and discussions often first conceptualised from the standpoint of modern/scientific agriculture, but

I complement such a starting point from the perspective of anthropological approaches and perceptives of local peoples to complement scientific perspectives. This complementarity is evident in such aspects of my thesis as my treatment of Tharu perceptions of changes in weather patterns and ultimately climate trends; whereas I endeavour to interpret their perceptions, I also test them against scientifically measured meteorological evidence in order to evaluate them. Thus, my own vision of the reality of climate change rests ultimately on the evidence provided by scientific canons of validity epistemologically and on the realist outlook of modern science ontologically.

4.2 Theoretical frameworks

I used a variety of theoretical frameworks that encompass emic and etic views—ethnoscience that brings the indigenous perspective, and the Vulnerability to Resilience (V2R) and livelihood capitals of sustainable livelihood framework that provide complementary etic dimensions for participatory and quantitative analyses and interpretations. The two theoretical frameworks applied in this study also acts as a theoretical triangulation to approach the issue of climate vulnerability, adaptive capacity and agriculture resilience of the Tharu. Flick (2004) described that the theory triangulation is looking at data from different theoretical angles to uncover the new facet of theories in the data. Triangulation views the issue at least from two points of perspective that validates information/data/approaches, hence increasing the research quality (Flick, 2004).Marsh and Furlong (2002) argue that the ontological and epistemological position of the social scientist shapes/determines understanding of subject matter. The general beliefs concerning how the world works — ontology — entail particular ways of understanding that world — epistemology — which itself then can specify particular methodologies for achieving such understanding. The ontology of the Tharu is posits a world in which spirits and deities ultimately control events, hence as "*Prakritivada*" they understand their life and wellbeing is connected with the operation of supernatural forces in nature, and their epistemological stance requires them to engage with these forces in apotropaic ceremonies and other obseervances.

As I study these phenomena, neutrality maintenance is a challenging for me. On the one hand, I belong to the research community as a Tharu myself; on the other hand, I am trained in Western sceientific disciplines. However, that tension can work productively in analysis. Drawing on my shared ethnic background, I can understand in emic terms how Tharu culture, knowledge and practices that inform their rituals, crop production/management/protection; however, my disciplinary training allows me to understand and analyse the information from agricultural science perspectives in order to draw relevant conclusions in terms of their efficacy and how they might be evaluated in terms of their future prospects for climate change adaptation and mitigation. The complementarity of these perspectives is evident in how I have structured this thesis. For example, I have analysed agricultural rituals, and the traditional knowledge underlying them from an etic scientific perspective in Chapter 6, whereas I have adopted an emic perspective focussed on Tharu understandings to interpret various traditional and local agricultural practices in Chapter 7. I then attempt to synthesise the analysis and discussion of different knowledges, practices and methods in terms of the notion of hybrid knowledge in Chapter 8.

4.2.1 Ethnoscience

Ethnoscience, one of the theoretical frameworks of this study, focuses on the worldview of local groups. It conceptualises and values Indigenous people's views, understandings, and beliefs on the subject matter; in this case, climate change and agriculture. Ethnoscience has been known as "the new ethnography" or "semantic ethnography" (Fowler, 1977). Ethnoecology is a common sub-discipline in ethnoscience, which has been used by anthropologists since the 1950s, including by its founders Harold C. Conklin and Charles Frake. Ethnoecology studies a group's conceptions of interrelationships among biota (humans, animals, and plants). So, it is an interdisciplinary study of how people perceive nature from their lens of beliefs (*kosmus*), knowledge (*corpus*) and practices (*praxis*), which form a complex matrix that determines the views of people towards nature and the environment (Barrera-Bassols & Toledo, 2005).

Conceptually, environmental and ecological anthropology encompass the broader study of nature and environment from an etic perspective that may or may not consider native perceptions and views. Therefore, to deal specifically with Indigenous people's perceptions, beliefs, knowledge and practices related to agriculture, ethnoecology is the most appropriate approach. It is the branch of ethnoscience that covers the "sum total of a group's knowledge, conception, and classification of objects, activities, and events of its social and material world." (Fowler, 1977, p. 217). The Indigenous ways to classify plants, animals, and climate, and identify with local terms are important for ethnosystematics in ethnoscience.

Within ethnoscience more generally and ethnoecology more specifically, ethnobotany is the most studied field and covers the economic and medicinal use of plants. According to Jain (2001), the main aim of ethnobotany is to fully understand and integrate culture, including spiritual aspects of IP's beliefs about biodiversity conservation and sustainable development. There are two classical approaches to ethnobotany—cognitive and economic. The cognitive approach is concerned with how people perceive the organisation of the plant world culturally, while the economic approach is focused on the knowledge of converting plant resources into useful products (Albuquerque & Alves, 2016). Biodiversity conservation focuses on both approaches, with the cognitive approach concentrating on peoples' attachment, affection, and cultural and spiritual connections (Hunn, 2007 & 2014). Similarly, ethnozoology deals with animals, including wildlife, marine life and insects. Agroecology is complementary to various aspects of ethnoecology, but is focused on etic views in the natural science of scientific innovation in agriculture, including farmer organisation and empowerment (Warner, 2007; Wezel et al., 2009).

This study encompasses the Tharu's knowledge of plants that are domesticated and cultivated. Specifically, it can be called "ethnoagriculture", which endeavours to draw out generationally transferred agricultural knowledge and practices. It can be linked with the work of anthropologists on agriculture and specific crops, such as potato in Peru (Rhoades, 1984), maize among the Maya in Mexico (Barrera-Bassols & Toledo, 2005) and rice among the Hanunoo in the Philippines (Conklin, 1957). Conklin (1980) also worked in Ifugao, detailing land preparation, irrigation management, production and harvesting, but not crop protection aspects.

4.2.2 From vulnerability to resilience (V2R)

Complementing the ethnoscience perspective, various etic analytical approaches are used to assess vulnerability at the micro-level, which emphasise reducing vulnerability factors and incorporating factors that improve adaptive capacity, thereby improving the resilience of people and their livelihoods. The Climate Vulnerability and Capacity Analysis (CVCA) of CARE International is based on the vulnerability and adaptive capacity analysis (CARE, 2009). Similarly, the Vulnerability to Resilience (V2R) of Practical Action is based on a vulnerability and sustainable livelihood framework with a focus on hazards and disasters as the main cause of vulnerability (Pasteur, 2011). Likewise, the Community-based Risk Screening Tool Adaptation and Livelihoods (CRiSTAL) of the International Union for Conservation of Nature (IUCN) integrates CVCA and V2R to synthesise information on climate vulnerability and livelihoods to plan and manage projects (Morgan, 2011).

I followed the V2R approach because it looks beyond vulnerability to integrate future risks (climate-related and others), institutional governance, exposure and livelihoods.

Furthermore, V2R covers the exposure to hazards and disasters that are often perceived as the impact of climate change. The framework focuses on how to reduce vulnerability, and thereby enhance resilience (Figure 4.2). I modified the V2R framework by adding the components of planning and implementation (six steps of project execution) for vulnerability reduction and adding an ethnoscience perspective, considering the contributions of Indigenous and scientific knowledge as complementary in a theoretical discourse of climate change adaptation and mitigation.

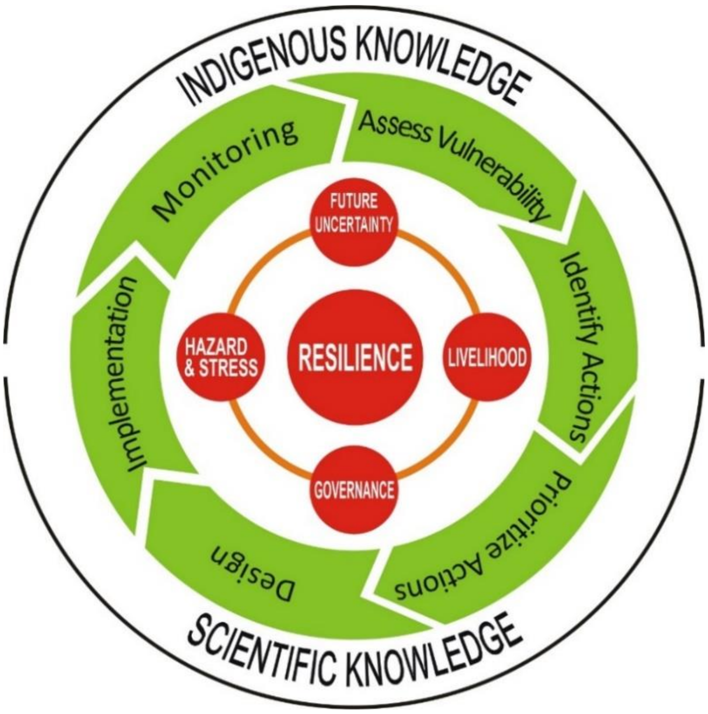


Figure 4.2 Research framework consideration in the study

[Modified from Vulnerability to Resilience (V2R) (Pasteur, 2011) and the Climate Resilience Framework (CRF) (ISET international, 2014)].

In the framework, resilience to climate change is the ultimate target for the people and their livelihoods, which is determined from the four components shown in the inner circle of the framework. Fragile livelihoods, weak governance, exposure to hazards and stresses, and future uncertainty due to climate change and other long-term trends increase the vulnerability of individuals and communities; therefore, the associated factors reducing vulnerability and strengthening factors contributing to improving adaptive capacities, such as livelihood diversification, disaster preparedness and decentralised governance, must be addressed (Pasteur, 2011). The second layer of the framework represents the identification, planning and implementation of projects to reduce vulnerability and improve capacity for adaptation to and mitigation of climate change impact. There are six steps in the planning and response to vulnerability: assess vulnerability, identify actions, prioritise actions, design, implementation and monitoring. The assessment of vulnerability can be done using one of three approaches: biophysical, socioeconomic, and integrated. The biophysical approach focuses on loss and damage in terms of yield, economic and causalities, whereas the socioeconomic approach emphasises that vulnerability is created by society due to changes in political and institutional paradigms (Deressa et al., 2008) and often excludes hazards and shocks. Therefore, I used an integrated approach in the framework that considered hazards and their impact and the sociocultural and political aspects of vulnerability in society. The outer sphere of the framework is bound by knowledge systems, where Indigenous and scientific knowledge contribute to vulnerability reduction, adaptive capacity improvement and resilient livelihoods.

The V2R framework asserts that forms of livelihood capital (natural, physical, social, financial, and human) are vital to improve adaptive capacity and determine vulnerability. The indicators of livelihood capital were identified by the community during the participatory group assessment of vulnerability and adaptive capacity. This framework combines the V2R with a livelihood framework, which is mostly used in rural development and poverty alleviation research. The analytical framework is based on a local level analysis that focused on hazard and livelihood assessments, and how knowledge contributes to resilient agriculture. The governance and future uncertainties are mostly covered at the community level, but not state institutions and mechanisms. This study did not cover detailed steps and project planning, implementation, and monitoring for vulnerability projects. It focused on how the agricultural knowledge and practices of the Tharu are climate-friendly, with low GHG emissions and energy use, including CO_2 sequestration and carbon sinks.

4.3 Research methods

This study used a sequential mixed-methods approach involving both qualitative and quantitative methods. The early fieldwork elicited mostly quantitative data, and the later fieldwork garnered qualitative information through in-depth interviews. This section describes various methods and tools used in the study; the specific research methodologies are also described in chapters 5 and 6 to describe a particular tool, models and methods of analysis.

Personal identity of participants is kept confidential by using pseudonyms. All English language documents, including questionnaire, participant consent forms, focus group discussion check lists, were translated into Nepali and approved by the Human Ethics Office of The University of Western Australia/UWA (UWA Ref. number: RA/4/20/4133). Participants consent was obtained in a written form to record audios and take pictures during the interviews, focus group discussions and household survey.

The research utilised a mixed-methods approach because the study deals with knowledge and agricultural practices of the Tharu that require data validation and triangulation. The knowledge, interpretation, and experience of people are guided by their cultural beliefs; therefore, ethnoscience, with its emic focus on local classifications and knowledge, defined one study framework. Etic analysis of climatic data and agricultural production required quantitative analysis. Data and method triangulation is performed not only to validate the results, but more importantly for deeper understanding and justification of issue/knowledge. In the contemporary social sciences, triangulation is less understand as validation, but more understand as a strategy for a deeper understanding and justifying knowledge in qualitative research (Flick, 2004). The specific data validation/triangulation acquired through the various participatory research methods is described in further detail in Chapter 5. Furthermore, Chapter 5 also triangulates methods to assess the climate change perceptions of the Tharu by using interviews for qualitative information and meteorological data for quantitative analysis. Similarly, in Chapter 6, adaptive capacity of the Tharu is assessed through the focus group discussions by using livelihood entitlement tools and binary logistic regression analysis to identify factors responsible for adaptive capacity.

Creswell and Plano Clark (2011) defined mixed-methods research as a research design with a clear set of assumptions and research methods. As a methodology, it comprises a philosophical direction to collect and analyse information, whereas as methods, it deals with collecting and analysing qualitative and quantitative information for a study. The mixed-methods approach helps to better understand the research problem than single approaches.

There are pros and cons to using the mixed-methods approach. One positive aspect is that it increases the reliability and validity of research from both approaches (Creswell & Plano Clark, 2011; Neuman, 2004). Qualitative research follows an inductive approach based on a small sample size that may render it unrealistic for generalisation to the larger population. However, it deepens the analysis of causal relationships between variables and provides answers as to why things happen. In contrast, quantitative research can reveal the interrelations among variables, but does not provide context at the micro-level. Therefore, mixed-methods approaches in social science are becoming more common (Creswell & Plano Clark, 2011). A negative aspect of the mixed-methods approach is that it requires competence in both qualitative and quantitative methods and is more resource- and time-intensive than individual approaches.

An exploratory sequential design[30] was used to collect primarily quantitative data in the first fieldwork and qualitative information in the second fieldwork. The qualitative and quantitative analyses were performed separately, and the findings mixed during discussion and interpretation. Despite prioritising the data to be collected during each visit, some qualitative and quantitative data were collected during both visits. In this thesis, qualitative descriptions are backed up with quantitative information.

4.3.1 Qualitative methods

Qualitative data were collected through various participatory rural appraisal (PRA) tools, participant observations and in-depth interviews. There is no fixed duration for ethnographic fieldwork; it depends on the issue under investigation. Long-term ethnographic research goes throughout the active life of anthropologists (Foster, 1979; Sandstrom & Sandstrom, 2011). Foster (1979) suggests at least 1–2 years of fieldwork, but long-term longitudinal fieldwork is advised for a detailed understanding of people and their culture. However, long-term longitudinal fieldwork is not yet possible for me since this is my initial study conducted for the PhD. The long-term study is in a longitudinal form where ethnographers conduct fieldwork at different times with varying lengths of stay. Royce and Kemper (2002) argued that human life is open-ended, as should be research, with every year having a different focus. Anthropologists believe ethnographic research demands long-term engagement with the community, but now anthropologists have started to study situations and interactions of communities at the meso-level rather than just the grass-roots level. Therefore, "mesography" is sometimes suggested

[30] There are six types of mixed-methods design: convergent parallel (equal emphasis to qualitative and quantitative); explanatory sequential (qualitative followed by quantitative; exploratory sequential (quantitative followed by qualitative); embedded (emphasis on quantitative and supplement with qualitative); transformative (any of the four earlier methods with an emphasis on social change), and multiphase (study 1 qualitative, study 2 quantitative, study 3 mixed). Data are collected in a single visit, except for the convergent and embedded designs (Creswell & Plano Clark, 2011).

for use in South-East Asia, instead of ethnography (G. Acciaioli, personal communication, 27 October 2017).

Focus group discussion

For each focus group discussion, 8–10 people were recruited by the researcher representing different ages, genders, educational levels, and landholding sizes. I led the focus group discussions with support from a local facilitator. Household survey information helped to identify participants and created the foundation for further consultation with the *barghar*. Experienced women who grew up or have lived in the village for a long time were among those selected, as they knew the prior farming systems and the local environment. Village resource maps of both villages were prepared and finalised upon transect walks. The maps identified hazard scenarios, which were complemented with a historical timeline. The group prioritised hazards through a matrix ranking based on severity and the impact on livelihoods. A crop calendar and observed changes in sowing and harvesting times and production systems in the previous 10–20 years was prepared. A focus group discussion meeting was conducted with the animal herders in each village to record their observations, experiences and perceptions of changes in agriculture, forest food and agrobiodiversity, and the possible reasons for such changes. The FGDs were conducted during pre-monsoon season (April–May) to reflect water-related hazards and preparation for coping with extremes. The FGDs took place in the community hall used by the entire village, and each lasted for a maximum of four hours. The questionnaire checklist and framework for each FGD were translated into Tharu to facilitate the researcher leading the discussion with support of a local facilitator. Details of the various research methods are given in Table 4.1. The questionnaire checklist and framework for each focus group discussion were developed and translated into Tharu language to lead the discussion in systematic ways.

Table 4.1 Research methods used in the study

Village	No. inter-views	No. events observ ed†	No. FGD	No. partici-pants in FGD	No. female partici-pants in FGD	No. hh surv eyed	No. female respon-dents in the survey	Female-headed hh in the village populations
Thapuwa	17	4	4	38	20 (53%)	143	45 (31.5%)	1 (0.70%)
Bikri	12	3	3	30	14 (47%)	86	32 (37.2%)	8 (9.30%)
Total	29	7	7	68	34 (50%)	229	77 (33.6%)	9 (3.93%)

†In Thapuwa, I observed a feast of house construction, public hearings of women's group, bore installations to lift underground water, and rice seedlings and transplantation. In Bikri, I observed two meetings of the Bhawani community forest user's group and one meeting of a women's saving and credit group. Acronyms: FGD = focus group discussion, hh = household

Participant observation

Participant observation is the heart of ethnography (Nader, 2011); it combines actors, activities, and places, and may require observations of actors at multiple sites and in different roles (activities) at a particular place (Spradley, 1980). Participant observation is a combination of observation, listening, taking part in activities, and taking notes (Spradley, 1979, 1980). Regular visits and interactions with people and participation in family and household activities were the primary sources of information, which took place during agricultural events, group meetings and feasts. There was intense discussion on the weather, groundwater, gender roles, and weed and pest management during different agricultural activities, such as bore installation for irrigation, rice seedling preparation and transplantation.

Sandstrom and Sandstrom (2011) stated that long-term fieldwork provides opportunities for participant observation to understand what people say, do and believe However, there is a risk of overlooking information that a researcher may not feel to be new and related to the subject. Sandstrom and Sandstrom (2011) identified four drawbacks[31] from their more than 30 years of fieldwork in the Nahua community in Mexico. One drawback was emotional fatigue (diminishing utility) and the feeling of knowing everything about the people and community. They suggested doing short-term fieldwork in different communities and geographical areas to bring a new perspective and to refresh yourself. In my case, I conducted two fieldwork trips with a few months gap in between and participated in the Hanoi Forum Conference where I gained preliminary validation of my findings on vulnerability, particularly in the context of South-East Asia (Chaudhary, Acciaioli, Erskine, & Chaudhary, 2018). In my experience, there is a high chance of obtaining reliable information if researchers share language and culture with the study group.

Interviews

Face-to-face interviews were conducted with informants on a wide range of levels. Brief semi-informal consultative meetings were held with non-government organisations (NGOs), such as *Tharu Mahila Utthan Kendra*, and at the district level and with Tharu journalists at the central level. I also interviewed the government extension officer and extension assistant of the local government to understand agricultural production and local agricultural practices in the district.

In-depth interviews were conducted with selected participants in the study villages. The selection included innovative farmers (early/majority adopters), traditional farmers, vegetable growers, sharecroppers (tenant farmers), women and young migrants and their families who were left at home. People associated with village governing bodies, such as the *barghar* (village head), *guruwa* (head shaman), *kesauka* (assistant shaman) and *chaukidar* (village watchman),

[31] The authors identified four drawbacks from their long-term longitudinal fieldwork—closeness and friendships with respondents who may ask for personal and communal support, emotional fatigue that can be revived through visiting new areas and people for short periods, management of the collected information (field notes and others), and the communication gap between insiders and outsiders, where some communities may be interested to learn their culture but this may cause conflict with outsiders.

were also interviewed. Interviews did not just take place on one occasion but throughout the fieldwork in formal and informal ways. Some of the grand-tour questions orienting interviews included: What are the indigenous terms used for climate, weather and season used in the Tharu community? How was your agriculture 10–20 years ago? What are the changes and what could be the reasons? What types of rituals do you perform in agriculture? Langness (1965) discusses how life history ethnographic interviews are long-term interviews with individuals and others, requiring long-term engagement with the informant. He suggested three ways to increase the reliability of the information: (1) interviewing the individual several times at different time intervals, (2) verifying with others, and (3) through observation. It was suggested to start with a *'grand-tour'* question and later focus the interview and observations on a specific domain, avoiding asking why but trying to understand the meaning (Spradley, 1979). Life-history ethnography was conducted with two participants to ascertain the context of their struggles for personal and occupational life, and then discussion was narrowed down to their agriculture, knowledge and strategies for management. Interviews were recorded on a voice recorder after asking for the consent of participants. Information was validated with observations in the family, field and daily life of participants.

4.3.2 Quantitative methods

Quantitative data were mostly collected through a survey of households in the two villages. A semi-structured questionnaire was designed, pre-tested and finalised for the survey (Appendix 2). The questionnaire was designed in three sections: Agriculture, Climate change, and Livelihoods. Interviews typically took 45–60 minutes for a household, so an in-between break was often provisioned. A local enumeratorhelped with the household survey.

The household survey started after one month of fieldwork, with the first month used for familiarisation and rapport building. A local survey assistant was hired from the Tharu community. Most of the youth and older men could understand and speak Nepali, but many women had difficulty with Nepali. Interviews and discussions became interactive in the Tharu language. A total household survey (143 households of Thapuwa and 86 households of Bikri) was conducted. An interview was conducted with a household head or member who was actively engaged in farming, both wife and husband if possible. Particular consideration was given in the household interview to people over 30 years of age, as they could recall about 10–20 years of climate and farming. It is hard for respondents to recall long-term information during interviews and that may lead to recall bias, hence Piya, Joshi, and Maharjan (2012b) considered a 10-year period in their study to access climate change perceptions.

4.4 Data processing and analysis

4.4.1 Qualitative data analysis

The interviews were manually transcribed by listening and writing. Different interviews of one person were aggregated in one document for qualitative coding in the QSR NVivo plus 12 qualitative data software. The software allowed the text to be coded into one or more defined nodes (domain/cover term). All data on knowledge types, agricultural practices and livelihood contexts were extracted for analysis. The data were explored through keywords and word clouds (Appendix 3) to familiarise the researcher with the content of the qualitative data.

The information uploaded in the software was studied line-by-line and word-by-word for the initial coding, called “open coding”, to capture important ideas by categorising into possible nodes (Neuman, 2004, p. 325). The second level of coding, called “axil coding”, was used to identify semantic relationships and connect nodes, leading to the conceptual framework (Böhm, 2004; Neuman, 2004). During the process, nodes and sub-nodes were constructed for analysis, as all the coded qualitative information from different sources was grouped into six nodes—future uncertainty, governance, hazards and stresses, livelihood assets, local agriculture practices, and local knowledge (Appendix 4). Different analysis facilities in NVivo, such as nodes comparisons (Appendix 5), hierarchical charts, and cluster analyses, were used to create a foundation for taxonomic and componential analyses (Spradley, 1979). For example, local knowledge and agricultural practices were compared that showed the source of information to create the nodes/ theme with specific information for each coded source (Appendix 5). The NVivo transcription provided a general idea of the important words and thematic areas (nodes). The analysis depended upon reading and re-reading the transcripts, digesting information, thinking and reflecting about the interviews to draw conclusions relating to the knowledge and practices of climate and agriculture.

4.4.2 Quantitative data analysis

Quantitative data collected through the household survey were entered into Microsoft Excel during the fieldwork to correct for missing and outlier data. The data were cleaned, verified, and additional variables were calculated based on the available data. The required variables for analysis were transferred from Excel into IBM SPSS Statistics 20.

The quantitative data were analysed for descriptive and inferential statistics. Descriptive statistics (frequency, per cent, mean, standard deviation, Student’s t-test, and regression) and non-descriptive statistics (Chi-square/X^2) were used. Binary logistic regression was used to analyse the relationship between climate change perceptions (dependent variable) with independent variables, such as education, gender, and access to information/services. Similarly, Chi-square was used to see the consistency of responses of household perceptions on climate change.

4.5 Conclusion

The study was conceptualised using a mixed-methods approach. Ehnoscience was used as one theoretical basis to understand the knowledge and practices in agriculture of the Tharu IP of Nepal. An ethnography-focused study was based on two villages, Thapuwa and Bikri, contrasting in climatic vulnerability and sociocultural aspects. Mixed-methods, involving qualitative and quantitative techniques, were used to collect and analyse the information. Focus group discussions, participant observation and in-depth interviews formed the basis of the qualitative data sources, whereas a household survey through face-to-face interviews was used to collect the quantitative data. The data were analysed with a combination of computerised tools and manual techniques, including the triangulation of information from the various research methods and approaches used in the study.

CHAPTER 5. THARU INDIGENOUS PEOPLE'S PERCEPTION AND VULNERABILITY TO CLIMATE CHANGE

5.1 Introduction

Climate change is a global issue with different impacts across regions and people. In Nepal, rapid increases in temperatures and unpredictable precipitation patterns have been reported (Practical Action, 2009; Shrestha et al., 1999). Increases in extreme climatic events and natural disasters[32] have further increased the vulnerability of local people and the future risks and uncertainty in farming and natural resource management (MoHA & DPNet-Nepal, 2015; Practical Action, 2017).

A commonality in most definitions of vulnerability is the susceptibility of a system due to the inability to cope with the adverse effects/impacts of climate change and other hazards. Adger and Kelly (1999, p. 253) described vulnerability from an adaptive capacity perspective as the "ability to cope with and adapt to any external stress placed on their livelihood and well-being." It is important to increase adaptive capacity to reduce vulnerability, thereby reducing climate risk and improving the resilience of people and the ecosystems they inhabit. Vulnerability and risk assessment are the first steps to address the impact of climate change through adaptation and mitigation.

The perception of climate change is important to analyse vulnerability and hazard risks. Perception is a process by which individuals feel and realise changes in climate-related stimuli, where stimuli include a change in climate variables and extremes. Extremes in climate (too hot/cold) and measurable shocks help to build such perceptions (Wachinger et al., 2010).

[32] Disaster is defined as "severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery" (IPCC, 2014c, p. 122). Disasters, which always have a human component, have a higher impact and disturbance on natural and human systems than natural hazards. However, the terms disasters, hazards and extreme events are used interchangeably in this thesis for the sake of simplicity.

Perception is built on a series of observations, experiences, and ultimately realisations, influenced by the sociocultural context and the information/service system (Gbetibouo, 2009; Ghorbani et al., 2012; Piya et al., 2012). Indigenous knowledge plays a crucial role in forming such human perceptions (Chaudhary & Bawa, 2011; Chaudhary et al., 2011). In Nepal, local people have perceived warmer winters, upward-shifting agro-ecological zones, changes in rainfall patterns, and an increased frequency of climate-induced disasters (Chaudhary & Bawa, 2011; MoE, 2010a).

Climate change alters natural cycles and the patterns of physical phenomena, thereby accelerating natural hazards and extreme events (Anderson & Bausch, 2006; IPCC, 2012). Nepal has been ranked 30th in flooding risk among all countries (Practical Action, 2017). Flooding is the greatest hazard in Nepal, particularly in the Tarai and hill regions; it was responsible for 1235 deaths, 663 missing and 693 wounded in the period 2011–2016 (MoHA, n.d.; MoHA & DPNet-Nepal, 2015). Major flooding disasters in Nepal occurred in 1993, 2008, 2014 and 2017. In 2017, floods around the country were the cause of death of 160 people and the temporary displacement of 20,900 families (UNRCO, 2017). Drought, fire, cold and heat waves are other hazards related to climate change in Nepal, all of which can impact agrarian livelihoods and wellbeing (DesInventar, 2018).

Indigenous people comprise 35% of Nepal's population and are scattered throughout the country. Having close relationships with forests, water bodies, land and territories, Indigenous people in Nepal are highly dependent upon agriculture and farming. The Tharu in the southern plain of Nepal are engaged in agriculture. Any change in climate variability has a direct consequence on their farming and related livelihoods. This chapter largely concentrates on addressing the first research question of the thesis, "What are the perceptions of the Tharu about vulnerability and the impact of climate variability and weather extremes on their livelihoods?" This chapter also includes Indigenous knowledge and scientific knowledge for coping with climate-induced hazards and disasters. This study expands the knowledge on climate change perception beyond climate variables, temperature and precipitation (Devkota et al., 2011; Maharjan et al., 2011) to climate extremes and hazards, such as flooding and droughts, and how they impact agriculture and livelihoods. Furthermore, it adds a dimension of Indigenous knowledge and associated practices for further exploration and study in agricultural science concerning climate change.

5.2 Climate change in the study area

5.2.1 Temperature and rainfall data analysis

Changes in weather and their effects are critical to extreme events and agriculture, so an analysis of temperature and rainfall time-series data for the Bardiya district was undertaken using data from meteorological stations in Chisapani (Karnali) and Rani Jaruwa Nursery for temperatures and the Gulariya for rainfall of the Department of Hydrology and Meteorology (DHM), Kathmandu. Annual mean temperature (maximum, minimum and average) data of 38 years (1979–2016) were compared for 19-year periods pre- and post-1997. Similarly, the inter-seasonal variations during the winter and monsoon seasons were compared (DHM, 2015). Rainfall data from 1973–2016 (44 years, 2012 and 2013 not available) at Gulariya meteorological station, Bardiya were analysed, including the mean annual rainfall trend and inter-seasonal variations (winter and monsoon) to validate the perceptions of the Tharu to climate change. IBM SPSS version 20 was used to calculate means, standard deviations and tests of significance (Student’s t-test) for the temperature and rainfall trend analyses.

An analysis of annual temperature trends pre- and post-1997 showed significant increases in maximum and mean annual temperatures of almost 1°C and 0.6°C, respectively (Table 5.1). The seasonal temperature trend analysis showed that the winter annual temperature increment is slightly higher (0.03°C) than the monsoon increment (0.02°C).

Table 5.1 Comparison of mean annual temperatures from 1979–2016 in Bardiya

Timeframe	Maximum temperature	Minimum temperature	Mean temperature	Standard deviation of mean temperature
Pre-1997	29.9	18.8	24.3	0.30
Post-1997	30.7	19.1	24.9	0.72
Sig. difference	*	NS	*	

*Significant at 5% significance level; NS= non-significant

The increasing temperatures and higher increment during the monsoon and winter seasons than the other two seasons (pre- and post-monsoon) have been reported for Nepal (DHM, 2017; Practical Action, 2009; Shrestha et al., 1999). Shrestha et al. (1999) reported higher temperature increases in the Mountain and Himalaya (0.06°C/year) than the Tarai (0.03°C/year), with the highest incremental rate (0.08°C/year) post-monsoon (October–November). Increased temperatures have also been reported for the Tarai region of Nepal (Devkota et al., 2011; Karna, 2014; Manandhar, Vogt, Perret, & Kazama, 2011).

There was no clear trend in rainfall. The analysis of total annual rainfall, and seasons showed decreasing trends, but the year-to-year variation for all rainfall variables (total annual, monsoon season and winter season) was very high (Figure 5.1A and 5.1B). As a result, we could not tell if the apparent reducing trend for rainfall was real or just due to chance/random fluctuation in rainfall. To illustrate the erratic nature of rainfall, for example, it decreased drastically in 2002 and increased in 2007, but again decreased in 2013 (Figure 5.1A and 5.1B). Temporal predictability of rainfall in the Tarai and elsewhere in Nepal cannot be accurately predicted because of large inter-annual and inter-season variation.

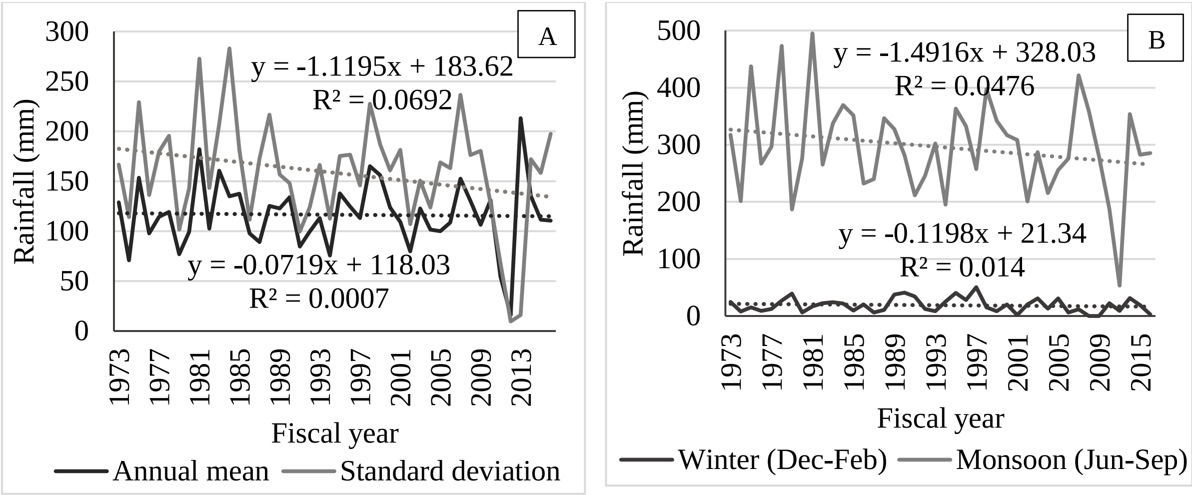


Figure 5.1 Rainfall trend in Gulariya, Bardiya from 1973–2016. (A) annual variation and (B) seasonal variation

The rainfall pattern, particularly in monsoon and winter seasons, is in line with major longitudinal climatic data studies (MoE, 2010a; Practical Action, 2009; Shrestha et al., 1999). Unpredictable (low and sometimes high rainfall) and erratic rainfall patterns have been reported in different ecological regions (e.g. Tarai, hills and mountain) of Nepal (Chaudhary & Bawa, 2011; Chaudhary et al., 2011; MoE, 2010a; Piya et al., 2012b; Practical Action, 2009).

5.2.2 Tharu Indigenous people's perceptions of climate change

Knowledge on weather patterns are typically constructed based on "local knowledge" with interactions traditional knowledge and scientific information. However, people's perceptions are important for realisation and strategies for adaptation and mitigation, and their ways of assessing weather patterns may indeed be an example of Indigenous knowledge if they are relying on indicators and modes of interpretation that are unique to their world view. Individual perceptions of climate change were recorded in terms of changes in temperature and rainfall during the winter season (December–February) and during the monsoon season (June–September). Following Chaudhary and Bawa (2011) and Chaudhary et al. (2011), the participants' perceptions of climate change were rated based on their experiences and observations: “yes” if they have experienced change, “no” if they have not experienced such change and “don't know” if they were not sure about the climate change indicator (seven indicators, as shown in Figure 5.2). The frequency of climate change perception was counted and computed for the percentage. Chi-square (X^2) statistics were used to determine the consistency of the household perception responses to climate change. Vulnerability and the impact of climate change were measured in terms of hazards and extreme events in agriculture and livelihood in the 10-year and 20-year period from the household survey and focus group discussion.

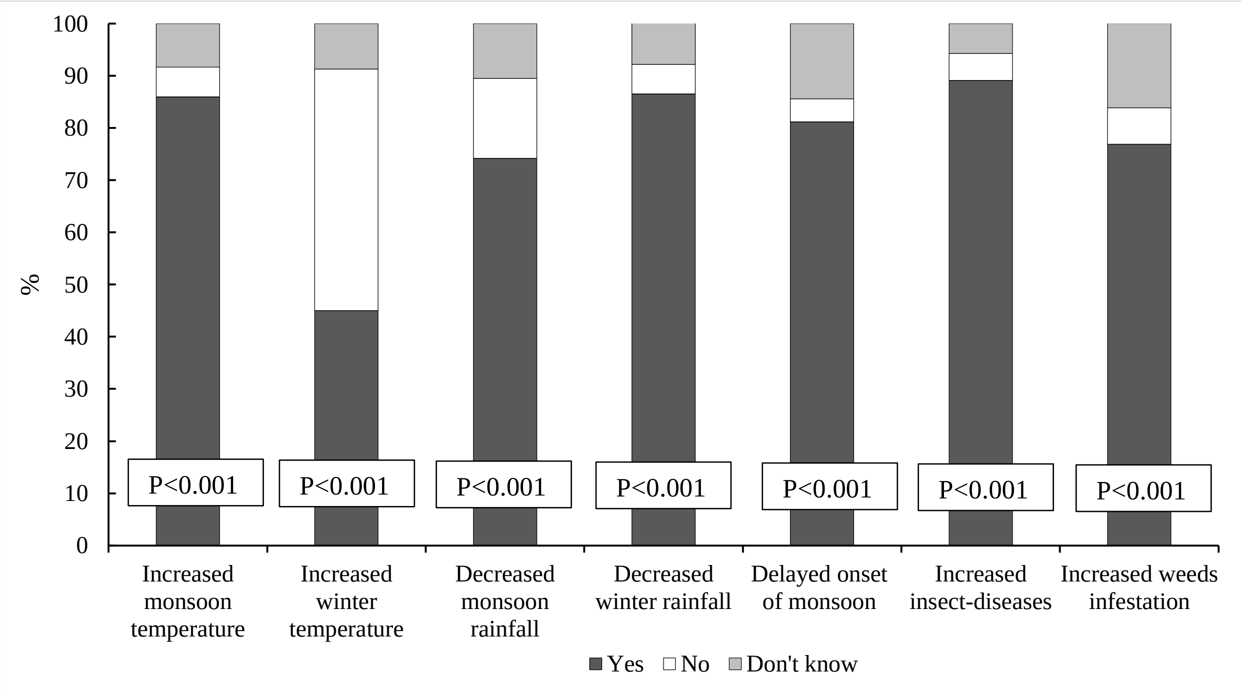


Figure 5.2 Combined perception of Thapuwa and Bikri villagers to climate change

Note: black, yes; white, no; shaded, don’t know; n=229; p-values are shown in boxes

The vast majority (three-quarters) of the Tharu in the study villages had perceived the climate change indicators, except for winter temperature (Figure 5.2). They had perceived increased temperature, decreased rainfall, delayed onset of monsoon and increased prevalence of insect-disease and weeds. Warmer winters were not perceived, with most (55%) perceiving increased cold or no change. Chi-square tests showed highly significant ($p<0.001$) positive responses of respondents to the indicators when combining the responses of both villages (Thapuwa and Bikri) Figure 5.2, but not when comparing between the villages, which indicates the consistency of perception in both communities. All indicators except one (increased winter temperature) were consistent with the perceptions, with three-quarters of the respondents having observed changes.

The perceptions of the Tharu to indicators of climate change (temperature and rainfall) were validated by the scientific climate analysis of the area/district. The perception of temperature had a positive correlation with measures of climate trends in the region. Most of the interview participants indicated increased monsoon temperatures, which is in line with temperature data trends. Temperature data for the area verified the perception of increased temperatures (maximum and annual mean) during both monsoon (June–September) and winter seasons (December–February). There is some lack of agreement in the perception of the winter temperature trend. Some perceived warmer winters than 10–20 years ago, but most (55%) perceived either colder winters or no change in winter temperature. This may be due to the increasing intense cold waves, even for short periods, compounded by thick fog in the Tarai. Increasing trends of cold waves, foggy days, foggy hours and dense fogs during the winter days have been reported in the Tarai (Manandharet al., 2011; Shrestha, Moore, & Peel, 2018). Shrestha et al. (2018) reported, on average, 24–56 foggy days per year and 71–169 day-time foggy hours, both of which followed an increasing trend from 1980 to 2015. In the past, when there were fewer foggy cold days, people from the hills and mountains used to come to Tarai to escape the cold, but now the situation is reversed.

The community's perception of decreasing rainfall was not validated with the analysis of climatic data. The data trend showed a non-significant decreasing trend of rainfall. The Tharu perceived that rainfall was delayed in the monsoon season and that the total number of rainy days in both monsoon and winter had decreased. But, Thapuwa village is less vulnerable to water scarcity now due to the availability of irrigation technology—pumping underground water. They can start early transplanting of rice and irrigate crops as per the requirements. But, scenario is different at Bikri village, where they depend on canal irrigation. The Babai diversions are likely more subject to weather variations than the groundwater, therefore farmers at Bikri often face scarcity of timely irrigation. However, people felt that the increased rainfall intensity, particularly post-monsoon (October–November), had caused flooding.

Increased temperatures have a direct relationship with plant–water relationships. Higher temperatures increase evapotranspiration, which further accelerates low precipitation and drought conditions, thereby reducing biomass, grain yield and quality, as seen in winter wheat (Asseng et al., 2004; Gooding, Ellis, Shewry, & Schofield, 2003; Lal, 2011). Using crop residues is a traditional agricultural technique for conserving soil moisture and suppressing weed growth, as well as improving soil fertility. Sapkota et al. (2015) found that conservation agriculture reduces canopy temperature (1–4°C), emits 10–15% fewer GHGs than the conventional system, and increases irrigation productivity (66–100%) in the rice–wheat system in the Indo-Gangetic Plains (IGP) of India. The use of crop residues also suppresses weeds and adds organic matter to the soil.

Unpredictable and erratic rainfall affects irrigation planning, imposes frequent droughts and sometimes off-season rainfall damage to crops in the field. Fulfilling water requirements is critical for plants at specific crop growth stages, particularly during tillering and the reproductive stage in most crops (Hiler & Howell, 1983; Singh, Angadi, Grover, Hilaire, & Begna, 2016).

Perceptions among individuals, communities, and in different locations are influenced by various sociocultural factors, such as age, gender, education, occupation, access to information, extension services, and income (Deressa et al., 2011; Piya et al., 2012). Piya et al.

(2012) found that gender, education, access to information (e.g. radio, training) and group memberships have a positive influence on the perception of climate change. The farming community might have increased perceptions of climate change, but this is not always the case for non-farming communities. Adaptation to the perceived climate extremes (hot/cold, droughts and flooding) is influenced by the adaptive capacity of households, which is largely determined by sociocultural factors (Adger et al., 2013; Sugden et al., 2014).

5.3 Climate-induced hazards

Various participatory rural appraisal (PRA) tools were used during the focus group discussions to assess the overall views of villagers related to climate change in terms of vulnerability and its impact, as well as local practices for adaptation measures (Table 5.2).

Table 5.2 Participatory tools, purpose of use and methodology used in the study

Tools	**Purpose of use**	**Methodology**
Hazard map	Identify and assess livelihood resources and the potential impact of hazards.	The community prepared social resource maps on paper indicating resources and hazards in their village.
Vulnerability matrix	Rank the hazards based on the severity of the impact on livelihood capital.	The facilitator oriented participants to five types of livelihood capital and requested that they rate each hazard from 1–4 (the higher the value, the higher the impact on livelihood). The hazard that received the highest score is the most disastrous.
Historical timeline	Know past hazards and extreme climatic events, their impacts, and coping and adaptation strategies.	Major hazards in the past 30–35 years were assessed in terms of their impact and coping and post-disaster adaptation strategy.
Hazard calendar	Analyse the trend of hazards occurrence and their consequences in the agricultural crop calendar.	Upon identification of disastrous hazards, the participants compared hazard occurrence times over 10 and 20 years.
Stakeholder mapping	Identify the organisation working in the community for livelihood	Discussed with *barghar*, *chaukidar* (village watchman), and group representatives; they listed the government agencies and NGOs

	improvement and climate adaptation.	working in the village. The impact of programmes and relationships with the community were assessed.

Adapted from CARE International (2009) and Pasteur (2011)

The vulnerability matrix ranking PRA tool was used to prioritise hazards in study villages (Table 5.3). Participants rated each hazard against each livelihood capital from 1 to 4, with 1 for no or least impact and 4 for the most impact. The hazard with the highest total scores was considered the most important in terms of vulnerability to the villagers. Flooding was the number one hazard in both villages, followed by storms in Thapuwa and drought in Bikri. The third most important hazard for both villages was cold waves. The government of Nepal also considers the Tarai vulnerable to flood, drought, and fire (MoHA & DPNet-Nepal, 2015).

Table 5.3 Hazard ranking at Thapuwa and Bikri

Livelihood	**Floods**		**Droughts**		**Hailstones**		**Cold waves**		**Storms**		**Insect/Dis***	
	Tp	**Bk**	**Tp**	**Bk**	**Tp**	**Bk**	**Tp**	**Bk**	**Tp**	**Bk**	**Tp**	**Bk**
Physical	4	4	1	1	2	2	1	1	3	1	1	1
Natural	4	3	2	3	4	3	3	2	4	2	4	3
Financial	3	1	3	2	3	1	4	2	4	1	1	1
Social	4	2	2	2	2	1	4	2	4	1	2	1
Human	4	3	3	3	1	1	3	3	3	1	3	1
Total	19 **I**	13 **I**	11 V	11 **II**	12 IV	8 IV	15 **III**	10 **III**	18 **II**	6 VI	11 VI	7 V

Th= Thapuwa, Bk= Bikri village; score: 1=no impact, 2=low impact, 3=medium impact, 4=high impact

Acronyms: Tp= Thapuwa village, Bk= Bikri village, Dis= Disease

* The lower ranking of droughts than storms and cold waves in Thapuwa was due to the availability of irrigation technology to pump underground water.

A hazard calendar of major hazards was prepared with participants to analyse the changes in incidence over the last 20 years. In general, there was a discernible shift in hazards across this timeframe. The timeframe period of occurrence shortened for floods, cold waves and droughts, but storms took place at a similar time each year (Table 5.4). Flooding used to occur from late-June to mid-October 10–20 years ago, but in the last 10 years, it has started later (July) and ended earlier (September). Cold waves also have a delayed start by two weeks (mid-December), compared with early December 10–20 years ago (Table 5.4). Participants perceived a significant decline in the impact of drought during rice cultivation, particularly post-monsoon (October–November) due to the availability of irrigation facilities (groundwater irrigation in Thapuwa and canal irrigation in Bikri) and short-duration improved rice varieties. Many short-duration hybrid and improved varieties of rice are available that can be harvested within 90 days after transplantation, which is about 30 days earlier than local rice varieties.

Table 5.4 Combined hazard calendar over Thapuwa and Bikri

Hazard		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Flood	20 years onward												
	10 years onward												
Cold wave	20 years onward												
	10 years onward												
Storm	20 years onward												
	10 years onward												
Drought	20 years onward												
	10 years onward												

Source: FGD on 4 and 5 April 2018 and verified with RKJS/Practical Action (2013)

5.3.1 Hazards historical timeline

The historical timeline is an important PRA tool for analysing trends of hazards, impacts and adaptation strategies within the community. Since both villages are affected by the Babai River, the hazards timeline is in a single table (Table 5.5). However, different impacts and adaptation strategies are mentioned separately. The focus group discussions also assessed the impact, coping strategies, pre- and post- hazards management strategies, and future risks.

Table 5.5. Hazards timeline for Thapuwa and Bikri

Year	**Hazard**	**Impact on livelihood**	**Local coping and adaptation**
1979 (2036)	Drought	Rice completely dried up in the field, hunger situation in the village.	Boiled rice loan from the *mahajan* (money lender), consumption of Maar (rice soup with pulses).
1985 (2042)	Flood	Riverbank erosion ~1 ha in Bikri and ~8 ha in Thapuwa; maize crop buried.	Plantating of bamboo and *bersama* (*Ipomoea sp.*) in the riverbank; sandbags piled up for the river wall.
1988 (2045)	Drought	No production from rice and maize.	Pouring of water from pond and canal; water lifting from the Babai River.
1995 (2052)	Flood	Flooded 20 ha maize, nine houses submerged in Bikri; cattle, pigs, goats swept away in flood; stored grains damaged.	Transferred household goods and livestock to a safe place; flood control river wall and spur constructed in several places.
2005 (2062)	Flood	~10 ha riverbank erosion with standing field crops in Thapuwa.	Grain and food support from relatives; flood control river wall and spur construction; cleaning of water drainage canal in the village.
2007 (2064)	Hailstones	Can happen throughout winter and spring seasons (November–May); damaged wheat and lentil.	No measures; people believe it is a natural phenomenon.
2014 (2071)	Flood, Insect-disease	Riverbank erosion ~8 ha and damaged 33 ha standing rice in Thapuwa and 12 ha in Bikri.	Earthen embankment and stone filled in gabion wires spur constructed.
2017 (2073)	Drought	Reduced rice yields reported at varying levels (15–25%).	Irrigation, local landraces, short-duration rice varieties, and early rice transplantation.
2017 (2074)	Flood, Insect-disease	Land erosion with field crops ~8 ha, partially damaged 47 ha of rice in Thapuwa; flooded 30 ha of	Direct seeding of local rice landrace (Karangi); earthen embankment constructed; many houses shifted to

		rice and rice fields deposited with sand in Bikri. Rice panicle-cutting insects (armyworm) in the flooding year; damaged 12 ha of rice.	a safe area; house foundations constructed at flooding height. Irrigate rice if it is in early maturity state; early harvesting of rice to protect from armyworm.
2017 (2074)	Storm	Strong winds during summer before the monsoon starts a regular phenomenon every year; frequency and intensity vary; damages homes and trees and destroys summer maize.	House design north–south facing; house roofing materials fastened tightly.
2017 (2074)	Cold waves	Hard to work in the field; children and elderly people suffer from cold and pneumonia; some crops such as potato suffered from late blight disease.	Wearing warm clothing, woollen cap and muffler; firewood and rice husks burned to warm humans and livestock; spray ash and fungicide in crops.

Note: Figures in parentheses are *Vikram Samvat* - Nepali vernacular calendar, which is about 56 years earlier than the Gregorian calendar.

The Tharu community has experienced frequent flooding, droughts, and intense cold waves over the past 20 years. Other hazards, such as storms and hailstones, are considered natural phenomena. Table 5.5 reveals that hazards related to water have had the greatest impact on the two study villages in the last 20 years. Flooding has had the most disastrous impact on agriculture and livelihoods, destroying food stored in houses, standing crops in the field, and livestock. The survival of the Tharu in frequent hazards becomes inadequate to adapt the future risks because the projection of their increasing frequency neither allow the Tharu live optimally nor to adapt optimally to the challenges of climate change. The Tharu people rely on Indigenous knowledge—using a combination of physical and biological indicators—to predict extreme climate phenomena, such as excessive rainfall and drought (see Chapter 7).

While irrigation technology has reduced the perception of drought, accessibility to irrigation technology was a pertinent issue. Small landholders own less pumping equipment, tractors, and other farm machinery than large landholders, which affects their capacity for timely irrigation and other agricultural operations. Similarly, Bikri village is poorly connected with the Babai irrigation project, and, in addition, villagers are the end-users of irrigation. The timely provision of adequate quantities of water is thus a major issue for Bikri farmers. The Bikri farmers repeatedly commented on the lack of water availability in the canal during rice transplantation, and excess water at unwanted times, such as rice harvesting and during the winter pulse crop growing season. Issues of irrigation water access for the tail-enders under the farmers' managed irrigation system (FMIS) are reported in Nepal (Shivakoti & Ostrom, 2002) because existing water users consider that they have exclusive rights to the water and resist sharing it with new users, creating conflicts around water resources (Pradhan, Pradhan, Meinzen-Dick, & Bruns, 1997). The *kulapani* Chaudhari was a traditional leader for FMIS among the Tharu, selected through the *barghar* system (the Tharu Indigenous organisation that manages the village) to construct and manage the irrigation system, mostly through user participation (Howarth & Lal, 2002). However, this position has been replaced by government-operated mechanisms. Drought remained problematic in Bikri, causing varying levels of yield reductions, even complete crop failure; hence, farmers recognise the impact of drought on yield.

5.3.2 Flooding

Flooding is periodic in nature, occurring in almost 10-year intervals in the past (1985, 1995, 2005), but the frequency has increased in the last decade, with floods in 2014 and again in 2017 (Table 5.5). According to the villagers, the 1995 and 2017 floods were the biggest flooding disasters they have experienced.

The vulnerability of flooding at the household level is depicted in Table 5.6. Flooding damaged houses and caused losses of stored food and property within the house. There have been no human casualties from floods in the study villages, but many cattle, goats, sheep, pigs and poultry have been swept away by floods. Another significant impact of flooding is riverbank erosion and crop losses due to changes in the river course. About 181 ha of agricultural land have been converted into a less productive riverbed due to such river course changes and riverbank erosion (calculated from Table 5.5). At Thapuwa about 30 years ago (1990), the Babai River entered the village by changing its course and the village became like an island. Thereafter, many homes were shifted to safer places, and the riverbed is now called *bhagraiya* (riverbed). It is a big area, roughly 200 ha in the south-east of the village. These losses have many implications for poverty, livelihoods and culture, more so in Thapuwa than in Bikri in terms of housing damage and loss of land, livestock, and crops.

Table 5.6 Household-level vulnerability to flooding from 2007–2017

Livelihood capital	**Thapuwa (n=143)**	**Bikri (n=86)**	**Total (n=229)**
Land size per household (ha)	1.17	0.55	0.93
Land damage (ha/hh)	0.48 (108)	0.12 (50)	0.37 (158)
House damage (USD/hh)	491 (93)	289 (20)	455 (113)
Livestock loss (USD/hh)	125 (30)	76 (6)	117 (36)
Crop damage (USD/hh)	516 (137)	261 (69)	430 (206)

Value in parentheses are number of affected households (frequency) from floods. Acronyms: ha = hectare, hh = household; 1 USD=116.35 NPR as of 6 October 2018

There are no specific flooding prediction technologies, so villagers have relied on their knowledge and experience, as well as scientific weather forecasts from the weather stations. Farmers cultivate local rice varieties, Karangi and Sauthyari, when flooding destroys transplanted rice and there is lack of rice seedling to re-transplant or farmers also cultivate as a late season varieties. The autonomous adaptation of the villagers was supported by government agencies and non-government organisations (NGO). Villagers spontaneously supported each other during flooding to secure stored food, livestock and other important properties of the household. The *barghar* traditional leadership facilitates the effective dissemination of information and responses during flooding disasters. The villagers receive disaster preparedness training, tools, and equipment from NGOs, including safety houses built in each village. Post-flooding adaptation measures, such as tree planting along the riverbank, and a temporary river wall by piling sacks filled with sand, were not long-term solutions. Now, earthen embankments and wire fencing with stones or sandbags are being constructed by government agencies as a long-term planned adaptation strategy to control flooding in both villages.

5.3.3 Droughts

Drought was the second important hazard for people at Bikri but the fourth most important in Thapuwa. The most severe droughts that the villagers remembered were in 1979 and 1988. The participants indicated that rice and maize production were severely affected. The drying up of rice in the field caused food scarcity, so many farmers had to borrow rice from *mahajan* (money lenders). Jilbul Tharu, aged 45 years, from Bikri, recalled:

> In the past, drought was more frequent and severe, the growing period of rice was long, and irrigation machinery was lacking. Almost every year we used to suffer from drought, though there was not a complete failure of crops. In 1979 and 1988, rice even dried up in the field, so we cut it and fed to cattle. Rice planted in the *jabda* (lowlands rice field) did not develop grain as well. We had a terrible food scarcity in the village, so we borrowed partially boiled rice and money from *mahajan* (money lenders) in Nepalgunj. It took us a long time to repay because of their high-interest rate.

Drought is still a common threat despite the presence of an irrigation canal in Bikri and pumping of underground water at Thapuwa. Since there has not been a complete crop loss in recent years, Thapuwa farmers prioritised drought as less important. During the interviews, six farmers (five from Bikri and one from Thapuwa) commented on the varying reductions in rice yields (10–20%) in 2016/2017. Furthermore, farmers perceived shorter durations of drought, particularly post-monsoon because, by that time, most of the short-duration rice is ready to harvest. Farmers also experienced more problems with weeds during a drought than a year with flooding.

In response to agricultural droughts, Tharu have a long tradition of practising relay sowing of winter crops, mostly lentil, linseed and grass pea, before harvesting the rice to make use of soil moisture and crop residues. Conservation agricultural techniques, such as covering the soil with plant residues and crop rotation, are also practised. Most of the rice fields are rotated with legume crops, but in recent decades, this practice has been replaced with winter–spring maize. Similarly, mixed cropping, mostly in winter, has reduced vulnerability to complete crop failure and has provided food diversity for smallholders (see Chapter 6). Nowadays, the Tharu also use non-farm-based adaptation strategies, such as wage labour, to diversify their income to deal with climatic shocks and stresses, including droughts.

5.3.4 Storms

The people of Thapuwa consider storms as the second most important threat to their livelihood. Storms occur most years from February to May. During my fieldwork, I experienced several storms and observed their impact on agriculture and households. For example, on the night of 29 April 2018, I observed the damage caused by a storm of about an hour (8:30–9:30 PM). I estimated that about 10% of maize plants lodged on 8–10 ha, particularly those with immature cobs, were destroyed. Similarly, orchards, especially mango orchards, were heavily damaged with about 25% of immature mangoes dropping from the trees. Pati Ram Tharu stated,

> What can one do, *bhaiya* (brother)? I have collected 2 *bora* (2 sacks of about 80-100 kg) of dropped mangoes and will go to sell at the Gulariya *hatiya* (market) on Tuesday. If it is not sold, then I will dry it to make *amchur* (immature dried mango pieces used as pickles and source of citric acid).

When I visited Ram Shahi's house for the household survey, his wife was peeling fallen mangoes to make *amchur*. Before I asked anything, she said,

> This year there will not be more mangoes in the trees, though flowering and fruiting were good. Just last day's strong storm dropped 4 *bora* (sacks) of mangoes. Branches of mangoes and *jamun* (*Sizium cumini*) have fallen.

There was minor damage to the houses, with many house tiles, tin sheets, and *khapada* (*roofing materials*) removed. I saw two houses where tin sheets, including the main beam '*balli*', had fallen on the road. Many people declared that falling tin sheets are more dangerous than roof tiles and *khapada,* so fastening tin sheets with strong bolts onto the main beam or other supporting strong materials is necessary.

There were no specific strategies to protect houses and crops from storms apart from making durable physical infrastructure. There could be an opportunity to explore the use of trees as windbreaks at Thapuwa to mitigate the impact of strong winds on agriculture, and for firewood supply, and many farmers have planted trees in a small orchards.

5.3.5 Cold waves

Cold waves are considered a regular climatic phenomenon. During winter, it feels intensely cold in combination with thick fog. For cold waves, villagers use warm clothes, campfires, and warm clothes to keep warm, and protect crops by mulching, and using resistant varieties and fungicides.

Farmers expressed hardship during cold waves, but also mentioned the need for cold for good winter crop production. In the Tarai, cold waves become difficult when the weather is foggy, temperatures drop suddenly, and the sun does not appear for many days. Increased mortality, particularly of children and elderly people, has been reported in the Tarai region of Nepal due to the prolonged cold waves during winter (Pradhan, Sharma, & Pradhan, 2019).

The number of foggy days, foggy daytime hours and dense fog with low visibility have significantly increased in the Tarai region of Nepal (Manandhar et al., 2011; Shrestha et al., 2018). The impact of low temperatures (drop in minimum temperature) and reduction in photosynthetically active radiation (PAR) increases cold stress and favours disease incidence in crops (Singh & Singh, 2010). Farmers reported that crops such as potato, tomato and onion were severely affected by the cold, fogs and cloudy weather. They dust ash on onion, eggplant, and tomato crops and spray fungicides, particularly on potato.

5.4 Source of weather information

Weather information is important for preparedness. Radio is still the most important source of information. Accessibility to radio stations and local FM on mobile phone devices has greatly increased access to weather information (Table 5.7). Other sources of information are social networks (friends, relatives, neighbours) and TV. More than 90% of people receive reliable weather information in a timely manner, so they act upon it, especially in the case of flood warnings.

Table 5.7 Top five sources to obtain weather information

Source of weather information	**Thapuwa (n=143)**		**Bikri (n=86)**		**Total (n=229)**	
	%	**f**	**%**	**f**	**%**	**f**
Radio	72.7	104	96.5	83	81.7	187
Mobile phone	4.9	7	0	0	3.1	7
Social network	4.2	6	0	0	2.6	6
Television	3.5	5	0	0	2.2	5
IK and *Pandit**	6.3	9	2.3	2	4.8	11

IK= Indigenous knowledge **Pandit* is the Hindu priest, f = frequency

Note: Total per cent is not 100 since only the top five sources of information are presented here.

Access to information plays an important role in building perceptions of climate change. Radio is the most common source of information in Nepal, in terms of cost, convenience and frequency coverage. Piya et al. (2012b) reported that radio, training and agriculture extension services are important sources of climate information, perception and adaptive measures. Similarly, Marvin et al. (2013) described the supportive role of various media in information dissemination during climate extremes and disasters. In addition to scientific climate/weather information, Tharu follow some Indigenous and traditional weather forecasting techniques, including religious expert advice based on the Hindu calendar.

5.5 Conclusion

The Tharu in the western Tarai of Nepal have perceived changes in temperature and rainfall and experienced their impact in the form of flooding, droughts and other hazards affecting agriculture and livelihoods. Local people's perceptions of most of the climatic variables were validated for temperature with long-term climatic data, but not for rainfall. Participatory vulnerability prioritised flooding and drought as the two most important hazards affecting agriculture. Flooding has multiple impacts and the possibility of increased risks in the future. Local people have developed adaptation strategies to flooding, drought and cold wave hazards. The adaptation and mitigation strategies and measures are insufficient to reduce vulnerability, mainly for smallholders, which leads to income diversification through non-farm activities such as wage labour and migrant work. Integration of the flood early warning system into the Tharu *barghar* system of village governance has increased the adoption and efficiency of the early warning system. Farmers also use various local and traditional agricultural strategies, such as relay sowing, direct seeding of rice and sowing date adjustments, in combination with hybrid seeds, inorganic fertilisers, and irrigation technologies to reduce the impact of climate change in agriculture.

The reliance of the Tharu on Indigenous knowledge for weather prediction, disaster management, and agricultural technology and practices has been decreasing mainly due to increased access to information and increasing family needs of smallholders. The role and contribution of information and communication technology (radio, mobile phones, and extension services) have increased access to information and technology for weather predictions and preparedness for climatic extremes and events such as flooding and droughts. The scope and use of digital agriculture are increasing through the use of a broad range of data for precision agriculture by reducing risks (Shen, Basist, & Howard, 2010).

Adaptation to and mitigation of climate change relate not only to technical responses, but also to sociocultural and behavioural factors (Casimir, 2008). Hence, Indigenous knowledge and its associated practices are important to reduce the impact and future risks of climate change. Indigenous knowledge and practices are accurate, practical and useful for local people in various decision-making processes that might not be replaced through externally created knowledge (Ellen, 2007; Lodhi & Mikulecky, 2010; Nakashima et al., 2012). Therefore, Sillitoe (2017) emphasised the need to transform the contribution of Indigenous knowledge from “unknown known’ to ‘known known”. Furthermore, he argued that Indigenous knowledge is simple, specific and directed to problem-solving and may not be exactly accommodated with scientific knowledge (Sillitoe, 2007). Hence, the integration of Indigenous knowledge and scientific knowledge is becoming an important approach for disaster risk reduction (Iticha & Husen, 2019; Masinde & Bagula, 2011; Paul & Routray, 2013), natural resource management (Nakashima et al., 2012; Sterrett, 2011; Warren, 1991), environmental protection (Galloway McLean, 2009), and climate change adaptation (Chaudhary & Bawa, 2011; Chaudhary et al., 2011).

CHAPTER 6. ADAPTATION TO CLIMATE CHANGE: ADAPTIVE CAPACITY, STRATEGIES AND BARRIERS OF THARU IN THE WESTERN TARAI OF NEPAL

6.1 Introduction

Climate change is universal, but its impact differs based on geographical location, sectors and the adaptive capacity of individuals and the nation (CARE International, 2009; Galloway McLean, 2009; Pasteur, 2011). Agriculture and other natural resource-based productions are more sensitive to climatic variability and extremes/hazards than other sectors (Smith et al., 2014; Sterrett, 2011). Chapter 5 discussed Tharu's perceptions of climate change and how various hazards increase their vulnerability. This chapter continues to expand on the long-term experiences of the Tharu in terms of the climate change impact on agriculture, forest and biodiversity, particularly their capacity and strategies for adaptation, and the barriers and limitations for adaptation and mitigation.

Adaptive capacity is considered socially constructed, in which types of livelihood capital (natural, physical, human, social/cultural and financial) govern the adaptive capacity of an individual or group/community (Adger, 1999; Adger & Kelly, 1999). Adaptation and adaptive capacity determine a community's vulnerability: the higher adaptive capacity, the lower the vulnerability (Hufschmidt, 2011). Furthermore, actual adaptation is influenced by the perception of vulnerability and willingness to implement adaptation strategies/practices (Hufschmidt, 2011). Studies on the sustainable livelihood framework (SLF) have used livelihood capital as an integral component for improving adaptive capacity and reducing vulnerability (CARE International, 2009; McNamara, Westoby, & Smithers, 2017; Pasteur, 2011). Not only do physical, natural and financial capital need strengthening, but the social/cultural and human aspects of livelihood capital, which ultimately determine sustainable livelihood development, are equally important (Adger, 1999; Adger et al., 2013; Adger & Kelly, 1999).

Adaptation practices are the actions implemented by affected people to reduce the impact/vulnerability in livelihood means, such as agriculture, to improve wellbeing. As adaptation and mitigation complement one another, the mitigation aspect of agricultural practices is as important as adaptation for practical adaptation and emission reduction (Aggarwal & Sivakumar, 2011; IPCC, 2014b).

6.2 Impact of climate change on agriculture and biodiversity

Chapter 5 reported that farmers perceive that increased temperatures, decreased total rainfall, but increased post-monsoon rainfall, have caused flooding, drought, and other climate-related hazards in the study villages. This chapter analyses the impact of climate change in agriculture and biodiversity in the last 20 years from an adaptation perspective using data from the focus group discussions (farmers, animal herders, and older people) conducted during the study.

In agriculture, the overall impact of climate change is observed in terms of changes over time in cropping pattern, crop calendar, and crop type/variety. The crop calendar for the study villages is shown in Table 6.1, with possible reasons for changes in the agriculture system summarised in Appendix 6.

Rice and wheat are cultivated about two weeks earlier than 10–20 years ago. Monsoon-season maize has been almost entirely replaced with rice. Kaluram said, “Farmers near my maize field started to cultivate rice that creates soil waterlogging that makes my field unsuitable for growing maize; then I also started to cultivate rice in that field.” Many farmers started to cultivate rice instead of maize in the summer/monsoon season due to the availability of short-duration rice varieties, high rice yields, and preference for eating rice over maize. Also, maize can be grown in winter/spring after harvesting rice, but rice normally grows only during the summer/monsoon season. No changes in lentil and pea cultivation were observed, but mustard cultivation has declined.

Table 6.1 Comparison of crop calendar (current and 20 years ago) in Bardiya

Crop		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Rice	Past													*	*	^	^	^	^	^	^	x	x	x	
	Current												*	*	*	^	^	^	^	^	x	x			
Wheat	Past	^	^	^	^	^	^	^	x	x													*	*	^
	Current	^	^	^	^	^	^	x	x													*	*	^	^
Maize	Past										*	*	^	^	^	^	^	^	x	x					
	Current	^	*	*	^	^	^	^	x	x													*	*	^
Lentil/ Pea	Past	^	^	^	^	^	x	x														*	*		^
	Current	^	^	^	^	^	x	x													*	*	^	^	^
Mustard	Past	^	x	x															*	*	^	^	^	^	^
	Current	^		x	x	j	j	j													*	*	^	^	^
Legend	*sowing, ^growing, and x harvesting. j : *Brassica juncea* harvest																								

Traditional minor crops, such as linseed and sesame, are rarely cultivated due to the changes in land cultivation patterns and possible decline in market demand. Similarly, pigeon pea and pointed gourd cultivation have practically disappeared in Thapuwa due to changes in the river course making the land unsuitable for their cultivation. Local soybean, Tharu *alu* (Tharu potato) and chickpea cultivation have also drastically declined in the study area.

Rice field preparation is traditionally (up until 10–20 years ago) very labour-intensive, with at least three tillage passes before rice transplantation. The first preparatory tillage of the *khetwa* (rice terrace field) is called *ofar/chir*. It is performed after the onset of rain to loosen soil, exposing it to sunlight, and to accelerate later land preparation for rice and maize cultivation. The first tillage of *dihwa* (flat land traditionally used for maize cultivation) is called *dhuriya* tillage—meaning dusty tillage without soil moisture. The main characteristics of *ofar* and *dhuriya* are one-way tillage (no cross-sectional tillage), shallow depth, and not tilled in a flooded condition. The second tillage is called *gejar*, which is performed during the rice cultivation season in the shallow flooded field. The field is then left for 7–10 days so that weeds can decompose. The final tillage, called *lewa,* is then undertaken, followed by *danta/kilwahi* (raking) and *henga* (levelling) to puddle the field for rice transplantation. The wider transplantation spacing of hybrid rice and use of inorganic fertiliser promote weeds in the field that need herbicide or manual removal. Increased weeds also occur through seed dispersal during flooding and with favourable climatic conditions.

A change biodiversity is one of the most observable sector due to climate change. The observations and experiences of cattle and goat/sheep herders are important to trace the perceptions regarding the impact of climate change on agricultural, pasture and forest biodiversity. Striking cases were the disappearance of *chakon (*sickle pod, *Senna obtusifolia), perar* tree *(Tamilnadia uliginosa), garjuwa* mushroom and *chhtaka* leech (terrestrial). In their opinion, increased population and economic pressures, vegetation losses and food insecurity impinged on biodiversity. The participants reported that water sources and lakes in the forest have dried up, which might be due to the increased temperature and droughts.

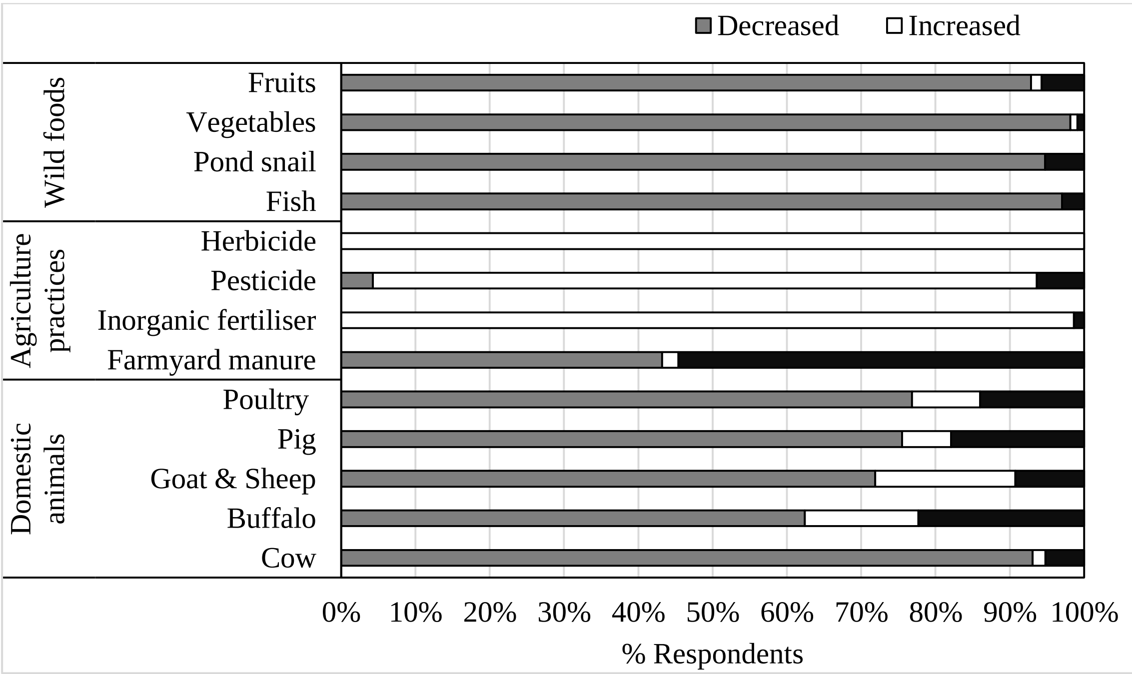


Figure 6.1 Changes in agriculture and wild foods in the last 20 years (Ref. year 1997)

The household survey results show an overall decrease in livestock species and wild food use in the past 20 years, and an increase in the use of external inputs in agriculture (Figure 6.1). The household survey questionnaire consists of three parts. The first part focuses on how agricultural practices have changed over the last decades. It also covers food security and contribution of wildfood in food security (see Appendix 2, Part A, Question 3). The second part of the question is on perceptions and impact of climate change in agriculture. The decreasing population of livestock and its possible reasons for change comes under this part (see Appnendix 2, Part B, Question 5.1). The third part of the questionnaire includes demographic and household information. Cattle numbers, particularly cows, have drastically declined due to decreasing demand of for animal draft, grazing land and forest areas, and the market value of cows. The pasture land at Bikri has been distributed to *sukumbasi* (landless people), and the forest is under pressure due to the settlements of *mukta kamaiya* (earlier bonded labourers in agriculture) near this village. Local cows are a draft breed with extremely low milk production (1–2 liter per day). In the past, cattle were the major source of farmyard manure, but due to the availability of inorganic fertiliser and farm machinery, the value of draft animals, notably the bullock, has decreased. The market price of water buffalo is good due to the high value of fatty milk and buffalo meat in Nepal. Farm power is now in a hybrid mode, with the first few tillage passes done with tractors (mostly 4 wheel) followed by ploughing. A significant number of farmers use inorganic fertiliser in small quantities, and all available farmyard manure is used. The increased herbicide and pesticide use is mostly due to the adoption of other agricultural practices, such as the use of new seeds and technologies. The Tharu believe that changing weather patterns exert pressure on forest biodiversity, wild food and agriculture. Furthermore, the decline in farmyard manure, due to fewer livestock and the use of cattle dung for firewood, increases the demand for inorganic fertiliser.

The availability of wild foods has also declined, including wild fish, *ghonghi* (geniculate river snails), wild fruits such as *kosam* (*Schleichera oleosa*) and *tend* (*Diospyros malabarica*), and wild vegetables such as *dakhi* (*Antidesma acidum*) and *piyar* (*Buchanania latifolia*) (Appendix 7). Cattle herders mentioned that there had been no shift in the flowering time of wild fruits, but their overall availability has declined. Forest regeneration of some fruit species, such as *tend* and *kosam* trees, might be constrained due to the change in climate and human pressure. The reduction in wild fish in the river and lakes may be the result of overharvesting, but also the shallowing, burying, and drying up of lakes. Similarly, the construction of irrigation dams and fish poisoning in the river have reduced the availability of fish.

6.3 Adaptive capacity

It is crucial to assess the adaptive capacity and associated factors determining the capacity for designing and practising adaptation strategies for climate-resilience. Quantitative approaches, such as principal component analysis, are commonly used to assess the vulnerability and adaptive capacity of individuals and communities (Deressa et al., 2008; Deressa et al., 2009; Shrestha, 2014; Tiwari, Rayamajhi, Pokharel, & Balla, 2014). Various participatory tools (e.g. wellbeing and matrix ranking) are also used in community-based development projects (CARE International, 2009; Gentle & Maraseni, 2012; Maharjan, Maharjan, Tiwari, & Sen, 2017; Pasteur, 2011; Van de Sand, 2012). As noted earlier, this study used a mixed-methods approach, incorporating a qualitative approach (spider web method) to assess the adaptive capacity of the community through focus group discussions, and a quantitative analysis (logistic regression) to identify the determinants of adaptive capacity.

An overview of household characteristics is presented first to connect livelihood capital with adaptive capacity.

6.3.1 Household characteristics

Landholdings and other essential household characteristics are presented in Table 6.2. The households are small landholders, with households in Bikri have smaller landholdings (0.55 ha/household) than Thapuwa (1.17 ha/household). There are 19 *mukta kamaiya* families in Thapuwa with small plots of land (0.07 ha/family). Despite the small landholdings, particularly in Bikri, the primary occupation of people in both villages is agriculture (Table 6.2). The Tharu have been a patriarchal society, but the leadership of women is increasing in nuclear families.

Table 6.2 Average household characteristics of the study villages

Characteristics	**Thapuwa (n=229)**	**Bikri (n=86)**
Mean landholding (ha)	1.17	0.55
Mean family size	5.8	5.7
Median age of household head (hhh)	42	39
% literacy of hhh	96	99
% occupational agriculture of hhh	88	85
% female-headed households	4	5

Table 6.3 Landownership categories in the study villages

Household type		**Thapuwa (n=143)**	**Bikri (n=86)**
Sharecropper (*bataiya*)	%	64	27
	n	91	23
Small owner cultivator (<0.5 ha)	%	36	58
	n	52	50
Medium owner cultivator (0.5–2.0 ha)	%	46	40
	n	65	34
Large owner cultivator (>2 ha)	%	18	2
	n	26	2
Local non-cultivator with land	%	6	2
	n	9	2

For the analysis, the households were divided into three main categories (small, medium, and large) based on the size of land ownership: small owner cultivators (<0.50 ha), including those owning no land, medium owner cultivators (0.5–2.0 ha), and large owner cultivators (>2.0 ha) (Table 6.3). Most large farmers cultivate the land themselves, while some of them lease additional land or rent out part of their land for cultivation. When renting land, 50% of the product is usually shared, which is called *adhiya bataiya* (sharecropping). Sharecropping is common among many families, with 64% in Thapuwa and 27% in Bikri participating in the practice. Local non-cultivators with land are those who own land, but who do not farm themselves. These families mostly engage in salaried work or are in skilled employment.

6.3.2 Adaptive capacity analysis

I considered the livelihood capital approach for assessing the adaptive status/capacity of household and gender dimensions (men and women). Livelihood capital is an established approach for rural livelihood analysis (Ellis, 2000), which is also widely used to assess the adaptive capacity for sustainable farming (Brown et al., 2010; Nelson et al., 2010). Ellis (2000) broadly divided livelihood strategies into five categories—natural, physical, social, financial, and human, which can complement, substitute or transform each other. The objective of this study, however, is to analyse adaptive capacity giving equal emphasis to five capitals to reflect the overall adaptive capacity, rather than assessing the dynamics of livelihood capital and its transformation.

Following the spider web technique — a pictorial reflection of variables in the shape of spider web — of van de Sand (2012) to assess adaptive capacity in regard to climate change, I conducted focus group discussions in the Thapuwa and Bikri villages, each comprising 10 participants, representing different ages, gender, socioeconomic status. Though the adaptive capacity primarily exits in household levels, it differs with gender within the household due to human capacity, financial access and income. Therefore, the focus group discussions were conducted separately with men and women's groups keeping constant which household they (the men or women) represented. Furthermore, the family structure in the Tharu community is changing from a joint family to a nuclear family, therefore it is relevant to assess adaptive capacity of men and women separately. First, the participants identified the livelihood indicators that they felt important for coping with climate extremes and hazards, which were then grouped into one of five types of livelihood capital (physical, natural, financial, social and human). The participants then selected the five most important indicators for each livelihood capital. Two subgroups, one for men and the other for women, rated the status of each indicator from 1 to 4, where 1 is the weakest and 4 is the strongest situation. Finally, the average of each type of livelihood capital for men and women was calculated by dividing the total value with the number of indicators (5) (see Figure 6.2 and Appendix 8, 9). The adaptive capacity analysis is also trigulated through the adoption of improved agriculture practice as a proxy indicators of progressive adoption by using the binary logistic regression in later section.

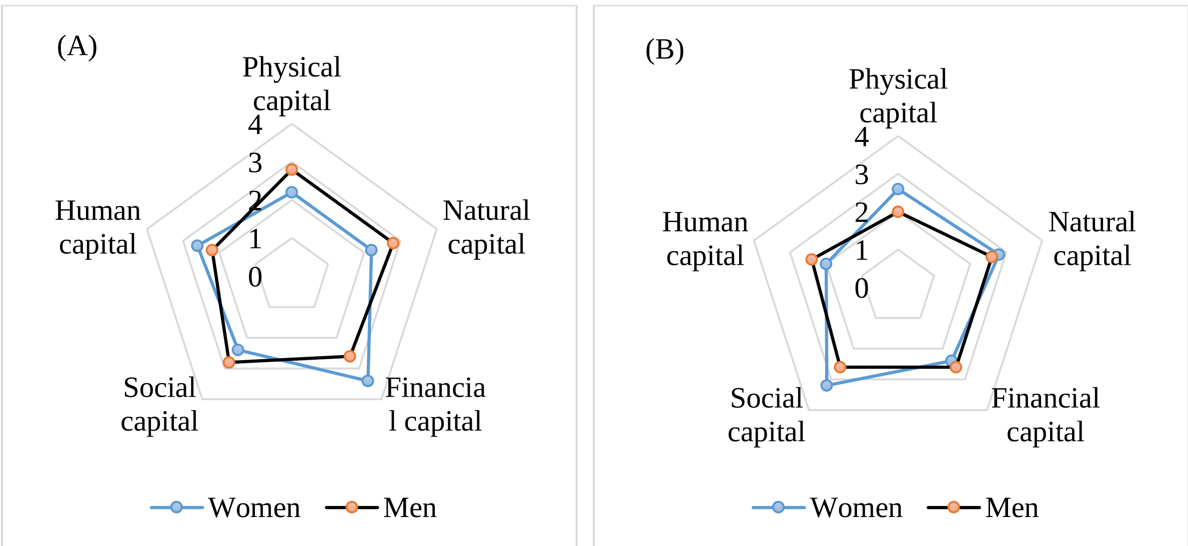


Figure 6.2 Adaptive capacity based on livelihood capital in (A) Thapuwa and (B) Bikri

According to this analysis, the livelihood capital (adaptive capacity) differed by geography and gender. People in Thapuwa have better adaptive capacity than Bikri in terms of accessibility to markets, services and road/transport systems, as well as financial and physical capital, whereas people in Bikri scored higher in terms of natural (forest) and social capital. Here the adaptive capacity of men and women reflects an overall strength to cope with climate-related hazards and contribute to adaptation in long-run. Flooding and drought hazards differentially impact men and women due to the nature of their work within the household. Women are often responsible for saving household assets during such times and for coping with post-disaster food insecurity.

Land, a major natural resource, is the most critical source of livelihood capital in an agrarian setting. Land is not only an object for farming, but it also determines social status and wealth (Dhakal et al., 2000; Regmi, 1977).

Table 6.3 shows that a large number of families have small landholdings; 45% (102) of households have <0.5 ha land. As such, many families depend on *adhiya bataiya* (sharecropping), more so in Thapuwa (64%) than Bikri (27%) because Bikri has a high percentage of small farmers (58%) and less land available for lease. In contrast, Thapuwa has more medium and large farmers in the village and neighbouring villages (Kothiya, Parasiya) with land available for sharecropping. Furthermore, four landlords, with about 20 ha of land between them in Thapuwa, do not live in the village, so villagers rent that land for sharecropping.

In terms of gender, women have fluctuating livelihood capital, while men almost consistently have better adaptive capacity. Women are better with financial (group saving, seeking financial support from relatives and friends) and social capital (saving group membership, forest user group membership, participation in meetings and training), whereas men have better access and control over natural (land) and human capital (education, trade-based skills and employment). The men in Thapuwa have better adaptive capital than women, while the reverse is true for Bikri due to the better natural (community forest, goat/sheep raising, and fruit trees) and physical (motorbike for emergency transport, mobile phone for communication and river protection embankment) capital. While women are scored as having better financial status than men, it is mostly limited to the local saving and credit group and cooperative, as women have limited access to banks and financial institutions. The family and sociocultural networks of women play an important role in coping with food insecurity and for post-hazard rehabilitation. Women also play a vital role in the post-harvest crop processing, storage, and saving seeds for the next season. The Indigenous knowledge of the Tharu women in crop storage and preservation of crop landraces is described in Chapter 7.5.3 (Table 7.8).

Women have a higher workload than men, being involved in farm work, household chores and family care responsibilities, which hinders their participation in education and leadership. Women, therefore, have overall lower socioeconomic status in the Tharu communities. Women are culturally restricted from performing certain agricultural activities, such as ploughing and driving bullock carts. The wives of migrant workers and widows suffer from such restrictions, which results in poor production. One of my female participants (Krisni, 30, Bikri) told me:

> My husband went to India without informing me at a critical stage of my having a daughter; even the navel cord was not fallen off. He went out of contact for many months because of no communication means at a village like this [showing her mobile phone]. I cannot live separately from the joint family in absence of my husband for ploughing land and bund in the rice field. After a few years, one day I heard from someone else that he is coming to Nepal, and then he arrived home with a faded face and empty hands without money. He started a small shop in the village after his next return from India, but the shop was destroyed and the house was cracked by flooding so, he went to Qatar two years ago. I cannot continue farming in my husband's absence and I luckily got an assistant job in a primary school in Bikri village.

Land ownership, access to forest resources, social networking and skills are important aspects of livelihood capital that make a difference to the adaptation to climatic shocks. Road, transport and markets have increased accessibility for inputs, services and income diversification. The Tharu communities have an increasing role for women in all aspects of livelihood capital, but they still have a lower adaptive capacity than men.

6.3.3 Determinants of adaptive capacity: logistic regression model

Logistic regression is a widely used econometric tool to evaluate the effects of various explanatory (independent) variables on explained (dependent) variables. The binary logistic regression model has dichotomous options for dependent variables (Long & Freese, 2006). The model indicates the degree and direction of relationships between two variables (dependent and independent) for the adoption of modern agriculture practices (Ndamani & Watanabe, 2016; Tiwari et al., 2014). I used this model to identify factors contributing to the adoption of improved agricultural methods because innovative and modern agricultural technologies (crop variety, irrigation, weather information and services) are considered important for adaptation to climate change (Adger et al., 2007; Bhatta & Aggarwal, 2015; Chalise & Naranpanawa, 2016). The adoption of improved seeds and other inputs (e.g. inorganic fertiliser, pesticides, and herbicides) are the proxy indicators indicating readiness of farmers to the adoption of new agricultural methods. The cultivation of climate-smart crops/varieties (resistance to heat, drought, flooding and biotic stresses), mixed cropping, sowing date adjustments, and soil conservation practices are strategies for adapting to climate change impacts (Bhatta & Aggarwal, 2015; Chalise & Naranpanawa, 2016; Piya et al., 2012a).

Here, I considered adoption (as a strategy for adaptation to climate change) as a dependent variable in the dichotomous form: adopted (yes) or not adopted (no). Six practices—use of hybrid seed, inorganic fertiliser, pesticides or herbicides, change in maize cultivation seasons, and irrigation/ pumping equipment ownership—were used to classify farmers as adopters or non-adopters. Farmers using at least three practices were considered adopters, coded “1”, with the remainder non-adopters, coded “0”. All agricultural practices (independent variables) were considered with equal weight because this analysis is simply to find out about the adoption or non-adoption of technologies based on two choices. The adoption of inorganic inputs (fertilisers, pesticides, and herbicides) does not indicate that the adaptive capacity of farmers has improved, but it signals the receptiveness of farmers to new agricultural practices and innovations. The adoption of improved agricultural methods, including inorganic inputs, increases crop yields and incomes, and thereby helps to improve adaptive capacity. There is an integration of Indigenous/traditional knowledge and practices with modern agriculture making the hybridization of knowledge and practices suited to the local environment and producing a reasonable yield. An example of this is the cultivation of an improved wheat variety (Kundan) in combination with the traditional method of seed broadcasting. However, the effective and efficient use of inorganic inputs are emphasised in agriculture (Datta et al., 2013; IPCC, 2014b; Kesheng & Zhen, 1997; Smith et al., 2014). Individual, cultural, economic, institutional and geographical factors are deemed explanatory (independent) variables (Table 6.4) for the analysis.

Table 6.4 Selected independent variables used in the regression model

S.N.	**Dummy variable**	**Measurement**
1.	Adoption	1 = adopted; 0 = not adopted (dummy variables)
2.	Age of household head (hhh)	Number
3.	Gender of hhh	1 = male; 0 = female
4.	Education of hhh	1 = literate; 0 = illiterate
5.	Family size	Number
6.	Primary occupation of hhh	1 = agriculture; 0= non-agriculture
7.	Pumping equipment ownership	1 = yes; 0 = no
8.	Access to weather information	1 = yes; 0 = no
9.	Access to extension service (agriculture and veterinary)	1 = yes; 0 = no

10.	Membership in agriculture/saving groups	1 = yes; 0 = no
11.	Access to credit/loan	1 = yes, 0 = no
12.	Seasonal migration (Nepal, India)	1 = yes; 0 = no
13.	Overseas migrant worker	1 = yes; 0 = no

The logit model uses the function form of logistic regression in which the dependent variable converts into the natural logarithm of the odds upon positive choice. Hence, if the estimated value is significant, then there is a higher probability of adoption of agricultural practices. The model compares coefficients with the probability of occurrence or not with values between 0 and 1. The model is specified as (Agresti, 1996):

$$\ln [P_x / (1 - P_x)] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots\ldots\ldots + \beta_k X_{ki}$$

where P_x = probability of adoption; $(1 - P_x)$ = probability of non-adoption; i = i^{th} observation in the sample; β_1, β_2, …… β_k = regression coefficients of the explanatory variables; X_1, X_2 …… X_k = explanatory variables; β_0 = constant term

The binary logistic regression model showed that several socioeconomic and institutional factors are responsible for the adoption of agricultural practices that contribute to adaptation to climate change in agriculture. Education of the household head, land size and access to extension services significantly affected the adoption of agricultural practices (adjustment and switching crops, hybrid seeds, inorganic fertilisers, pesticides, herbicides and irrigation equipment) (Table 6.5). The adjustment of crop sowing and harvesting dates also applies to tradtitional crops and landraces. Similarly, the use of pesticides and herbicides are limited and recent trends, mostly used in hybrid crops and vegetables due to labour scarcity. There was no modern method of replacing the traditional practice of cooperation at the early stage of maize cultivation to remove weeds and loosen the soil.

Table 6.5 Determinants of adoption in agriculture in the study villages

Variable	Coefficient	Exp (B) odds ratio	Std. error	p-value
Age of household head (hhh)	–0.005	0.995	0.022	0.828
Gender of hhh	–0.001	0.999	0.942	0.999
Education of hhh	1.234	3.434	0.415	0.003**
Family size	0.024	1.024	0.093	0.799
Primary occupation of hhh	–1.027	0.358	0.586	0.080
Farm size	1.174	3.235	0.380	0.002**
Access to weather information	–0.759	0.468	0.898	0.699
Access to extension service	1.801	6.055	0.735	0.014**
Membership in groups	0.260	1.297	0.961	0.787
Access to credit	–0.366	0.693	0.458	0.423
Seasonal migration	–0.050	0.951	0.499	0.920
Overseas migration	–0.463	0.629	0.604	0.444
Pseudo R^2 (Nagelkerke R square)			0.259	

**significant at 5% level; Households surveyed (n) =229

Education had a significant role in decision making as a vector for adaptation to climate change. Literate farmers are three times more likely to engage in adoption than illiterate farmers. Educated farmers are role models for improving agriculture and integrating Indigenous knowledge and traditional agricultural practices. Educated farmers also have greater exposure, social networking and and services than illiterature farmers, which helps them to assess and integrate Indigenous knowledge and practices in their agriculture. Studies have shown that education has a significant positive role in climate change adaptation elsewhere (Deressa et al., 2009; Ndamani & Watanabe, 2016; Tiwari et al., 2014).

Land ownership played a significant role in farmers' increased probability of adoption. Every additional hectare of land ownership increased the likelihood of adoption by a factor of three. Since land is the most important source of wealth and assets, it determines the credit, investment and risk-taking capacity of farmers. Large landowners can salvage production under harsh conditions due to the large farm size. They can even survive in complete crop failure due to their storage of the previous year's production. I found smallholders have greateer responsibility to increase crop productivity for household food security, but were often constrained from buying the improved/hybrid seeds due to their high price. In such cases, farmers cultivate local varieties with traditional methods. Tiwari et al. (2014) found that large farmers had better resilience than smallholders in Nepal. However, a study in Ghana reported a negative effect of farm size on adaptation, as larger farms require higher investments for improved seeds, irrigation, fertiliser (Ndamani & Watanabe, 2016). Landholding is a primary determinant of reducing vulnerability to climatic stresses in agriculture in the Indo-Gangetic Plains (IGP) of South Asia (Sugden et al., 2014). Similarly, Deressa et al. (2009) identified various socioeconomic indicators, such as education, gender, wealth, credit and extension services, and climate information for adaptation capacity to climate change.

Farmers with access to agricultural extension services, such as inputs, training, and technology, have a six times higher likelihood of agricultural adoption than those with no access (Table 6.5). In the study villages, farmers have access to private, government, and non-government organisation services. Farmers buy agricultural inputs from agro-vet shops and also receive technical guidelines and services. Farmer groups receive financial support for irrigation, seeds, and technical services (vegetable production and marketing training). The input support, training, market information and access to technical services have helped the farmers in these villages to diversify crops, increase yield/income, strengthen their agricultural knowledge, and deal with constraints and challenges, including climate change, all of which improve adaptive capacity. It indicates that there is an emerging role for social groups, cooperatives in relationship with input suppliers and service providers, including the government extension office. The significant influence of extension services and input suppliers reflects the emerging role of institutions and service providers in shaping climate perceptions at local levels.

Farmers update their understanding of local knowledge and farming practices through the government agency that mostly focuses on intensive agriculture. The farmer-to-farmer approach of extension helps to disseminate local knowledge and practices in agriculture. In addition, an informal seed distribution system (farmer-to-farmer) is prevalent in the Tharu community; this system not only conserves local agrobiodiversity, but also transfers local knowledge on production, storage, and food utilisation. Local agricultural knowledge and practices are shared, modified, updated and transformed to the larger farming community and new generations through explicit knowledge creation from tacit knowledge (local and Indigenous knowledge) (Nonaka & Takeuchi, 1995). Adesina, Mbila, Nkamleu, and Endamana (2000) stated that organising farmers into group brings farmers together to educate themselves and share information, which has a positive impact on the adoption of agricultural technology, such as agroforestry in Cameroon.

6.4 Adaptation strategies

Keeping in mind that the adoption of crops, production inputs and technologies are determined by various types of factors, such as, social/cultural (e.g. labour, children education), economic (yield and price), the adaptation strategies described here are analysed from the perspective of climate change. Farmers used a combination of strategies to adapt to the impact of climate change and to reduce climatic risks in agriculture. The most common adaptation strategies found in the Tharu study villages of the western Tarai of Nepal are described in Table 6.6. The table highlights that the farmers adopt multiple strategies in agriculture even beyond the agriculture itself, such as income diversification and migration for wellbeing.

Table 6.6 Adaptation strategies used by farmers in the study villages

Adaptation practices	**% household**	**Frequency**	**Detailed adaptation practices**
Change in cropping pattern	90	207	Monsoon maize replaced by rice cultivation in the monsoon; maize cultivated in winter.
Change in crop calendar	50	115	Rice transplantation starts about two weeks earlier, which allows early sowing of winter crops (wheat, lentil, pea), but it delays mustard cultivation. Mustard now cultivated in rice fields instead of maize fields (*dihwa*).
Crop diversification	47	107	Mixed cropping and intercropping to increase number of crops on the same piece of land; local crops and varieties.
Improved crop variety	93	213	Replaced local rice, maize and wheat varieties with improved and hybrid varieties with drought-resistance, early maturity.
Irrigation	48	109	Pumping underground water and canal irrigation.
Chemical-based agriculture	95	217	Application of inorganic fertilisers, pesticides and herbicides.
Income diversification	41	94	Wage labour, skills-based work outside agriculture
Migration	31	70	Seasonal and permanent migration elsewhere in Nepal, and to India and overseas.

Note: Calculation based on the household survey with some information from focus group discussions, n=229

The above listed agricultural strategies are not solely for climate change adaptation, but also to increase yield. The use of chemical inputs (seeds, inorganic fertilisers) and change in cropping patterns (shifting maize cultivation from summer to winter-spring) were the most common strategies of farmers to increase production, food security and climate change adaptation. Improved and hybrid rice is resistant to heat and has a short growing period, so does not suffer post-monsoon. Maize cultivation after rice harvest has increased land productivity and income, but replaced leguminous crops (lentil, pea) in the cropping system.

Intensive rice–maize/wheat has increased the use of inorganic fertilisers and herbicides that increase emissions from agriculture. The early transplantation of rice, crop diversification through mixed cropping, cultivation of local landraces and associated cultivation techniques were associated with adaptation to climate change. Local crop landraces, cultivation technology, and knowledge systems play an important role in changing modern agriculture practices. Landraces can be used for crop improvement through breeding and biotechnology. The traditional cultivation practices, such as mixed cropping, relay sowing as well crop protection provide a basis for technological improvement. There is a potentiality of investigating possible contributions of traditional rituals and practices in modern agriculture. Various traditional and local agricultural practices prevalent among Tharu are described in section 6.4.3 (riverbed vegetable farming) and Chapter 7.

6.4.1 Adoption of modern agriculture as an adaptation strategy

Adoption of modern agriculture inputs and technology is one of the most important adaptation strategies, but there are also interconnections between modern inputs and technology and Indigenous/traditional knowledge in the form of knowledge integration— hybrid knowledge. Although adoption is concerned with the incorporation of new innovations, technologies and practices over time, it is also related to adaptation through innovative technology and practices (e.g., high-temperature and flood-resistant crop varieties). Adaptation practices are developed from past experiences, which may not be applicable for innovations in a new place or amongst different people (Rogers, 1958; Zilberman et al., 2012). Therefore, adoption is becoming an important strategy for climate adaptation in agriculture through the use of improved crop varieties, agronomic management (e.g., crop rotation, adjusting sowing dates) and forecasting (weather, insect/disease) in agriculture (Bhatta & Aggarwal, 2015; Nelson et al., 2009; Shen et al., 2010; Speranza, 2010). The cultivation of various locally adapted crop landraces also becomes an important strategy together with modern agriculture which is described in Chapter 7.4.4 (Table 7.6).

The adoption of modern agriculture, particularly crops, varieties and irrigation technology that allow changes to the crop calendar and cropping patterns, is an important way to adapt to climate change. Irrigation is the most critical factor for the early cultivation of rice crops in the area. Improved and hybrid rice varieties are not only high yielding, but also resistant to heat, drought and floods. The use of herbicides and introduction of farm machinery (tractor, ripper/harvester, and thresher) have reduced production costs by cutting labour inputs.

Agricultural adaptation strategies in the Thapuwa and Bikri villages in response to climate change were analysed and graphically represented in Figure 6.3 (irrespective of the size of land ownership) and Figure 6.4 (size of land ownership). The percentage of farmers using hybrid crop varieties (95%), pesticides (25%) and herbicides (50%) was significantly higher in Thapuwa than Bikri (Figure 6.3), but there was no significant difference in those using inorganic fertiliser (>95%). It is noted that the use of hybrid seeds are mainly in major cereal crops (rice, wheat and maize) with smaller proportion of land (less than 50%), whereas traditional varieties are cultivated in minor crops (e.g. lentil, mustard). The use of herbicides and pesticides is increasing, particularly in Thapuwa. Herbicides are mostly used by large landholders in wheat crops and some rice crops. Pesticides are mostly used in vegetable crops upon high invasion. Various preventive measures using local materials and knowledge are applied before adopting chemical measures.

When the agricultural adaptation strategies were analysed based on the size of land ownership, the use of hybrid seed, inorganic fertilisers, herbicides, and irrigation equipment increased with increasing size of landholding, while pesticide use decreased. The number of households is a key basis for major defining events in the adoption of new agricultural practices, such as inputs and machinery. The higher use of pesticides by smallholders might be to protect their small production, whereas large producers can adapt to small reductions in yield. Small and medium holding farmers also cultivate vegetable crops to sell in the market that often require insecticides and fungicides. Large farmers also cultivate specific local varieties of rice for home consumption that require low chemical inputs. Even when large landholders have low production in a season, the total quantity of rice should be enough for their food security.

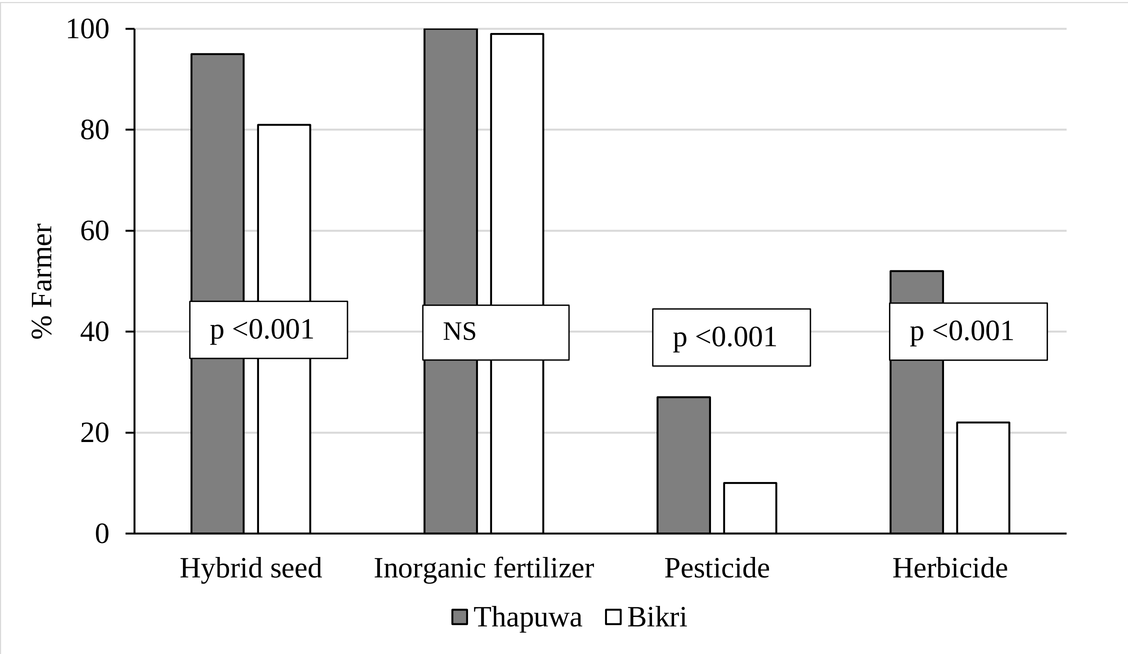


Figure 6.3 Adoption of agricultural inputs compared in the study villages

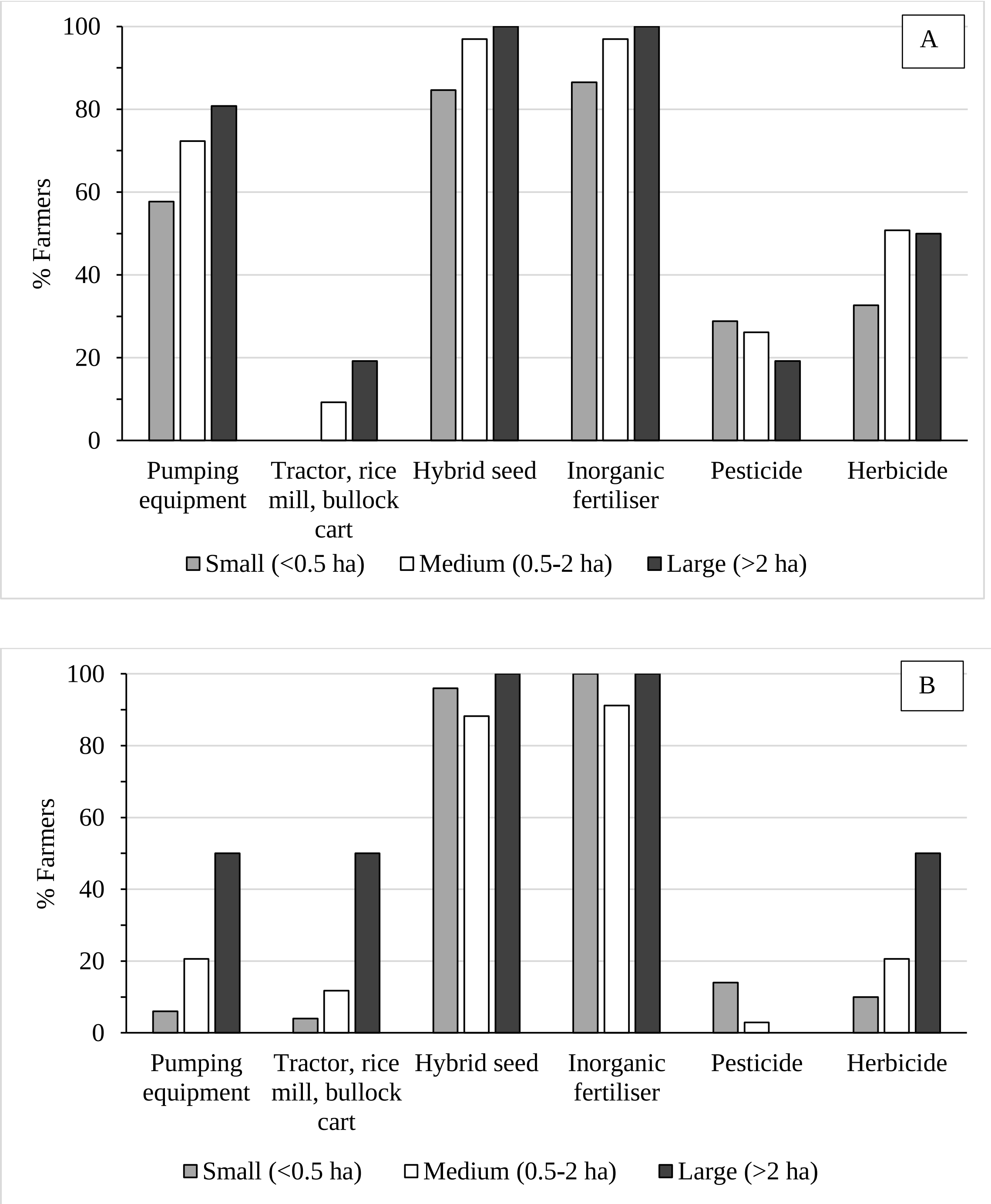


Figure 6.4 Ownership of equipment and agricultural input use by land holding size in (A) Thapuwa and (B) Bikri

Improved crop varieties are increasingly used to adapt to climatic variability and obtain high yields. The cultivation of hybrid rice varieties, such as Arize–6444 Gold and US–312, has increased in the villages, particularly Thapuwa. Farmers can produce hybrid rice within three months, which allows them to cultivate wheat, lentil, and other winter crops as succeeding crops. Two improved wheat varieties, Kundan and Gautam, are popular among farmers. Similarly, Decalb and Bisco series and Kanchan hybrid maize varieties are mostly cultivated by farmers in the winter-spring season.

Water deficit occurred during the season, after the point at which these adaptation measures could be implemented. In Thapuwa, farmers own pumping equipment because they have had no access to canal irrigation. In contrast, few farmers own irrigation equipment in Bikri because they have access to surface irrigation from the canal. Large and medium farmers in Thapuwa mostly own their pumps, while small farmers rent theirs on an hourly basis: Nepali Rupees (NPR) 30/hr (USD 0.25/hr) for electric pumps discharging water of 3 inches volume and NPR 250/hr (USD 2.25/hr) for diesel pumps. Large and medium farmers also own tractors and other farm equipment, such as threshers, rice mills, and bullock carts, because they have the capacity to buy and/or access to financial institutions. It indicates that large and medium farmers have greater adaptive capacity than smaller farmers in both villages. In addition to the contribution of modern agriculture inputs and machinery to modernise agriculture, there is a long-standing contribution of Indigneous knowledge for crop cultivation, protection and post-harvest handling.

Agricultural adaptation strategies and practices, both Indigenous and scientific, are effective at different levels. A combination of Indigenous knowledge and modern agriculture technologies significantly increased major crop production. The farmers' reported yields of the three major crops—rice, wheat, and maize—were analysed to compare yields from the past 20 years (Figure 6.5). In 2017, maize had the highest yield (6.9 t/ha) followed by rice (4.2 t/ha) and wheat (3.1 t/ha). When compared to 1997, maize had the highest yield increment (3.94±1.88 t/ha) followed by rice (3.16±1.73 t/ha) and wheat (2.37±1.4 t/ha). The yield of all crops had significantly increased since1997.

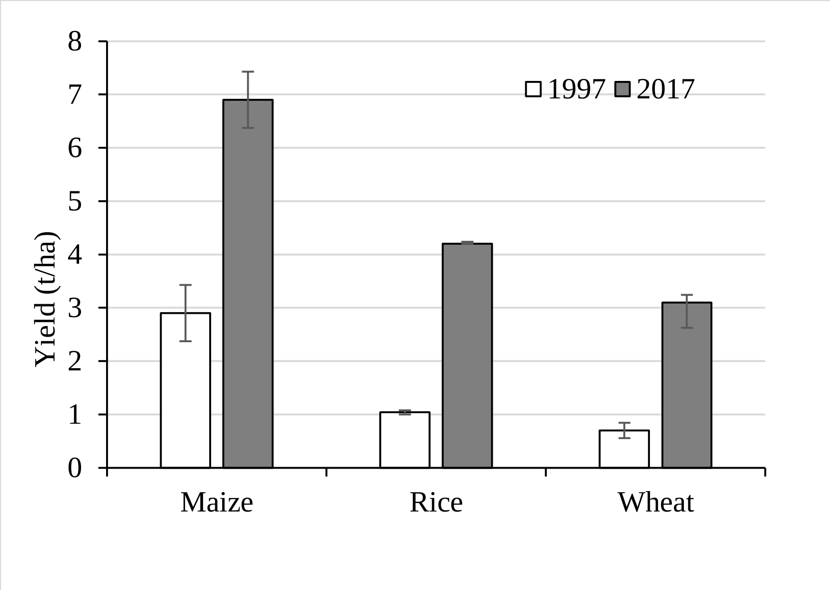


Figure 6.5 Comparative yield of major crops in the two study villages in 1997 and 2017

Various factors can increase crop yield, including irrigation, inorganic fertiliser use, and farmer knowledge and experience, but the most important is the use of high-yielding crop varieties. Bharose Tharu said, “I have the same piece of land granted from my father, but the yield is increased by three times in maize and two times in rice and wheat than in my father’s time. It is because of hybrid seed, irrigation facilities and use of inorganic fertiliser.”

6.4.2 Crop protection as an adaptation strategy

Traditional agriculture by the Tharu is environmentally friendly. Crop protection from insects, diseases and weeds is based on an ecological approach and the interrelationships between plants, animals and humans using Indigenous techniques, ritual-based practices and physical control. Many rituals such are still performed by the Tharu to protect crop, livestock and peoples in the villages. *Hareri* is performed each year after transplantation of rice for green and productive crops. Similarly, the Tharu also perform *gaiya berhna* and *magha lotna* to request rain from the god Mahadeva (details in Appendix 10). There has been a gradual shift towards intensive agriculture through improved/hybrid crops, chemical inputs, and farm machinery. However, the Tharu still practise eco-friendly methods related to crop protection and post-harvest storage. Weeds are mostly removed manually in the first month of crop growth so that weeds do not dominate crops. Weeds from the fields are an important source of feed to the livestock. The use of pesticides and herbicides remains low and only for limited crops.

The most common insects and diseases of cereal crops reported by farmers in Thapuwa and Bikri are summarised in Table 6.7. The use of chemical pesticides is a recent trend (10–15 years) at the start of off-season vegetable, hybrid rice and maize cultivation in the villages. Pesticides are not used in pulse crops or other minor crops, such as mustard. Farmers use appropriate varieties, management practices, and early harvest techniques rather than pesticides. Although farmers practice Indigenous knowledge-based as well as scientific techniques to manage insect pests, diseases and weeds, the understanding and use of local resources (e.g. botanical pesticides) is decreasing due to the ready availability and quick effect of inorganic pesticides/herbicides. Furthermore, the education system places less emphasis on local knowledge in comparison to scientific knowledge.

Dithane M–45 (DM–45) is a commonly used fungicide in potato crops to protect from late blight disease, especially in winter when there is frost at night and foggy days. They call it *palak dawai* (medicine for frost).

Table 6.7 Common insect pest and diseases with local management practices

Insect and disease	**Local name**	**Crop damage**	**Local management practice**
Insects			
Gandhi bug (*Leptocorisa* spp.)	Gandhi	Sucks milky sap from rice panicles	Gandhi removal ritual, tyre burning, women walk in the fields during menstruation
Armyworm/swarming caterpillars (*Mythimna separata*)	Fauji Kira	Cuts rice panicle in the night of nearly mature rice, problematic in flood years	Early harvest, irrigation, collect cut panicles

Leaf roller (*Cnaphalocrocis medinalis*)	Pat Beruwa	Eats leaf chlorophyll during early stages of rice growth when there is no water in field and rainfall gap	No need for pesticides; once rainfall starts and rainwater enters the rolled leaf, the insects fall into the water, and birds eat them
Aphid (*Aphidoidea* spp.)	Mahiya	Rice, wheat, maize, and vegetable crops	Ash spray, cattle urine spray mixed with water (1:5) in vegetable crops
Diseases			
Bacterial blight (*Xanthomonas oryzae* pv. *Oryzae*)	Dahiya	Rice	Spray yoghurt mixed with water
Late blight (*Phytophthora infestans*)	Pala	Potato, tomato, onion	Ash spray, Dithane M–45 (Mancozeb)
Zinc deficiency	Khaira	Rice	Khayar tree *(Acacia catechu)* branch pegging in the four corners of the rice field

Farmers are more cautious about insect attacks in hybrid maize than rice, as they are more severe. Pesticide applications for insects and diseases are based on the crop's growth stage and damage status. Farmers realise the need for control measures if symptoms appear in more than 10% of the plant population. The control measures involve various local techniques, including pesticides as a last resort. Various local materials (ash, urine) and plant material (neem/*Azadirachta indica* and bakaino/*Melia azedarach*, bojho/*Acorus calamus*) are traditionally used by South Asian farmers, including those in Nepal (Rivera-Ferre et al., 2013).

Herbicides are used primarily to reduce labour due to family labour scarcity and unavailability of workers during peak agricultural activities. Herbicide costs are 8–10 times cheaper than labour costs. Both pre-emergent and post-emergent herbicides are used in rice, but only post-emergent herbicides are used for wheat and maize. The common weed types found in the area and farmers understanding are described in Chapter 7 (section 7.3.3).

The Tharu farmers use both Indigenous and scientific knowledge—hybrid knowledge—for weed management. The decision to apply herbicides is based on the history of the land and the weed infestation. Farmers use pre-emergent herbicides based on the weed prevalence in preceding years. However, most post-emergent applications are based on direct observations of the weed population. If less than 25% of the land is covered by weeds, then the weeds are removed by hand. The decision making is also based on weed vigour. If the crop is taller than the weeds and the weeds are scattered, then farmers prefer hand removal or even no weed removal. Hand removal of weeds also loosens the soil, and walking on the soil works as inter-tillage for the rice. Within the village, anyone can harvest weeds from any field, so manual harvesting of weed grass is common for livestock. If weeds remain in the field, then farmers will use a post-emergent herbicide.

Farmers are not fully satisfied with the results from herbicide application. Some farmers reported that pre-emergent application of herbicides during rice field preparation reduces rice yield and even affects pulse crops (lentils and peas). Bharose Tharu from Thapuwa declared,

> Last year, I did not use herbicides in rice after five years of regular use. I had a problem with weeds, then started manual hand removal. It took us 22 days in two *bigha* (about 1.25 ha) of land. I couldn't use post-emergence herbicides because it had become too late to spray by the time weeds matured.

Likewise, Binod Chaudhary from Bikri shared,

> A couple of years ago, I had used a pre-emergence herbicide in rice soil that badly affected my succeeding peas and lentils. Crops grew well, but when reaching the flowering stage, they turned yellow and died. I did not get any harvest. After that, I use post-emergence herbicide by spraying mainly in rice and wheat at the early stage.

This suggests that herbicides work well when applied during the early stages of weed growth as they kill whole plants, while applications later in growth only kill leaves, which reappear. Sequential pre- and post-application of common herbicides in a strip-tilled non-puddled rice field is advised because sole pre-emergence use is not effective. However, no residual effect is reported in the next crops (wheat and lentil) (Zahan, Hashem, Rahman, Bell, & Begum, 2018). Similarly, farmers are concerned about the residual effects of herbicide for succeeding crops. Weed problems occur more in upland rice fields (*dadai khetwa*) than lowland rice fields (*jabda*) due to the lack of regular water.

6.4.3 Riverbed farming—a flooding recovery strategy

Riverbed farming is an ex-post coping strategy in flood-affected areas in the Tarai region of Nepal. The river span in the Tarai widens during the monsoon, with the increased flow of water, and contracts after the monsoon. In winter, when the flow is low, much land—mostly sand deposits—is exposed. Riverbed land is not permanent; it shifts subject to the river's ebbs and flows. Farmers that own registered riverbed land must pay land tax, even if their land is unproductive and is part of the river. The unregistered riverbed is public property, and the local government leases it to interested farmers.

Riverbed farming is an innovative, opportunistic approach to cultivate crops in the riverbed, and is a long tradition of Tharu farmers in the Tarai region of Nepal. They cultivate cereals (rice, wheat), and pulse crops (lentil, pea) in the fertile riverbed and watermelon in a limited area. Indian migrant farmers from adjoining districts in Nepal started the commercial cultivation of vegetable crops in the riverbed. Cucurbitaceous fruits and vegetable crops, such as watermelon, bottle gourd, pumpkin, bitter gourd, and cucumber, are grown in the winter-summer season before the onset of the monsoon and floods. Hence, riverbed vegetable farming is not an explicit Tharu Indigenous/traditional agricultural practice, but it is a local practice in the wider community that integrates techniques and inputs from modern agriculture too.

Riverbed farming received support from non-government organisations and later the government of Nepal. The number of farmers (households) and the area under riverbed farming in the Bardiya district of the western Tarai is shown in Figure 6.6. The district had the highest number of farmers and riverbed farmland in 2012 (28 ha), which decreased over the next two years, despite the cultivated riverbed area increasing drastically (32 ha) in 2014; thereafter the number of farmers and cultivated area have declined. The economics of growing crops on riverbed land is shown in Table 6.8. Income from the riverbed is inconsistent due to fluctuating market prices and crop destruction due to early river flooding. The highest average riverbed cultivation area was 0.27 ha/hh in 2014, but the income from riverbed farming was the second lowest (USD 392/ha). The highest total income in terms of household (USD 282/hh) and land productivity (USD 2248/ha) was in 2015 and 2016.

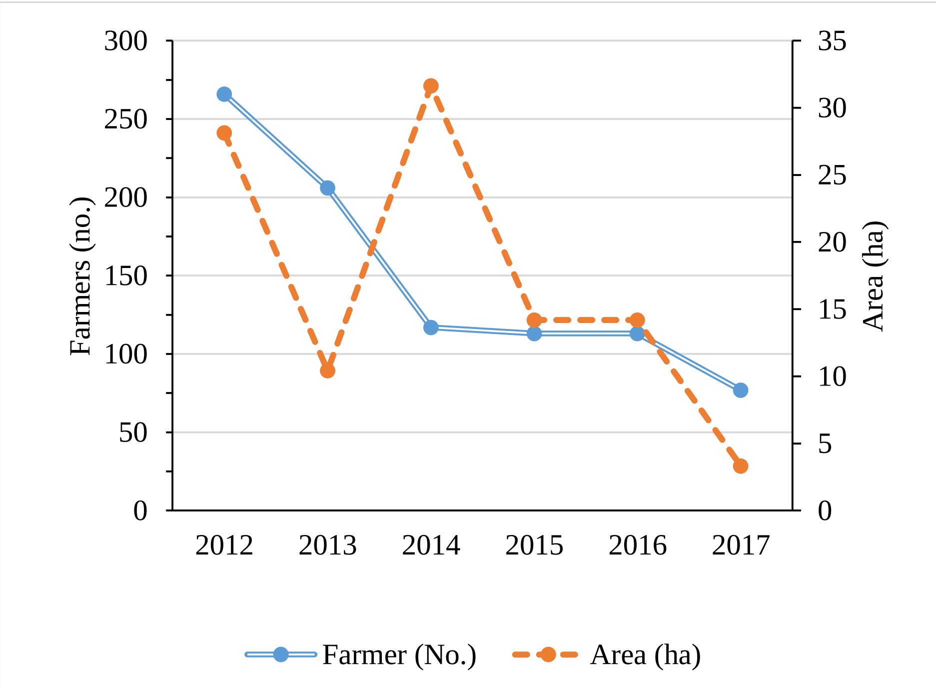


Figure 6.6 Riverbed farming in Bardiya district

Source: Helvetas—Swiss Inter-cooperation, Nepal

Table 6.8 Gross income from riverbed farming in the Bardiya

Year	Riverbed (ha/hh)	USD/hh	USD/ha
2012	0.11	47	442
2013	0.05	53	1044
2014	0.27	106	392
2015	0.13	282	2248
2016	0.13	282	2248
2017	0.04	9	205
Mean	0.11	112	983

ha=hectare, hh=household

Source: Calculated from raw data provided by Helvetas– Swiss Inter-cooperation Nepal

In 2014, government and non-governmental agencies (such as the Micro-enterprise Development Programme (MEDEP)/UNDP, District Agriculture Development Office, and Helvetas Nepal) expanded the riverbed farming projects in the district. The decline in the number of riverbed farmers and cultivated areas was due to a decline in support (financial/technical) and follow-up for farmers. Schiller (2014) argued that riverbed vegetable farming is technically feasible, economically profitable, environmentally friendly, and socially/culturally acceptable, especially for the landless and land-poor.

In the study villages, farmers mostly cultivated pulses (lentil, pea, and pigeon pea) on the riverbed. None of the farmers was growing vegetables in the riverbed although they used to cultivate vegetables in that setting a few years ago. Bhim Tharu, Bikri said:

> Riverbed farming is a risky and labour intensive. My field was in the low riverbed, and there was an unusual flood in the river in March/April, so all my crops died four years ago. I transplanted seedlings again and was able to harvest crops. It's like gambling with high labour investment, so I left riverbed farming and started a retail shop in Shaktinagar village (nearby Bikri).

Phulram Chaudhary from Balapur village reacted:

> Protection of watermelon, both from children and thieves, is one of the hard jobs. Children steal and even wilfully break off many watermelons in the field. I hardly sold any last year since I could not watch it at night, and it is almost 2 km far from my house.

Phulram further added,

> Vegetable farming in the riverbed is profitable in a commercial way, sending produce to the market in early or late season. The timing of floods also dictates the market possibilities for sales. Pre-monsoon flooding damages crops in the fruiting stage. The tillage, weeding, and irrigation are also convenient in RBF, but furrow making in pure white sand requires heavy labour. There are no other viable alternative options to the farmers whose land is riverbed and they are compelled to undertake riverbed farming in a flood-prone area.

Riverbed farming as an adaptation strategy to climate change is limited to landless people and very small farm holders, and presents risks from storms. Riverbed vegetable farming is a strategy to reduce flooding stress and shock in flood-prone areas such as those in the Tarai region of Nepal. Riverbed farming is labour intensive and risky; therefore, mainly landless and small landholders are engaged in such farming. Gurung, Pande, and Khanal (2014) found that riverbed vegetable farming helped to improve the livelihood of small farmers, but riverbed farming has issues related to poor soil quality, livestock grazing, intense storms/flash flooding, and drought. It not only generates cash income, but also contributes to the food and nutrition security of farming families (Gurung et al., 2014; Schiller, 2014; Sharma, Shrestha, & Chaudhary, 2010).

6.4.4 Migration as an adaptation strategy

Climate-induced disasters displace people by destroying their place of residence and source of livelihood. Displacement can become unmanageable, making people “environmental refugees” at the domestic and international level (McLeman & Smit, 2006; Perch-Nielsen, Bättig, &

Imboden, 2008; Koko Warner, Ehrhart, de Sherbinin, Adamo, & Chai-Onn, 2009). Many households in Thapuwa have been flooded several times and been forced to shift their houses to safer, less flood-prone locations. In contrast, at least eight households in Bikri shifted to the forestland due to the lack of available safe residential land.

Individual outmigration in domestic and foreign labour work is an important strategy for poverty and shocks relating to climatic extremes. Migration is becoming an increasingly important source of income diversification in rural farming communities, including among the Tharu in the western Tarai, Nepal. Normally, the household head and youth enter the labour market either in local, domestic cities or foreign countries. Foreign labour work is mostly permanent and long-term (at least 2–3 years), whereas domestic labour work is mostly during the lean agriculture season. Seasonal labour employment within Nepal and India and the recent trend of foreign labour is shown in Table 6.9. Most seasonal labour workers from Bikri work in house construction, whereas youth from Thapuwa are engaged in carpentry and blacksmithing.

International youth labour migration is a new dimension, which is more prevalent in Bikri (32%) than Thapuwa (7.5%). Malaysia is the most popular destination, attracting 58% of the foreign labour workers from these villages. Salaries range from NRs 25,000 to 45,000 per month (USD 210 to 378) in foreign countries and 8,000 to 16,000 per month (USD 75 to 150) in Nepal and India.

Migration, particularly seasonal migration, contributes positively to the adaptive capacity of households. Youth earn an additional income on top of their regular farming by entering into the local/domestic labour. They enter into non-agricultural labour work once they complete the cultivation of rice and often return home for its harvesting and storage. However, permanent migration to India and foreign labour work reduces adaptation in agriculture because it detaches youth from agriculture and has left women and elderly people to work on farms. Women are culturally restricted in performing some of the agricultural activities, such as ploughing and rice field preparation, and this creates a labour shortage in agriculture.

Table 6.9 Labour force participation in domestic and foreign employment

Study village		**Local casual employment**	**Foreign employment (India)**	**Foreign employment (other than India)**	**Total**
Thapuwa	%	85	7.5	7.5	100
	n	80	7	7	94
Bikri	%	60	8	32	100
	n	32	4	17	53

The migration pattern differs based on landholding size (Figure 6.7). Small farmers are mostly engaged in seasonal migration to cities in Nepal and India for work, whereas medium farmers head overseas for migrant work. Large farmers tend to migrate less, as they have social networks, information and a good financial situation for education and jobs in Nepal. Studies have shown that positive human capital (education, skills) and income level determine the level of migration and income (Borjas, 1987, 2008). Mosse, Gupta, and Shah (2005) found that the seasonal migration of *adivasi* in India is locational (land and poverty) rather than occupational.

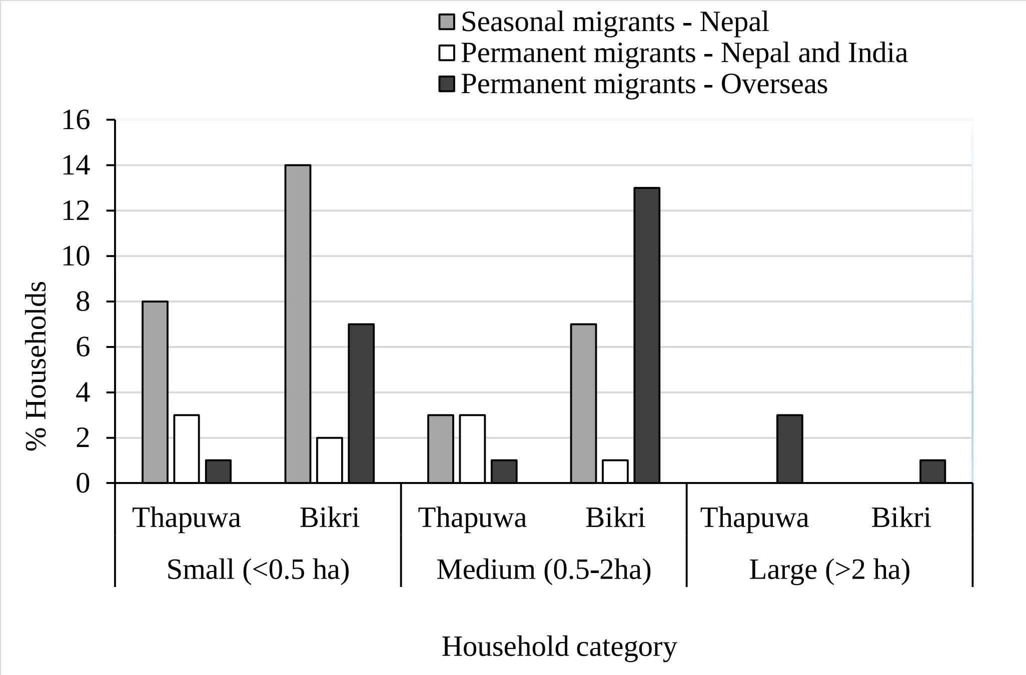


Figure 6.7 Migration scenario of households by landholding size in 2017–2018

Remittances (money from overseas, mostly migrant workers) constitute a major component of the Nepalese economy, contributing 24.9% GDP (NPR 755.1 billion, USD 6.9 billion) in 2017/18 (MoF, 2019). According to the Nepal Living Standard Survey Report 2010/11, 56% of households in Nepal received remittances, and the trend is increasing (NPC, 2011). Some critics argue that male outmigration has been feminising Nepalese agriculture by increasing the workload of women and the elderly left at home (Gartaula, Niehof, & Visser, 2010; Gartaula, Visser, & Niehof, 2012). Furthermore, women practice less intensive agriculture and leave fallow land that implies food insecurity (Tamang, Paudel, & Shrestha, 2014). Sunam and Adhikari (2016) suggested that remittance increases food security in the short-term by allowing the cultivation of land by tenants in the Tarai, but in the long-term, they erode food sovereignty because they increase food imports and reduce land productivity due to fragmentation and land alienation.

6.5 Mitigation strategies

Mitigation and adaptation are interrelated; therefore, the actions for one influence the other. This section explains the links and contributions of various adaptation practices to mitigation and those of some specific agriculture practices contributing to mitigation. The section also demonstrates how post-harvest management and the low energy-intensive lifestyle of the Tharu help to prevent emissions from agriculture.

6.5.1 Improving farmyard manure

Livestock, particularly cows and buffaloes, have made an important historical contribution to the Nepalese farming economy. The Tharu are a farming community and cattle are an integral part of their farming system. The ox is used for ploughing and pulling light carts, and male buffalo are used for heavy tillage and heavy cart pulling. Milk from cows and buffalo is a source of nutrition. In the rural economy, herd size used to be determined the wealth of the family. Cattle and goats remain bride wealth, as an index of important property in the Tharu community. The cows are a strong and hardy local breed adapted to the local climate, but their milk production is much lower than improved breeds. Oxen draft tillage and cart pulling have been gradually replaced with tractors.

Farmyard manure is embedded in Tharu society. There is no fertiliser better than farmyard manure for maintaining soil health. Inorganic fertiliser application remains low, but most households (>90%) use some for rice, maize, and wheat cropping. The number of farmers using inorganic fertiliser in Thapuwa and Bikri did not differ (Figure 6.3), but the amounts used significantly differed (Table 6.10). Inorganic fertiliser use was highest for rice (309 kg/ha, 100:70:37 NPK) followed by wheat (287 kg/ha, 92:67:9 NPK) and maize (286 kg/ha, 98:63:45 NPK) in both villages. Thapuwa farmers use significantly more inorganic fertiliser for the three major crops (rice, wheat and maize) than their counterparts in Bikri (Table 6.10). There is the possibility of increased inorganic fertiliser use in Thapuwa village near the Indian border area due to the informal—unregulated supply. Inorganic fertilisers are not replacing farmyard manure (FYM), but FYM has become unavailable with the decrease in livestock population (particularly cows) is responsible for its increasing use.

Table 6.10 Inorganic fertiliser use in Thapuwa and Bikri

Crop	Village	Frequency (no.)	Mean fertiliser use (kg/ha)	Std. error mean	P-value
Rice	Thapuwa	133	309 (100:70:37 NPK)	6.4	0.000
	Bikri	80	104 (31:25:15 NPK)	8.0	
Wheat	Thapuwa	120	287 (92:67:9 NPK)	5.6	0.000
	Bikri	71	93 (32:27:41 NPK)	6.5	
Maize	Thapuwa	75	286 (98:63:45 NPK)	12.3	0.020
	Bikri	1	30 (14:0:0 NPK)	NA	

NA: not applicable; Urea (46% N), Diammonium phosphate/DAP (18% N, 46% P_2O_5, and Murate of Potash (60% K_2O).

Farmyard manure and other organic matters are considered important sources of soil nutrients. The Tharu practice surface-piling of farm manure in the open near to the cattle shed for annual field application in April–May at the start of the agricultural season. The association of FYM with GHG reductions is not straightforward. The use of farmyard manure reduces inorganic fertiliser use, and thus reduces nitrous oxide (N_2O) emissions, but it can increase methane (CH_4) and N_2O if prepared inappropriately (Amon, Amon, Boxberger, & Alt, 2001). Hence, the traditional practices need to be modified with scientific knowledge to further reduce emissions. The surface-piling method creates anaerobic decomposition, thereby emitting higher CH_4 and N_2O emissions than aerobic decomposition in the shade (Amon et al., , 2001). The Tharu people distribute farmyard manure in small heaps in the open field and leave it for 1–2 weeks without mixing with soil (Figure 6.8 A, B). The early incorporation of farmyard manure in the soil reduces nutrient loss and reduces GHG emissions (Amon et al., 2001). Traditional farmyard manure and compost preparation can be improved by using a dome digester to reduce anaerobic fermentation in manure, which can reduce emissions by 0.62 t CO_2 -eq/m^3/yr (Pradhan, Shrestha, Hoa, & Matsuoka, 2017).

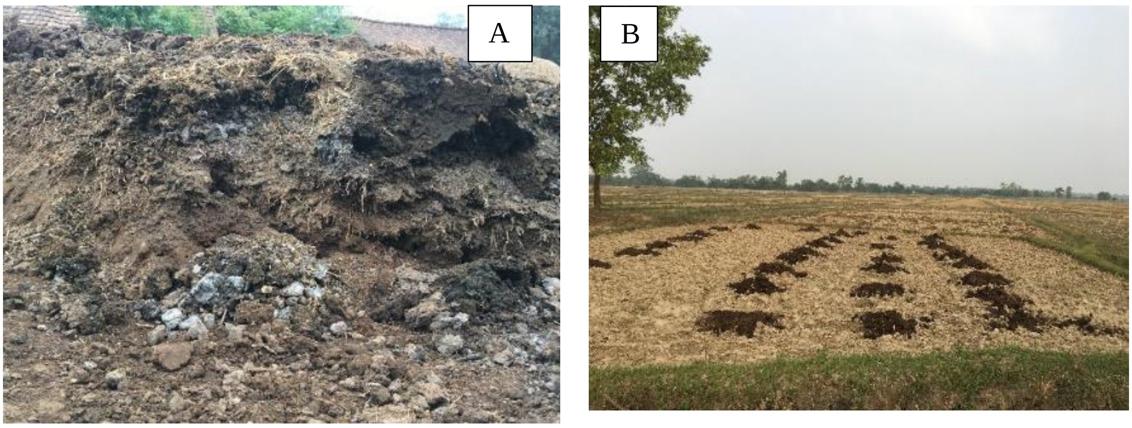


Figure 6.8 Farmyard manure (A) traditional method of preparation and (B) field application method

6.5.2 Agricultural practices contributing to mitigation

Various agricultural practices contribute to reducing GHGs emissions and indirectly prevent intensive energy use, thereby contributing to mitigation, including relay sowing of lentil in standing rice crops, no-tillage/zero-tillage of garlic (sowing garlic into harvested rice stubs) and zero-tillage (ZT) of winter crops (lentil, pea) with one-time minor tillage. Various traditional adaptive agricultural practices are detailed in Chapter 7. These practices reduce tillage energy and use no/low inputs (inorganic fertilisers, herbicides and pesticides). In the study villages, about 45% of farmers undertake relay sowing of lentil. Zero-tillage garlic is more prevalent in Thapuwa (90%) than Bikri (50%). Pokhrel and Soni (2018) claimed that ZT reduces energy use by 34% in lentil and 11% in garlic and reduces CO_2 -eq (carbon dioxide equivalent) emissions by 50% in lentil and 98% in garlic, compared to conventional tillage.

Similarly, the use of organic mulch in potato, garlic, and other winter crops prevails in farming. The mulch adds organic matter to the soil, conserves soil moisture, suppresses weed germination and increases garlic bulb size (Kabir, Rahim, & Majumder, 2016). Mulching in conservation agriculture, together with crop rotation and ZT reduces GHG emissions by 10–15%, in rice–wheat systems in South Asia (Sapkota et al., 2015).

Methane emissions from wet rice farming is a major challenge for climate change mitigation in agriculture. The traditional practice of direct-seeded rice (DSR) in dry seedbeds as well as wet seedbeds (puddled fields) is still practised in the Tharu community. Dry bed DSR reduces methane emissions, thereby contributing to climate change mitigation. In addition to the alternate wetting and drying techniques of rice cultivation for reducing methane emissions described in Chapter 3, there are promising findings using non-puddled techniques for rice field preparation in Bangladesh. A non-puddled rice field is prepared in the flooded field in strips or ridges using a zero-tillage machine that leaves less residue. The method produces similar yields to the puddled method, but reduces emissions by 29% with lower production costs and irrigation requirements (Alam et al., 2019; Alam et al. , 2016; Haque, Bell, Islam, & Rahman, 2016).

6.5.3 Reducing post-harvest loss

Post-harvest grain losses from harvesting, threshing, drying, and storage are a problem in the Tharu community. Field losses due to birds, field rats, wild animals (monkey, wild boar) are considerable. Grain storage in *dehari* is common, but it is not completely free from storage pests (rats, insects) and mould if the *dehari* is frequently opened or not airtight, or the crop is not properly dried before storage. The loss of stored grains is high in flood-hazard villages, such as Thapuwa and Bikri.

Fresh vegetable and fruit losses are nominal in the kitchen of the Tharu. The Tharu believe that no one is higher than food, *anaj se bhari nahi*! Cooked food losses are almost zero. Food left from lunch and dinner is used for *mijhni* (afternoon food) and *basi* (morning food), respectively, or to prepare *jaar* (local rice beer and liquor). Food losses from the table are determined by various sociocultural factors such as family income, family size, demographics, and culture. In general, a small, high-income family with young members wastes more food than a low-income family (Parfitt, Barthel, & Macnaughton, 2010).

There are various traditional methods of storing perishable and non-perishable commodities that save energy. Fresh vegetables are dried and stored for lean vegetable seasons. Potato is one of the most important vegetables, and the Tharu have a particular technique of storing potato for seed. The selected seed potato is air-dried and wrapped in rice straw, plastered with cattle dung, and hung in a shady open place. The storability of the local variety of potato (Tharu *alu*) is better than the improved varieties. With the adoption of improved potato varieties (such as true potato seeds/TPS, Cardinal), post-harvest losses have increased when the Tharu techniques of seed potato storage are used, so farmers prefer to store seed potato in cold storage in the local towns (Kohalpur and Shitlabazar). The traditional technique of seed potato storage continues in rural areas among smallholders; however, there is a possibility of further decrease in cultivation of the local variety of potato.

6.5.4 Using sustainable renewable energy sources

The livelihoods of rural people in Nepal, including the Tharu, are largely dependent on the forest for wild food, house construction materials, fodder and basketry. Community forest management in Nepal is considered a success story worldwide, where Tharu have managed high-value tropical forest species such as *sakhuwa* (*Shorea robusta*). The traditional houses of the Tharu are constructed mainly from forest materials, such as *Kush* (*Desmostachya* sp.) and *kans (Saccharum spontaneum)* grasses for thatching, *bankash (Eulaliopsis binata)* for rope, and elephant grass for house walls and timber frames. The use of renewable forest resources is linked to the low energy-intensive lifestyle of Tharu that contributes to climate change mitigation (IPCC, 2007, 2014b). However, Tharu house construction is rapidly transitioning to concrete with the use of brick, iron, cement, and roofing with tin. The household survey revealed that almost three-quarters (72%) of house walls are now made of brick and most roof structures are covered with tin (55%) or clay tiles (37%). Most of the house floors (87%) are still plastered with straw, mud, and fresh cattle dung.

Firewood is a major source of kitchen energy for cooking and warming houses (Table 6.11). When firewood is scarce, dried cattle dung is used in the kitchen, which reduces the amount of manure available for agriculture and causes health issues due to the thick smoke in the kitchen. There are many projects for renewable energy, such as biogas from fresh cattle dung, solar energy, and improved stoves, but their application is limited to a few houses. In Thapuwa, people burn firewood in combination with cattle dung, since the villagers do not have a community forest. A few houses (<5%) use liquid pressurised gas (LPG) in the kitchen for cooking small quantities of a few food items, mostly during busy times and guest visits. Nuclear families with non-agricultural jobs and businesses use gas in the kitchen.

Table 6.11 Kitchen energy sources in Thapuwa and Bikri

Energy source	**Thapuwa (n=143)**	**Bikri (n=86)**
Firewood	143 (100)	86 (100)
LPG gas	4 (2.8)	0 (0)
Biogas	9 (6.3)	5 (5.8)
Cattle dung	40 (28.0)	0 (0)

Note: The above resource used in combination with firewood and others. Figures in parentheses are percentages. The sum of the percentages is more than 100 because of household use of multiple energy sources in the kitchen.

In my observation, apart from wild food consumption, the Tharu have a culture of using plant leaves as dishes (plates) in the kitchen. The leaves of *kachari (Holarrhena pubescens)*, *sakhuwa* (*Shorea robusta*) are readily available in the community forest of Bikri. Leaves such as *sakhuwa* and *namarain (Bauhinia vahlii*) are considered holy and used in *puja* (rituals and ceremonies). The leaves of banana and *purain/ lal Kewla* (*Nelumbo nucifera***)** are used for big gatherings, such as marriage, deaths and other feasts in the community. Leaf plates reduce the use of plastic plates and used leaf plates can be used as organic material for farmyard manure preparation. Thus, the benefits of a leaf plate culture are two-fold for climate change mitigation—saving energy from plate production (plastic, ceramic) and promoting farmyard manures.

6.6. Constraints and limits of adaptation

6.6.1 Constraints/barriers of adaptation

The constraints and barriers mentioned here are widespread in the western Tarai, Nepal. Constraints make it difficult to plan and implement adaptation/mitigation, whereas barriers reduce the options for adaptation or mitigation. Since both constraints and barriers hinder adaptation and mitigation, the terms are used interchangeably. Five main constraint categories for climate change adaptation and mitigation were identified in the Tharu: low productivity, small landholding, limited information and services, cultural barriers, and youth migration.

Low productivity

Local crop landraces are hardy, tasty, and adapted to the local environment, but many are lower yielding than improved varieties. "The local rice and lentil curry are mixed-up well, but it is even hard to mix *dal* (cooked lentil curry) with hybrid cooked rice," said Ram Kumar Tharu. Many women expressed views such as: "I do not give up the cultivation of sweet glutinous Andi rice, because it's tasty, produces more rice beer (*jaar*), and is needed to offer to our goddess." Aside from taste, small and medium farmers must ensure their food security and maintain their household expenditure. Hence, high-yielding hybrid crop varieties are becoming important. Farmers are producing 2–4 times higher yields than in the past, as a result of improved/hybrid seed and the agricultural inputs discussed earlier (Figure 6.5).

Small landholding size

Farmers in Nepal are smallholders, with about 53% of farmers operating on plots of <0.5 ha per family (small farmers) and only 4% of farmers owning >2 ha of land (large farmers) (NPC, 2011). The average landholding is 0.68 ha per family (CBS, 2011b). In general, landholdings in the Tarai are relatively large, but most Tharu have small landholdings for various reasons, including large family size. Land is mostly transferred to sons in the Tharu and Nepali patriarchal society. In both study villages, the number of small farmers with <0.5 ha/household is high (45%). There are 19 households of *mukta kamaiya* (former bonded labourers) in Thapuwa with just 2 *kattha* (0.1 ha). Few families own land >2 ha (12%), with most in Thapuwa (26 of 28). The small landholdings and dependency on agriculture compel them to rent land in *bataiya* (share cropping). *Bataiya* tenants are further exploited through equal sharing of agricultural produce (*adhiya bataiya,* half-half sharing of production) from the *tikur bataiya* (2 parts of production to tiller, 1 part to landowner) or *chaukur bataiya* (3 parts of production to tillers, 1 part to land owner).

Bataiya land tenure has persisted among the landless Tharu as *asami* (tillers) of *jimidar* (landlords) in the western Tarai, Nepal. It is an exploitative form of the land tenure system, where tillers are physically, financially, and socially exploited and stigmatised. Many sharecroppers had become trapped in the *kamaiya* bonded labour system that was abolished in 2000. Tillers had to serve free labour to the *jimidar*, and were not allowed to migrate from the village, said Shalik Ram Tharu. *Asami* had to pay *kanbhara* (1 male goat, 1 mat, 1 locally made chair called *machya*) to leave the village of the *jimidar*.

Leasehold contract farming is not common in the villages. The cash lease rate ranges between NPR 30,000–40,000/ha/year (USD 250–350). In my analysis of the adoption determinants, land holding had a significant positive relationship with the adoption of improved agricultural practices. Smallholders have pressure to increase production for food security, yet they are slow to adopt new technology and practices; so that they rely on non-farm related activities to fulfil the household's daily needs. The financial constraints to procure seeds, irrigation, and labour reduce adaptation activities in agriculture. Kailash Tharu, whose wife has suffered from a long-term illness since last year, sold his draft bullock, is indebted and now bankrupt, and unable to consider hybrid rice or inorganic fertiliser use. Small farmers can cultivate hybrid seed using available credit and non-farm sector income. Small farmers rely on short-term planning for food security and income to fulfil household needs rather than longer-term sustainable agricultural practices that contribute to climate change mitigation.

Limited information, credit and services

Information on weather, markets, and credit is important to undertake appropriate adaptation action in agriculture. Unreliable weather information can increase production costs and delay sowing. Farmers are often confused about when to establish rice seedlings for timely rice transplantation. Early-season rice transplantation may need artificial irrigation through pumps, which significantly increase the costs. Irrigation costs can be saved by a reliable rainfall forecast. More than 90% of farmers stated that weather information is reliable and continuous; however, the intensity and duration of rainfall forecasting is often inaccurate.

Farmers in the villages had limited information and access to credit, technical services and market information. The local government fixes the selling price of major agriculture commodities, such as rice in the districts, but many farmers complained about not getting the stated price. Big farmers (>2 ha land) sell their produce directly to local collectors in the cities and can sell based on the current market price, while small farmers end up with lower prices than the government announced.

Farmer access to credit is limited mainly to savings groups and cooperatives. The survey revealed that 72% of households have formal and informal access to credit facilities. Most (56%) have access to their savings through the group, and 4% have access to local cooperatives and banks. The amount of credit from the savings group is small and often used for non-agricultural expenses, such as medical treatment, social ceremonies (marriage, funerals) and migrant workers. The diversion of cash from agriculture to other sectors reduces adaptation options and actions.

In terms of agricultural extension services, government outreach to farmers has been reduced with changes/adjustments in the institutional and governance system. Various sectoral offices, including agriculture, are processing new institutional arrangements under the local government, creating misunderstandings between extension staff and farmers. A government extension representative told me,

> Extension staff are reduced, but the command area is almost the same, so how can we [agriculture technicians] provide a good service to farmers? I am a single person for the entire Gulariya municipality, which is not possible for me. I have administrative tasks, including attending official meetings, so that I hardly have time to visit the farmers.

The household survey result showed that 79% of farmers received agriculture and livestock services either from the government or the private sector. However, private sector services mostly focus on selling inputs rather than providing technical services. Two animal-health workers in Bikri provide basic door-to-door services for livestock, such as castration and medication.

Cultural barriers

The transformation of Tharu cultural institutions into state-designated institutions and governance mechanisms reduces social accountability. The group approach exemplified by the government of Nepal organising individuals into interest groups such as cooperatives, often does not operate smoothly in Tharu communities. Traditionally, the Tharu have the *barghar* institution (village head/social leader) that binds villagers in a community and operates various community systems, such as *guruwa* (shamanism) and *kulapani* (irrigation). The *barghar* system operates in agricultural activities and village rituals involving community participation without wages' payment (called *begari*). The village ritual ceremonies are also performed to ensure healthy and productive crops, livestock and villagers. The group approach is an officially recognised process for social and economic transformation in the village that lacks the role of *barghar*. The state law and policies do not recognise the Tharu Indigenous institutions, although there is informal support of the *barghar*. The group approach is also a substitute for the family-based traditional institution. A family and relative-based cultural group "*gotiyar*" has family ties and accountability; members help each other in different social (ceremonies and functions) and economic activities (house construction, agriculture work), which is lacking in the current modality of group formation based on common objectives.

The gap in accountability and financial transparency ultimately terminated the new approach based upon interest groups. In both villages, I heard several such stories of groups discontinued due to the inability to obtain debt repayments from members and lack of financial transparency (corruption) by executive members. For example, villagers in Bikri started pig farming in 2009 under the Bhawani livestock cooperative with the support of the district livestock service office (DLSO). It was running well with the sale of improved baby pigs and pigs for meat purposes. Within five years, the management committee of the cooperative mismanaged the income, so the cooperative is no longer functioning due to the elite capture of benefits. Even those who are educated and social leaders are not immune to corruption.

Traditionally, the Tharu work for the community in such schemes as road building and maintenance and infrastructure without seeking external support. Due to the lack political networking and linking social capital the Tharu could not prioritise projects for the village to reduce climatic hazards (flooding, drought, road, community infrastructures). The political and bureaucratic system has made significant efforts to mainstream the disadvantaged and excluded groups/societies, but stronger commitments and continuous efforts are needed.

Youth migration flux

Government policy and programs encourage youth into overseas employment, which has a negative impact on agriculture. The disengagement of youth from agriculture has compelled elderly people and women to work in agriculture. Traditionally, the Tharu are relatively immobile people; they rarely migrated from one village to another except in search of farming land or by forced migration due to the exploitation by *jimidar*. This relative immobility contrasts with other groups in Nepal, who moved to India from the hills and mountains of Nepal in search of food security and even to trade in India and Tibet/China. In recent decades, youth from the Tharu community have migrated seasonally to different parts of Nepal, India and overseas due to the small landholdings, which cannot support their changing livelihood needs.

Migration has diversified household incomes, but concurrently reduced the agricultural workforce available. In the absence of youth, older people and women are responsible for agriculture, which has implications for food security (Seddon, Adhikari, & Gurung, 2002; Sunam & Adhikari, 2016; Tamang et al., 2014).

6.6.2 Limits of adaptation

There are no hard (i.e., irreversible/immutable) limits for climate adaptation in the study villages, Thapuwa and Bikri. Adger et al. (2009) described the social/cultural limits of adaptation and argued the non-existence of immutable (irreversible) limits of adaptation. Flooding risks in riverbed farming, expansion of agroforestry, and deficits in canal irrigation were identified as soft limits for adaptation, where adaptation may be possible, but may not be cost-effective.

Flooding risks limit riverbed farming

Riverbed farming is a post-disaster adaptation strategy on agricultural land that is periodically destroyed by changing river flows. The return on invest on innovative riverbed farming is profitable, but it is a risky enterprise. Despite off-season production and income from vegetable production, there are risks associated with flooding during the crop period. Upland and safe riverbed selection for farming can reduce the probability of flooding. The availability of the riverbed and its quality depends on the river course and requires high labour investment to prepare trenches and furrows for vegetable crop cultivation. Therefore, riverbed farming could be a temporary and risky coping strategy for reducing flood and drought shocks in the region.

Agroforestry expansion limit

Agroforestry competes with agriculture, especially among smallholders. Due to the small landholdings, agroforestry and horticultural trees have not expanded in Thapuwa despite the lack of access to national/community forests, whereas in Bikri villagers have community forest—Bhawani community forest Most large landholders (>2 ha) have fruit orchards and other trees species (sisso, teak, poplars), but smallholders have limited opportunity to plant trees. However, some have planted multipurpose trees, such as bakaino (*Melia azerdarach*) and ipil ipil (*Leucaena leucocephala*) for animal fodder and household fire energy.

Irrigation water deficit

As tail-end users, Bikri villagers do not always receive irrigation water during rice transplantation; there are no other options for irrigation water without improving irrigation canals or increasing water volume in the main irrigation canal. Upon completion of the ongoing Bheri-Babai diversion project, there should be an increased volume of irrigation water in the existing irrigation project.

6.7. Conclusion

The Tharu in the western Tarai of Nepal have witnessed biodiversity losses, extinction of some species, and changes in the ways of farming. They understand the reasons behind such changes to be climate change in conjunction with population pressure, economic needs, food security drivers and the interventions of government policies and programmes.

Livelihood capital has a direct influence on the adaptive capacity and the adaptation to climate change. Landholding size, education and extension services significantly affect the adoption of improved agricultural practices and technology, thereby enhancing the adaptive capacity of farmers. Local crop landraces, traditional practices and knowledge relating to agriculture are an integral component of adaptive farming for the local environment. The replacement of local crops, cultivation patterns and methods are largely confined to the major cereal crops (rice, maize and wheat). The land has multiple impacts on livelihood capital influencing cultural, economic and financial aspects. Land ownership with access to road and public transportation systems for market and agriculture services further improves farmer resilience (adaptive capacity). Roads and transport increase accessibility to markets, and institutions that help to diversify income and enhance skills and social and institutional networks ultimately improve adaptation to climate change.

Smallholders undergo agricultural tenancy for *bataiya* (sharecropping) to sustain their livelihoods and diversify income through non-farm based wage and skilled labour work, including the recent trends in foreign labour work. Similarly, education of the household head has a direct effect on access to information and services, and therefore the adoption of productive and adaptive agricultural practices. Moreover, agricultural extension services relating to technical services, and credit, input and market information enhance the decision-making capacity of farmers to adapt in agriculture.

Since forms of livelihood capital ultimately determine vulnerability and adaptive capacity, they need to be strengthened through the adoption of resilient and productive agricultural practices, including income diversification. Indigenous knowledge, traditional and local agricultural practices are integrated into the complex farming system to reduce climatic vulnerability and improve food security and household income. Despite some temporary associated limitations, farmers continue to use available opportunities, such as river bed farming in flood-prone areas, accessing the limited irrigation and incorporating trees in agriculture. The limiting factors may increase labour and productions costs, but they contribute to adaptation in the given context.

CHAPTER 7. LOCAL KNOWLEDGE AND PRACTICES OF THE THARU INDIGENOUS PEOPLE FOR CLIMATE-RESILIENT AGRICULTURE IN THE WESTERN TARAI, NEPAL

7.1 Introduction

Traditional agricultural practices are the basis for innovation in modern agriculture. Mixed cropping, relay sowing and zero-tillage are examples of traditional practices that farmers have practised for many years in Asia and other parts of the world. Such agricultural systems are specifically suited to the local context, resilient to climate change, and also emit low greenhouse gases (GHG). Adoption of these practices is, in all likelihood, not related to perceived or actual climate change because these strategies have not been employed after perceiving the impact of climate change. Rather, the practices are embedded in the farming system with a consistent yield which is able to respond to climate vulnerability. Local and Indigenous knowledge and practices in climate information, disaster risk reduction, and natural resource management, including agriculture, have become part of the realm of scientific research (Galloway McLean, 2009; IPCC, 2014a; Warren, 1991). However, local land use systems dominated by traditional beliefs and Indigenous knowledge in agriculture may not meet future food demands due to the limited land resources and low productivity of local landraces (Van Vliet et al., 2012).

This chapter describes the knowledge, understanding and agricultural practices of the Tharu Indigenous people in the western Tarai of Nepal. This study uses ethnoscience as a complementary approach, incorporating the beliefs, understanding and knowledge of Indigenous people from their eyes and perspectives. The chapter starts with the various rituals and traditional events of Indigenous people related to agriculture, followed by their understanding of climate, land, weed, grain storage, and concludes with the drivers of change in agriculture in the Tarai of Nepal, in general, and more specifically among the Tharu in western Nepal.

7.2 Agricultural rituals and traditional beliefs among the Tharu

In order to understand why people engage in ritual and believe in its efficacy, it is important to understand the cosmology that provides its foundations. Handelman (2008, p. 181) described the expression of a Native American shaman, “You don’t know what I am talking about, and the same is true for anybody who reads this thing you write. What is real for me is not real for you.” The same applies for most tribes and Indigenous people in the world. The local cosmology of “being”, Tharu ontology, has a close connection with the relationships between people and non-human others, however classified with regard to the natural and ‘supernatural’. The performance and continuation of rituals as a custom and tradition reflect the strong beliefs of people

There are various rituals, traditions and beliefs of Tharu in Nepal that are linked to spirits and spiritual power. The ritual specialist *gurau/guruwa* has special powers through the knowledge *mantar*, which includes traditional medicines (Guneratne, 1999; McDonaugh, 2000; Müller-Böker, 1999b; Sarbahari, 2016). Guneratne (1999) states that the rituals and beliefs of the Tharu are primarily based on the forest, where evil spirits stay if the deceased are not given proper burial rites. Such beliefs about evil spirits are declining with deforestation and the adoption of Brahminic rituals (e.g. *satyanarayan puja* and *kanyadan* in marriage); however, worship of Tharu deities within households, villages, and communities (more than one villages) is performed in every Tharu village (Guneratne, 1999; McDonaugh, 2000; Sarbahari, 2016). The room allocated to deities in each Tharu house is called *deuhrar* and the place allocated for village deities is called *bramathan* in the eastern Tarai and *thanhwa/marwa* in the western Tarai. At the household level, the household shaman *ghar guruwa* is responsible for worshipping the deities, while at the village level, a shaman from a particular group is nominated by the villagers, and known as *patharithiya/desbandhya guruwa*. The various rituals performed for farming, agriculture and protecting crops, animals, and livestock relate to the shamanistic *guruwa* system of the Tharu. The Tharu forest beliefs are evident in the offering of green branches and leaves on entry to and exit from the forest. The Tharu believe that the *Bansapti* protects them from wildlife and allows them to return safely from the forest. Müller-Böker (1999b) states that the *ban Dewi* (*Bansapti* in the western Tarai) trained the first *gurau* in the Tharu by providing *mantar* and knowledge of medicine. The *ban Dewi* lives in the forest and protect people from spirits, such as *ban Bayar*.

There is a special process for training *guruwa* called *guruwa khelna*, where only boys from a house or extended house family are trained by a group of *guruwa*. Shamanism is the process by which an individual is accredited as a shaman (*guruwa*) and communicates with the spirits and deities (Sarbahari, 2016). *Guruwa* offer their blood from various parts of the body in the form of *bandhup*[33] to satisfy the spirits and deities. The roles of *guruwa* have largely dwindled due to modern health services and state laws; however, *guruwa* and *baidawa* (healers) still engage in the treatment of patients in the Tharu society.

There are many rituals in the Tharu community that have direct or indirect relationships with agriculture. Table 7.1 lists some of these rituals along with the agricultural calendar, and Appendix 10 provides some further details of rituals.

Traditional institutions determine the existence and functionality of rituals based on Indigenous knowledge and practice at the village/community level. The *barghar/mahtawa*[34] system is the Tharu Indigenous institutional system that governs the village. This system

[33] A mixture of blood in rice, flower of rice, *duba* grass (*Cynodon dactylon*), bee hive and pinewood that is prepared by *guruwa* to offer deities during worship by putting into the fire. It is normally prepared during the *Dashya* festival during the first moon of September–October.
[34] The terms refer to the village head and traditional leader selected during the annual village meeting *kachehri*/*khayala* of the *Magh* festival; the *barghar* chairs and leads the meeting. It is the highest level of institution with legal jurisdiction managed in a participatory way; however, it is not recognised by the state authority.

manages the implementation of Tharu rituals at the community level. It binds villagers together, regulates village governance, and even performs social justice. Without the *barghar* system, the *guruwa* system in the village and related agriculture rituals cannot function.

Table 7.1 Tharu agricultural calendar in wet rice and associated rituals.

Months	**Rainfall (mm)***	**Season**	**Activity**		**Agricultural ritual**
			Rice–wheat system	**Rice–maize system**	
Magh (Jan–Feb)	22	*Jar*	Fallow	Irrigation, fertiliser	*Maghi, Pendia*
Fagun (Feb–Mar)	18	*Gham*	Fallow	Fallow	*Darbandhi*
Chait (Mar–Apr)	18	*Gham*	Wheat harvesting	Fallow	*Nikasi*
Baisakh (Apr–May)	37	*Gham*	Fallow	Maize harvesting	*Dhuriya*
Jeth (May–Jun)	138	*Gham*	Fallow	Fallow	*Harot lena*
Asar (Jun–Jul)	321	*Barkha*	Rice seedling	Rice seedling	*Barka kalwa*
Saun (Jul–Aug)	365	*Barkha*	Rice transplantation	Rice transplantation	*Hardahwa*
Bhadau (Aug–Sep)	268	*Barkha*	Rice weed removal	Rice weed removal	*Hareri, Gandhi hakna*
Kuwar (Sept–Oct)	142	*Barkha*	Rice irrigation	Rice irrigation	*Auli lena*
Katik (Oct–Nov)	29	*Jar*	Rice harvesting	Rice harvesting	*Lawangi*
Aghan (Nov–Dec)	8	*Jar*	Wheat sowing	Maize sowing	*Auli utarna*
Pus (Dec–Jan)	18	*Jar*	Weed removal, herbicide	Weed removal, herbicide	

*Based on the mean monthly rainfall data of Gulariya meteorological station calculated from 1973 to 2016 (44 years, 2012 and 2013 not available). Mean rainfall calculated from the two Gregorian months shown in brackets.

However, the *barghar*, *guruwa*, and other traditional practices such as *kulapani Chaudhari*[35] have not been acknowledged by the state. The consequences of these practices

[35] Kulapani Chaudhari is the Tharu Indigenous irrigation management system in western Nepal, e.g. in the Rajapur area of Bardiya. *Kulapani* Chaudhari leads the construction and management of the irrigation system in their command area (*Praganna*) and is responsible for the main *kulapani* Chaudhari, who inherits this position. The *barghar* system governs the *kulapani* Chaudhari system (Howarth & Lal, 2002).

judged negative by the government render them illegal in Nepal. Ritual performance by Tharu in *thanhwa/marwa/brahmathan* (village deities place) is not legally recognised in Nepal. However, the Hindu temple and Buddhist *gumba* have legal land unanimously granted by the government, and the hill migrant community (*pahariya/parbatiya*—hill, mountain people) recognise this, as they follow the same religion and culture. Without acknowledgment and regulation by the states, such local knowledge and practices are likely to erode and fade. Khadka (2016) found that the Tharu *barghar* system is inclusive, participatory and plays an essential role in peacebuilding and conflict resolution in Tharu society; however, its functions are threatened by the state and outsiders. Major decisions, such as those regulating rituals and festivals, take place during the *kachehri*/*khayala* (village meeting). Tharu activists strongly believe that the culture and tradition of the Tharu will diminish without the *barghar* institution.

The practice of rituals is to protect people, animals and agriculture. The rituals specific to agriculture are listed in Appendix 10. Ritual practices may have scientific as well as cultural significance. There are many techniques and incidents in rituals that need to be explored for the scientific bases, such as removal of the *gandhi* insect (*Leptocorisa spp.*), use of *khirbhan*[36] in *hareri,* and use of botanical insecticides in *darbandhi* (also see section 6.4.2, chapter 6). The *gandhi* insect was once considered a major pest of rice, and the Tharu have a specific tradition for *gandhi* removal. The Tharu believe in the spiritual power of *guruwa* to remove *gandhi* insects. *Guruwa* blow flutes made from deer horn and eat a pair of live *gandhi* insects. The use of *khirbhan* in the canal during *hareri* and hanging of a bottle gourd containing a mixture of plant materials in *darbhandhi* may have a scientific basis for insect pest control. *Panchgavya* (a mixture of cow's urine, milk, curd, ghee and dung) has significance in Hindu religion and

[36] *Khirbhan* is a mixture of new rice, cow milk, and *kush* (*Desmostachya bipinnata*) prepared by *kanya* (premenarchal girls); it is considered holy and put in the *kush* ring and poured at the starting point of the canal in the village.

Indian culture as a treatment for various human diseases and as a pesticide and fertiliser in agriculture (Dhama, Rathore, Chauhan, & Tomar, 2005).

Likewise, the Tharu perform other traditional agricultural practices that are ecological and environmentally friendly. For example, the placement of *khayar* tree (*Acacia catechu)* branches in the four corners of a rice field for *khaira* disease (zinc deficiency) and rice blast disease, dragging a thorny branch of the *bayar* tree (*Ziziphus jujube)* to drop rice leaf roller insects, and spraying yoghurt mixed with water in *dahiya* (rice blight and chlorophyll eating insects). Such practices may have originated due to the lack of inputs and technologies, but are still practised by the community in combination with chemical-based methods. Technology and infrastructure development has played a crucial role for advancing agriculture including crop protection. This is a perfect example of a hybrid approach to pest control in agriculture. These rituals and beliefs need technical studies of their efficacy.

From a sociocultural perspective, village rituals play a vital role in social cohesion, communal work and self-help aspects in the Tharu community. They help to strengthen traditional village governance and the local judicial system in Tharu society. *Begari* (compulsory free labour) for community work, such as the construction of irrigation canals, foot-trails and common work in the villages, is still practised in Tharu villages; such labour is part of agricultural and rural development for the self-reliant community. Ritual practices help to update knowledge and understanding and its transfer to successive generations. Farmers exchange experiences of Indigenous and local knowledge and learn how to perform rituals in their farming system. Ritual ceremonies are important for the continuation and institutionalisation of Tharu communities.

7.3 Tharu farmers’ knowledge on climate and agriculture

7.3.1 Classification of seasons

The Hindu lunisolar calendar has six seasons called *ritu*[37], with two months for each season. The Tharu classify the year into three seasons based on the local climate, with each season comprising approximately four months: *Jar mahina* (winter, November to February), *Gham mahina* (summer, March to June), and *Barkha mahina* (monsoon, July to October) (Figure 7.1). The Hindu seasons, *Hemanta ritu* (pre-winter) and *Basanta ritu* (spring) are not commonly used by the Tharu. Air speed and direction differ in each season and month, so the winds are known by distinct names.

[37] According to the Hindu calendar there are six seasons: *Vasant Ritu* (spring), *Ghrisma Ritu* (summer), *Varsha Ritu* (monsoon), *Sharad Ritu* (autumn), *Hemanta Ritu* (pre-winter), and *Shishir* or *Shita Ritu* (winter).

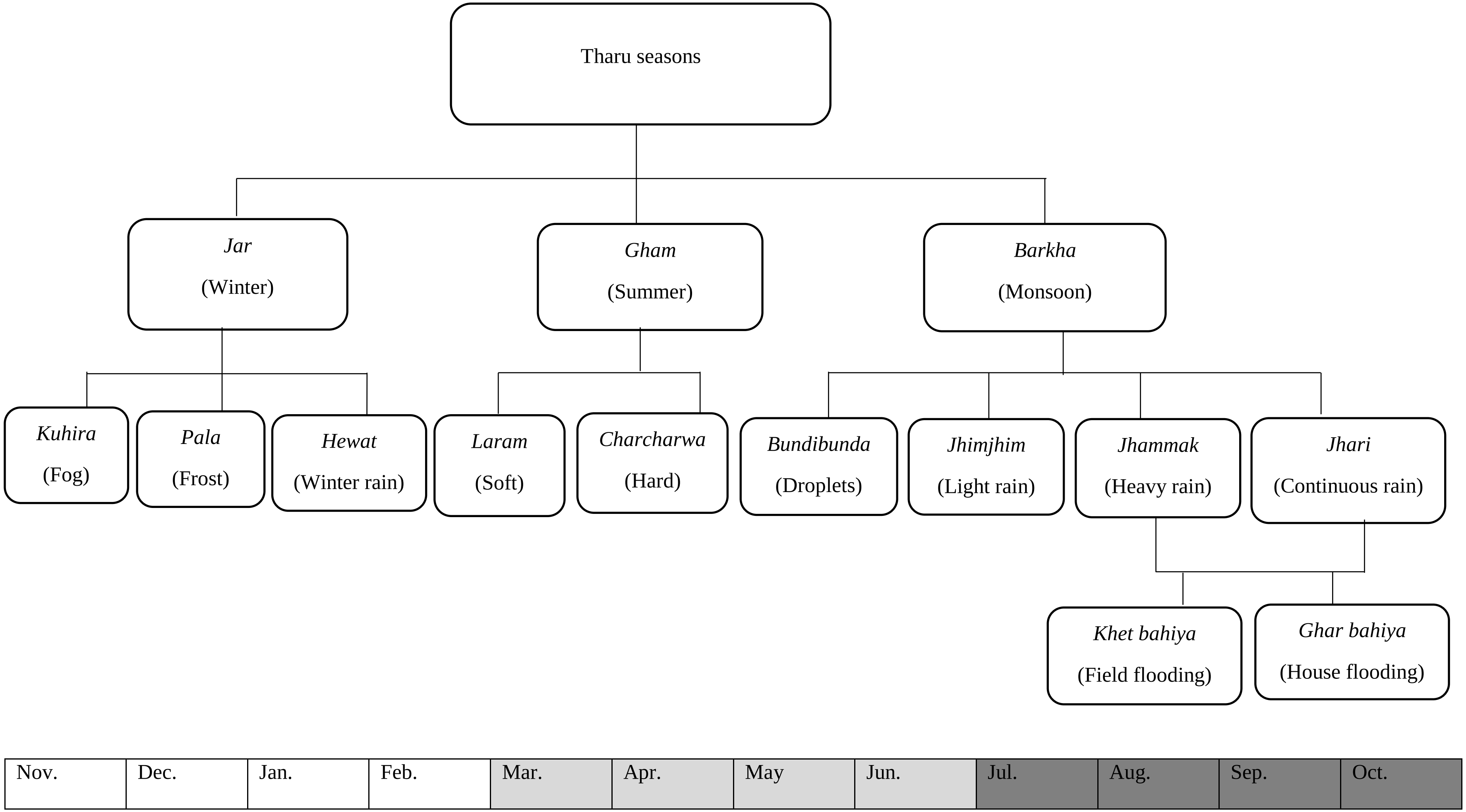


Figure 7.1 Tharu classification of seasons

Jar (winter season)

Katik Aghan ke Jar hie hie, Pus Magh ke jar karja mutu khae khae is a local idiom that means winter in November–December is difficult, but winter during January–February is harsh, cold penetrating to the liver and heart. A thick fog *kuhira* is followed by cold waves *shitlahar,* rendering life harder. The night frost is called *pala*. The area receives winter rainfall called *hewat* and rain in the peak of winter is called *chamar barha*, which kills cattle and goats due to the cold and lack of green fodder. If there is no rain, then the local people believe the chance of hailstorms is high and vice-versa.

Jar has positive and negative aspects in relation to agriculture. Farmers declare that the winter frost and dew are important for pulse crops (lentil, pea) and wheat. *Hewat* (winter rainfall) is an indicator of good winter crop production. Local farmers believe *hewat* increases the branching and growth of winter crops. Local people have a strong belief that canal irrigation without *hewat* is insufficient for good winter crops. Extended foggy weather with limited sunlight and high humidity increases the incidence of diseases, such as late blight in potato.

The cold wind blows during the month of *Aghan* (mid-Nov to mid-December) and energises people during rice harvest. It usually blows in the afternoon during the midday eating break that the Tharu people call *mijhani,* so the wind is called the *mijhniya* wind. The wind towards the end of winter in February and March that causes senescent tree leaves to drop is called *fagnahat*.

Gham (summer season)

The summer season (March–June) is characterised by high temperatures and low humidity. Frequent windstorms occur during summer. Villagers believe storms come from the north-west, causing damage to houses, trees and crops.

Gham is divided into two periods based on the intensity of sunlight: *laram gham* (low-intensity sunlight/soft summer) and *charcharwa gham* (high-intensity sunlight/hard summer). Winter crops are harvested and monsoon preparation occurs during *gham*. Farmers have some leisure time, so most house construction takes place at this time.

Barkha (monsoon season)

The monsoon season runs from July to October. Most of the annual rain falls during this period. *Barkha* is characterised by high temperatures (lower than summer season) and humid conditions. The monsoon season is one of the busiest seasons because of rice cultivation.

The classification of rain in the Tharu community is mixed with the *panchangam* Hindu calendar, which is derived from the *nakshatras*[38] of the Vedic astrological system. Tharu elderly people called it *nakhat*, but these terms are uncommon among Tharu youth. However, the Tharu in Thapuwa and Bikri villages know rainfall by different names based on the intensity and season of rain. Rainfall is commonly divided into four types (Figure 7.1), the characteristics of which are described below.

Bundibunda barkha has scattered raindrops for a very short time (5–10 minutes), which does not even compact the dust of foot marks in the soil. It has no significance for agriculture. *Jhimjhim barkha* is drizzling rain for a short period, up to a few hours, which does not create water flow over the ground. It may have some significance for agriculture in that it can temporarily fulfil plant water requirements. Rain that occurs with moderate intensity for more than ½ hour is called *jhammak barkha*. If this rainfall extends to hours and days, then it is called *musaldhare barkha*. *Jhari* is continuous rainfall of low to medium intensity for a couple of days. It usually occurs in the months of *Sawan* and *Bhadau* (August–September). Farmers

[38] There are 27 *nakshatras (“which never decays”*) in the Vedic astrology prevalent in the Hindu religion. Each *nakshatra* is 13° 20’ in duration; multiplying by 27 equal lengths equals the 360° of the zodiacal belt (Harness, 2000).

believe that this rain is necessary for proper rice and maize production as it increases tillers in rice and supports grain filling in maize. High-intensity continuous rain, such as *musaldhare* and *jhari*, can cause flooding in field and villages.

Village people also classify flooding based on its implications for agriculture and livelihoods. Flooding is classified as *khet bahiya* (field flood) or *ghar bahiya* (home flood). *Khet bahiya* does not necessarily come from river flooding, but also the rain of the catchment area, eventually inducing flooding. Villagers in Thapuwa prefer *khet bahiya,* as it deposits clay soil on the *khet* which gives bumper crop yields and improves soil quality. They believe that excessive use of inorganic fertiliser and lack of farmyard manure have damaged the soil in Thapuwa. This is an example of how the adoption of modern agricultural methods does not always contribute to climate change adaptation. One village watchman informed me, "I produced 28 quintals (2.8 ton) Radha-4 rice in 12 kattha (0.4 ha) of land in bhagraiya (land which normally gets river floods during the Monsoon season) without applying compost and inorganic fertiliser." However, flooding deposited sand in rice fields at Bikri, making rice fields shallow and less productive than before. Bikri farmers use decomposed organic matter from the forest water catchment in the rice field. This is an example of how traditional agriculture practices contribute to local resilience in climate change adaptation.

After filling the *khetwa* (rice field), *khet bahiya* can gradually enter the villages and flood homes (*ghar bahiya*), destroying houses, stored food and other physical property, and even causing death. The flooding of many households in a village is called *sailaf*. It is a disastrous form of flooding where villages are flooded for a few hours to day(s).

The Tharu classification of seasons, rainfall and flooding does not drastically differ from the classification of other communities in Nepal. The differences are mostly related to linguistics and meaning. For example, the prefixes, *khet* and *ghar*, of *bahiya* (flood) covering rice field and houses are the same in Tharu and Nepali languages. Thus, such knowledge prevalent across different communities in the region can be considered local knowledge.

Tharu farmers perform activities based on the agricultural calendar and a combination of Indigenous and modern weather forecasting systems. Preparatory activities for agriculture are based on the Tharu season and crop calendar. Some local indicators that Tharu farmers consider the basis of their decision making in daily life are listed in Table 7.2. The regional weather forecast from local media is not accurate for specific locations; therefore, local knowledge is important to farmers.

Table 7.2 Tharu Indigenous indicators of weather and extreme events

Indicator	Behaviour	Indication
Biological indicators		
Ant	Carrying eggs from the nest to an uphill safe place	Rain
Poultry (a hen)	Spreading feathers under the balcony of house	Rain
Cattle	Running, jumping and producing sounds with tail straight	Rain
Earthworm	Comes out of the ground and crawls on the mud	Rain
Dhansuhi bird	Cries near villages is an indication of no rain during the summer and monsoon seasons	Drought
Common crane *(Mansi Surwal*)—migratory bird)	Groups of birds return south at height, producing *karlyang kurlung* sound that signals the end of the monsoon	End of the monsoon
Physical indicators		
Wind direction	Easterly wind for 2–3 days followed by westerly wind from March–June Easterly wind from July to September	Rain No rain
Rawaniya wind	Wind blowing from the southeast on rainy days	No rain
Sunlight and wind direction	Bright sunshine during the day, air blowing from the west in winter	Frost
Winter rain	No or less winter rain	Hailstorms during next summer

The specific indicators of climate variability and local weather allow farmers to take appropriate actions to cope with the incoming changes and challenges in agriculture. Agricultural planning and decisions start during the great festival *Magh(i*), which is also the Tharu New Year.

Based on the above discussion, the Tharu have their own way of classifying seasons, rain and floods that help them to take appropriate actions to minimise climate-related hazards and risks. For example, a biological indicator (e.g. behaviour of insects, animal and birds) indicates severe rainfall so they prepare for safety. Similarly, wind velocity and direction help to predict frost during the winter, thereby they may take appropriate measures. Local knowledge shapes agricultural practices, helping farmers to make informed decisions, thereby making agriculture resilient to climate change.

7.3.2 Classification of agricultural land

Tharu farmers classify agricultural land into three categories: *dihwa/dadwa*, *khetwa/khet* and *baggarwa*, which are further divided into sub-categories.

Dihwa is flat land that is not normally divided into smaller units (plots). A bund (low height, 10–15 cm) separates *dihwa* from the plots owned by others. There is no stagnation of rainwater in the field and traditionally no provision for irrigation. Farmers generally cultivate maize in the monsoon and mustard in the winter on such land. Nowadays, *dihwa* has been converted into *khetwa* (rice fields) for rice cultivation due to the availability of suitable rice varieties and irrigation. Terraces (bunds) are constructed to convert *dihwa* into *khetwa* for rice cultivation. Farmers grow many short-duration improved (Radha–4, Sabitri) and hybrid (Arize–6444 Gold, US–312) rice varieties. Residential land, *gharauri,* also comes under the *dihwa,* which is comparatively further upland than normal *dihwa* land. *Gharauri* is the safest land and accessible by foot-trails and road.

Khetwa is wet rice land that is divided into square or rectangular-shaped small plots (350–650 m^2) called *oenra*. Bunds are normally higher than the *khetwa* (about 30–50 cm height) to conserve water for rice cultivation. Irrigation is mostly feasible on this type of land, and the soil has good water-holding capacity. *Khetwa* is further divided into *dadai khet*[39] and *jabda*. *Dadai khet* is more upland than *jabda*, sometimes sandy and with low water-holding capacity for 1–2 days. *Jabda* is lowland with blackish-coloured soil that has better water-holding capacity than *dadai khet*. Short-duration *ashan* rice is grown in *dadai khet*, whereas *jarhan* rice (long-duration, late maturing) is cultivated in *jabda*.

Jarhan and *ashan* form part of the traditional classification system of rice that covers grain size and weight, aroma and duration to maturity. *Jarhan* rice has small grain size, superior quality, and aroma, so its market price is often high; it is also known as *garuh dhan* (weighty rice). Some local landraces of *jarhan* rice are Burma, Latera, Kala Namak, Basmati, Sohawat and Andi. Since it has a long growing period, *jabda* or land with irrigation is needed for cultivation. *Ashan* rice has large, light, and coarse grains after milling; it is also called *mota dhan* (coarse rice). Karangi and Sauthyari are two *ashan* local rice landraces that the Tharu still cultivate.

Baggarwa is riverbed land that is affected by river and stream flooding and erosion. It usually floods when the water volume increases during the monsoon. *Baggarwa* is further divided based on its suitability for farming. In the initial few years, rice can be grown in low land areas, and black/green gram, lentil and linseed in upland areas. *Baggarwa* soil is sandy, so crops such as watermelon, groundnut and gourds can grow during lean periods; this is called *baggar kheti* (riverbed farming) which is discussed in section 6.4.3 (chapter 6). Bushes, shrubs

[39] This type of land is known by different terms in different places, e.g. *dadai khet* is *tandi* in Deokhuri and *Dabara* in Dang. Similarly, *jabda* is *behra* in Deokhuri and *gandar* in Dang. Dang and Deokhuri are in one district, with two valleys and slightly different cultures.

and tall grasses in the *baggarwa* that make land not suitable for cultivation are normally called *bhagraiya*.

The Nepalese government has classified land into four categories: *abbal* (best quality), *doyam* (good quality), *sim* (average quality) and *chahar* (poorest quality), which is not commonly termed by the Tharu and nearby non-Tharu communities in Bardiya District. What is normally called in Nepal is *khet*, *bari* and *ghaderi*, which the Tharu call *khetwa, dihwa* and *gharauri*, respectively.

7.3.3 Classification of weeds

Weeds were commonly observed during fieldwork in the winter and monsoon seasons. A series of individual and group interviews were conducted to capture local people's understanding of weeds, their management, and the local weed ethnotaxonomy. A list of major problematic weeds in summer crops (rice, maize) and winter crops (wheat, lentil/pea, mustard) was prepared from the HH surveys, field observations and farmer identification.

The common term used for weeds in the Tharu is *dharrha*, which can be thorny or non-thorny. Thorny weeds are known as *kanta*. Farmers understand and classify weeds based on edibility and seasonal prevalence. Local farmers do not consider volunteer crop plants as weeds. For example, a maize plant germinating in mustard or a pulse crop in winter is not considered a weed. They understand that weeds appear naturally without cultivation in the field. Weed management strategies and methods have been discussed in section 6.4.2 of chapter 6.

Tharu farmers classify weeds based on the season of growth, crop of prevalence, habitat (herb, shrub), consumption (edible, inedible) and physical characteristics (thorny, non-thorny). The Tharu mostly classify weeds as edible or inedible (Table 7.3). Edible weeds are further divided into edible for humans, animals, or both. Inedible weeds are noxious for both humans and animals.

Table 7.3 Major weeds and local classification

Category	**Local/ Tharu name**	**English name**	**Scientific name**	**Parts used by humans and livestock**
Edible weeds				
Consumed by both humans and animals	*Akra*	Common vetch	*Vicia sativa*	Seed, foliage as a vegetable and fodder
	Munmun	Hairy vetch	*Vicia hirsuta*	Seed, foliage as a fodder
	Bethe	Goosefoot	*Chenopodium album*	Tender stem and leaf
	Berseem	Berseem	*Trifolium alexandrinum*	Tips and new leaf (eaten by some people in Bikri village)
Consumed by animals only	*Ghauda*	Sorrel	*Oxalis* spp.	Roots and stem/leaves; causes diarrhoea in animals
	Maobadi jhar	Santa-Maria	*Parthenium hysterophorus*	Goats eat leaves and branches
	Baglalwa/Patpuria	Lathyrus	*Lathyrus aphaca*	Whole plant; excessive eating causes diarrhoea in animals
	Bharkatiya	Burr medic	*Medicago polymorpha*	Whole plant after wilting for some hours
	Sawai	Wild rice/ Deccan grass	*Echinochloa colona*	Whole plants, seeds (some people use to make liquor)
	Chhatiya	Fingergrass/ crabgrass	*Digiteria ciliaris*	Whole plant
	Bhadaure/ Mothe	Coco-grass/ purple nutsedge	*Cyperus rotundus*	Whole plant

	Guli-danda/ Mama-bhanja		*Phalaris minor*	Whole plant; found in wheat crops
Consumed by humans only	*Gholgholiya/Siur*	Cereus cactus	*Cereus* spp.	Flowers, stem
	Katmorsa/Lunde	Spiny amaranth	*Amaranthus spinosus*	Tender stem and leaves
Inedible and noxious weeds				
Not consumed by humans or animal	*Bharbhanda*	Mexican prickly poppy	*Argemone mexicana*	Not consumed
	Banmara	Lantana/wild sage	*Lantana camara*	Not consumed
	Bersama		*Ipomoea spp*	Not consumed

In winter, the main crops are wheat, lentil, pea, mustard, and potato. In wheat, *gulli-danda* (*Phalaris minor*) and *Lathyrus* are the main weeds. Other common weeds in *dihwa* (flat upland fields) *Argemon*, *Medicago*, *Chenopodium* and *Amaranthus* are common, whereas *Oxalis* and *Vicia* are common in *khetwa* (rice fields). *Oxalis* spp. is the most problematic weed with its branching habit. In summer, the major weeds in rice and maize crops are *sawai* (*Echinochloa colona*), *bhadaure* (*Cyprus rotundus*) and *chhatiya* (*Digiteria ciliaris*).

Tharu farmers understand that weeds come naturally without sowing. Weed classifications based on livestock consumption indicate their possible use in the farming community. Non-Tharu farmers in the local area have a similar understanding of weeds, but the classification of weeds based on consumption emerged from generations of Tharu farmers watching animals graze; hence, it is considered local knowledge.

7.4 Climate-resilient agricultural practices

Farmers use several locally adapted and climate-resilient methods and practices in agriculture for crop cultivation, protection, management, and ultimately preservation and storage. The local agricultural practices are adapted and resilient in the local environment, thereby improving the adaptive capacity of the farmers. This section discusses some of these agricultural practices, including crop protection and post-harvest storage technology. These practices are not exclusive to the Tharu community in the region, but they have been used for generations.

7.4.1 Mixed cropping

Mixed cropping is one of the oldest farming techniques of smallholders to maintain food security, reduce the risk of crop failure, and conserve agrobiodiversity. Mixed cropping involves growing more than one crop simultaneously on the same land without row maintenance (Sekhon, Singh, & Ram, 2007). Growing two or more crops in separate rows is known as intercropping, which is a modified version of mixed cropping (Sekhon et al., 2007).

In the study area, various combinations of mixed cropping occur, e.g. the cultivation of lentil with mustard and pea. Cereal crops (rice, wheat and maize) are generally grown as monocrops[40], but also in crop rotation with winter crops. Common mixed cropping patterns in Thapuwa and Bikri are listed in Table 7.4.

Table 7.4 Cropping patterns on *khetwa* and *dihwa* at Thapuwa and Bikri

Type of agri. land	**Thapuwa**	**Bikri**
Khetwa	Rice–wheat–rice Rice–maize–rice	Rice–lentil+mustard–rice
Khetwa	Rice–lentil/pea+mustard–mint/black gram*–rice	Rice–lentil+mustard+pea–rice
Dihwa	Rice–potato–mint/black gram–rice Maize–mustard/vegetable crops	Maize–lentil+mustard–maize/rice Maize–vegetable crops

Legend: – followed by, / or, + and (i.e. at the same time)

*Mint and black/green gram are short-duration crops (3 months, March–May), so crop intensity increases from 2 to 3 crops per year.

[40] Monocropping (monoculture) is where the same crop is grown for a number of years on the same land. In Nepal, crop rotations are practiced in winter, such as after the rice harvest when the field is rotated with wheat, pulse, potato or other winter vegetable crops. Sequential cropping refers to growing two or more crops in successive years on the same land (Sekhon et al., 2007).

Mixed cropping is more prevalent in Bikri (96%) than Thapuwa (64%) (Figure 7.2), with an average of 82% of households in two villages cultivating lentil in mixed cropping. The yield analysis of lentil under different tillage and cropping systems is presented in Table 7.5. Lentil yields are significantly higher in mixed cropping (0.84 t/ha) than sole cropping (0.61 t/ha). Farmers reported that the higher lentil yields from mixed cropping than sole cropping were due to the production of two or more crops from the same piece of land, low weeds and few insect-disease problems. Based on my field observations, winter crops in Bikri had lower yields than Thapuwa, which may be due to small land size, limited irrigation facilities, and low use of agricultural inputs. As noted above, the average landholding at Thapuwa is more than double (1.17 ha) that in Bikri (0.55 ha). Bikri farmers depend on rainfall and canal irrigation more than pump irrigation, and canal irrigation is irregular; the 14 pumps are often non-functional. Farmers received pumps from the Ground Water Irrigation Project, Government of Nepal, which were considered village property that no one cared about. Canals are not maintained.

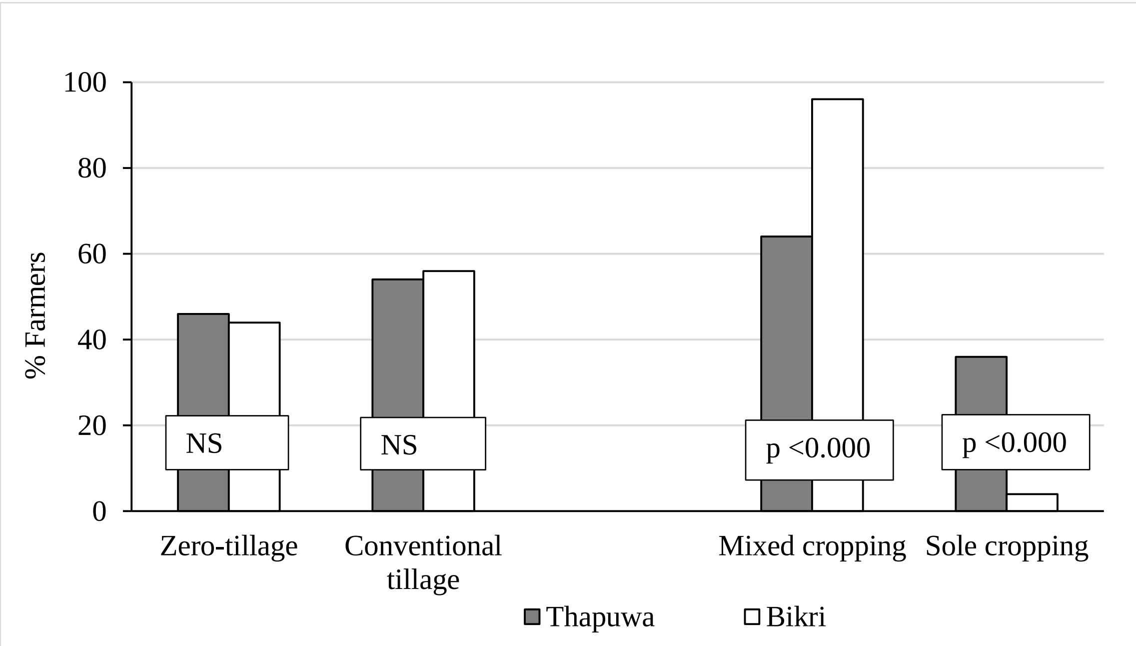


Figure 7.2 Prevalence of zero-tillage and mixed cropping with lentil in the study villages

Table 7.5 Lentil yields under different tillage and cropping systems

	ZT (n=58)	CT (n=69)	p-value	Mixed crop (n=105)	Sole crop (n=22)	p-value
Area (ha/hh)	0.29±0.025	0.24±0.026	0.148	0.26±0.021	0.28±0.037	0.578
Yield (t/ha)	0.71±0.055	0.83±0.050	0.020	0.84±0.040	0.61±0.088	0.016

ZT=zero-tillage, CT=conventional tillage

Note: ZT includes no-tillage (NT) or one minor tillage, and conventional tillage (CT) includes 2 or >2 tillage passes with tractor and/or mouldboard plough

The literature indicates that mixed cropping is productive with an appropriate planting density. Optimum seeding rates are important to maintain plant density and the crop configuration in mixed cropping. Mixed cropping avoids complete crop failure and increases per unit area productivity of land, and reduces weeds, pest incidence, lodging as well as provides crop insurance against unstable market price and extreme weather conditions (Lithourgidis, Dordas, Damalas, & Vlachostergios, 2011; Sarker et al., 2004; Wang, Gruber, & Claupein, 2012). In Bangladesh, wheat+lentil (two parts wheat/one part lentil or one part wheat/two parts lentil) was the most suitable and economically profitable (Ahmed, Rahman, & Kelley, 1987), and 30% wheat-weight of lentil seed in India (Sekhon et al., 2007). Similarly, mustard and lentil mixed cropping was productive at a 3:1 seeding ratio in Bangladesh (Sarker et al., 2004). In India, mustard+lentil (5:1) and lentil+linseed (5:1) out-yielded lentil sole cropping (Sekhon et al., 2007). Wang et al. (2012) found higher lentil yield in mixed cropping than in sole cropping when cultivated with naked barley, wheat, oat and buckwheat as a companion crop (3 parts of lentil and 1 part of companion crop or vice-versa or 1 part of lentil and 1 part of companion crop), but lower yield of lentil in mixed cultivation with linseed.

Mixed cropping is a common strategy by farmers for climate change adaptation as it reduces the risk of total crop failure and diversifies the household food basket, contributing to food and nutritional security. One drawback of mixed cropping, especially for the medium and large farmers in the study villages, is that machine harvesting is limited to rice and wheat.

7.4.2 Relay sowing

Relay sowing is broadcast sowing of lentil, grass pea, linseed and other crops 2–3 weeks before rice harvesting. Relay sowing is a traditional practice in the Tharu community to overcome high and low moisture. Broadcasting lentil in standing rice is the most dominant practice followed by grass pea, linseed and faba bean. The relayed crop extends the period for vegetative growth, uses residual soil moisture and reduces tillage costs (Sarker et al., 2004). Relayed crops germinate at the time of rice harvest; the relayed crop grows fast after rice harvest that meets the appropriate winter length for the growth and development. Relay cropping is a form of zero-tillage that meets the principles of conservation agriculture[41].

Relay cropping varies with soil type and availability of irrigation facilities. No relay sowing occurs in Thapuwa; in Bikri, about 50% of the fields are under relay crops (lentil, pea and grass pea). In Thapuwa, the soil is sandy, which is easy to till, and farmers have pumps for irrigation, so they cultivate wheat or maize after the rice harvest. In Bikri, relay-sown lentil had more uniform germination and better vegetative growth than conventionally tilled lentil.

The comparative yields of lentil under relay sowing and zero-tillage are shown in Table 7.5. Yields are significantly lower (0.71 t/ha) in zero-tillage including relay sowing than the convention tillage system (0.83 t/ha), contradicting the assertion of higher yields under zero-tillage than conventional tillage. Most zero-tillage lentil comes under relay sowing. Farmers reported that lentil production depends on the weather conditions, as some crops collapse due to waterlogging. Research shows that lentil yields under relay sowing depend on the variety

[41] Minimum soil disturbance, soil cover, and crop rotation are the fundamental principles of conservation agriculture; zero-tillage is one conservation agriculture technique for reducing soil disturbances and soil cover through residue management to some extent.

(genotypes), management, and other conditions (Sarker et al., 2004; Malik et al., 2016; Wang et al., 2012; Wiraguna, Malik, & Erskine 2017). In Bangladesh, relayed lentil (improved varieties: Barimasur–2 and Barimasur–4) into rice produced higher yields than conventional tillage of the local cultivar (Sarker et al., 2004). However, Malik et al. (2016) reported that relay-sowing the local lentil cultivar in Bangladesh was more economical (yield, >1 t/ha) than early flowering lines in sole cropping to fill the fallow gap in rice cultivation. Zaman, Malik, Kaur, and Erskine (2018) found that pea is sensitive to germination under relay sowing. Wiraguna et al. (2017) found that Bangladeshi genotypes of lentil are more adapted to waterlogged conditions with higher germination (21.2%) than in other countries.

The relationship between relay cropping and climate resilience is multi-dimensional, with various positive effects on soil health, risks reduction from pests and climatic extremes, GHG emissions, energy use and crop quality. Sapkota et al. (2015) reported a positive effect of relay sowing on soil nutrient management, energy consumption and GHG emissions from the soil in agriculture. Quinn (2009) found that integrating legumes in relay cropping improves soil fertility by adding atmospheric nitrogen and even increasing the yield and quality of cereals rotated with a pulse.

Relay sowing makes agriculture resilient under both wet and dry soil conditions. The practice allows farmers to sow lentil on time in the early drying rice field, and to broadcast lentil in low land. Timely sowing, selection of appropriate varieties, and adjustment of sowing dates are critical for all crops. Farmers being able to plant rice early, and hence sow winter crops (e.g. lentil, pea) in a timely manner, is one example of adjusting to weather conditions and adapting to water stress. Bhatta and Aggarwal (2015) stated that changing cropping patterns and adopting resilient crop varieties are the most common strategies for adaptation to climate variability in South Asia.

Increasing wet rice farming and decreasing swidden rice (shifting and dry rice cultivation) creates new dynamics in agriculture. Wet rice farming with the application of inorganic fertiliser is one of the biggest CH_4 and N_2O emitters; however, wet rice farming is predicted to increase in Nepal as climate change has limited effects on this cropping system (Chalise & Naranpanawa, 2016). While the transition to wet rice cultivation is an adaptation to climate change, it reduces mitigation, thus promoting further climate change. Studies have also reported an increase in *sawah* (wet) rice farming and decrease in *swidden* (dry) rice farming in South-East Asia and across the globe (Ellen, 2007; Fox et al., 2009; Van Vliet et al., 2012). Pulse crops in rice-based farming systems are replaced by winter maize and wheat farming, which affects soil fertility and the food and nutritional security of small households. Local practices need further research and innovation to increase yields; otherwise, winter legumes (lentil, pea) will be replaced with intensive rice–wheat farming that increases input use and emissions.

7.4.3 Zero-tillage

Zero-tillage is a method that involves minimum soil disturbance and residue incorporation with the objective of reducing soil and water losses. The overarching concept of zero-tillage in the context of climate change is to reduce emissions from soil tillage, minimise tillage costs and energy use, and adapt to climatic variabilities (drought and excess rainfall) in agriculture. Different zero-tillage implements are used to reduce soil disturbance during sowing (Reicosky, 2015). While conventional tillage uses the mouldboard plough, disc plough and deep ripper, zero-tillage uses the field cultivator, ridge tillage, vertical tillage, mulch tillage, and strip tillage. Conventional tillage, zero-tillage and no-tillage have the highest, moderate and lowest levels of soil disturbance, respectively (Reicosky, 2015).

Zero-tillage is practised in different crops to varying degrees. In the study villages, farmers practise zero-tillage mainly for lentil and garlic. Although zero-tillage in the rice–

wheat system has been widely researched in South Asia, it was not practised in the study villages. As discussed earlier in the mixed cropping section, slightly fewer households (about 45%) practised zero-tillage than conventional tillage (55%), with lentil yields significantly lower under zero-tillage than conventional tillage (Table 7.5). This finding contradicts others in Nepal and Bangladesh (Malik et al., 2016; Pokhrel & Soni, 2018; Sarker et al., 2004), but is supported by Jat et al. (2014), who reported competitive yields under conservation agriculture (zero-tillage is a main component of conservation agriculture) in the long-term (>5 years) in a rice–wheat system on the Indo-Gangetic Plain (IGP) in India. Another study reported equal or slightly higher yields under conservation agriculture in a rice–wheat system on the IGP than conventional tillage (Sapkota et al., 2015). Farmers practise conservation agriculture mainly because of the lower production costs in rice–wheat and rice–lentil cropping systems than conventional tillage (Kumar et al., 2011; Sapkota et al., 2015).

Zero-tillage wheat in the rice–wheat system is important for timely sowing to improve wheat yields in the Indo-Gangetic region in Asia. In this region, delayed sowing reduces yield potential by 1–1.5% per day from November onwards (Hobbs & Giri, 1997); thus, reduced-tillage options for wheat are often used in place of conventional tillage to ensure sufficient soil moisture for seed germination. Zero-tillage seed drills, such as the Happy Seeder, can cut rice stubble for mulch after drill-seed sowing (Sidhu, Humphreys, Dhillon, Blackwell, & Bector, 2007). In the study area, farmers do not use zero-tillage equipment; instead, they practice shallow tillage with a bullock-pulled plough and tractor-driven cultivators. Many farmers also use modern inputs (seeds, inorganic fertilisers, herbicides) in combination with the traditional practice of wheat broadcast sowing, a method using one plot of land – yet another example of the Tharu resort to hybrid agriculture.

Traditionally, some rice landraces, such as Karangi and Sauthyari, have been direct-seeded. Direct-seeded rice in a dry bed (no puddling) is locally called *dhuriya* because rice is sown in a dusty dry bed, while rice seeding into a puddled wet bed is called *buwari* (broadcasting). Direct-seeded rice allows early sowing in a delayed monsoon and late sowing in unusual contexts, such as flood-affected areas. Direct-seeded rice in dry beds and zero-tillage wheat reduce energy use, labour and some emissions. There are some counter-arguments that zero-tillage does not reduce emissions, and thus its role in climate change mitigation is over-emphasised (Powlson et al., 2016). The higher yields of direct-seeded rice compared with transplanted rice remains controversial due to the increased costs of weed management. With weed management, direct-seeded rice produces higher yields than flooded rice cultivation (Chakraborty et al., 2017; Farooq et al., 2011; Kumar & Ladha, 2011; Mishra et al., 2017; Rao et al., 2007). In contrast, Zhang et al. (2018) reported lower yields for direct-seeded rice than transplanted rice in south-eastern China. Thus, higher yields can be achieved under direct-seeded rice with effective weed management, which can help to mitigate CH_4 emissions, when compared with flooded direct-seeded rice or transplanted rice systems.

No-tillage (type of zero-tillage) of garlic is an innovative practice in rice-based farming systems (Figure 7.3). After the rice harvest, garlic is inserted in the harvested rice stub and, in some cases, covered with mulch (rice straw). Tharu farmers stated that no-tillage garlic produces few weeds, conserves soil moisture and produces larger bulbs than traditional tillage-based cultivation. It also reduces the costs of tillage, irrigation and weed management and increases yield. No-tillage garlic cultivation is common in Thapuwa, but rare in Bikri, where farmers cultivate garlic in the *dihwa* (flat upland field) together with potato and other winter vegetable crops. In Bangladesh, zero-tillage garlic with rice straw mulch produced large bulbs, and thus higher yields than conventional tillage (Kabir et al., 2016).

Garlic is a minor crop cultivated on a small piece of land (<0.07 ha), mostly for household consumption, with excess produce sold. One farmer, Kallu Tharu, said that in the previous year he cultivated garlic on one *kattha* (0.03 ha), consumed much of it, distributed some to relatives, and sold 75 kg for NPR 22 per kg (USD 0.2/kg) before the *Dashya* festival in October.

Figure 7.3 No-tillage garlic at Thapuwa

The agricultural practices—mixed, relay and zero-tillage—being environmentally friendly but challenged by low production in the short-term, are being replaced with crops that require high external inputs and hybrid varieties of rice and maize. Farmers have even changed to a cropping pattern that excludes those legume crops that degrade soil quality and thus increase the need for external inputs, which ultimately reduces profit margins. However, many agricultural practices of the Tharu are adaptable to climate change and help in climate change mitigation. The use of inorganic fertilisers and pesticides is a recent adoption so that small farmers can increase production for household food security. Farmers dependent on farming need to maximise profits for their evolving needs and livelihoods. Existing local agricultural practices could be improved to increase productivity and make agriculture resilient to climate change. Such practices could help to reduce emissions from agriculture and contribute to the global agenda of reducing the increases in global temperature.

7.4.4 Crop landraces

Landraces may produce lower yields than improved varieties, but many have characteristics that are preferred by farmers. Some of the crop landraces in the study area are listed in Table 7.6.

Table 7.6 Landraces cultivated in Thapuwa and Bikri

Crop	**Landrace**	**Characteristics**	**Reason of cultivation**
Rice	Karangi	Black seeded with awn	Early maturity/short duration, direct seeding in dry or wet bed, early or late sowing possible, suitable in upland
Rice	Sauthyari	Covered in sheath, black and seed with awn (shorter hair than Karangi)	Early maturity, early or late sowing possible, direct seeding in dry or wet bed
Rice	Andi	Tall plant, red seed coat, large seed	Sticky rice, cultural value, *jaar* (sweet rice beer)
Maize	Raksi/Gaiji	Short plant, normally two cobs, short and compact seed	Popcorn, hardy, short growth duration allows timely sowing of mustard in winter, taste
Mustard	Local lahi	Blackish brown seed, dwarf	Productive, oil has strong smell and taste, short crop duration
Lentil	Kariya Masri	Small and blackish seed coat, red cotyledons	Taste, mixes well in cooked rice, locally adapted, drought-resistant
Pea	Local	White and medium-size seed	Taste, withstands drought and cold waves
Potato	Tharu alu	White small tubers, red eyes in tuber	Taste, resistant to late blight, long post-harvest life
Vegetable	Poe sag *(Basella alba)*	Perennial, climber, red vine, berry red upon ripening	Waterlogging tolerant
	Kundhru *(Coccinia grandis)*	Perennial, climber, year-round fruiting	Drought tolerant

Low yields of landraces are a key challenge faced by farmers to continue their cultivation, such as resistance to high temperature, drought and waterlogging. Karangi and Sauthyari local rice produce almost half the yield of improved and hybrid varieties. As a result, many landraces are being replaced by hybrid rice in the villages. Similarly, local maize (Raksi/Gaiji) is being replaced by rice because of its low production. Farmers can produce at least twice the yield of hybrid rice and maize from the same piece of land. Farmers are now growing hybrid maize in the winter–spring season after the rice harvest. The new cropping pattern produces high yields of both rice and maize on the same piece of land, to the detriment of landrace cultivation. Farmers also cultivate landraces (e.g potato) in ridges and use inorganic fertiliser. In the ridge method, the furrow makes surface irrigation easy.

Despite low yields, farmers grow local landraces for their hardiness and taste and because they lack access to improved varieties. Total crop failure does not occur for landraces under hard climatic circumstances (drought, flooding, insect/ disease). However, Tharu farmers are open to adopting new crop varieties, technologies and practices.

7.4.5 Crop protection

Crop protection entails protecting crops from biological enemies, including insect pests, diseases, birds and other wildlife. Rural communities, such as the Tharu, mostly use non-lethal and non-chemical methods to manage pests. The Tharu Indigenous ritual practices related to agriculture, such as *hareri, darbandhi* and various non-lethal traditional techniques for protection of agriculture, reflect and enhance their adaptive capacity. In recent decades, chemical methods have become an integral part of farming, but various non-chemical techniques are still used that support the concept of integrated pest management (IPM).

Tharu have insect management embedded in their culture—performed through ritual practices, such as *hareri* rituals, use of cow milk and other plants in *khirbhan* and use of plant bio-pesticide in *darbandhi* (see Appendix 10). Some local techniques to manage insects and diseases in the Tharu community are described in Chapter 6 (section 6.4.2, Table 6.7) for climate change adaptation and mitigation. Here, some local traditional physical techniques used to protect crops from birds, rodents, and wild animals are described, many of which do not use chemicals and are non-lethal, such as the scarecrow.

Atwa (watchtower)

The *atwa* is a typical temporary structure constructed in the field to scare birds and wildlife before harvest. The *atwa* is built to a height of 5–20 m, and the *machan* (bedframe) is fastened into the frame (Figure 7.4). *Atwa* is a typical Tharu Indigenous structure to be safe from wild animals during crop protection. There is an oral story that a tiger tried to eat a Tharu farmer sleeping on a *machan*; rather, the tiger was trapped into the fork of the *lachar* and died. Thereafter, Tharu strike the stick against the *gedahi* (horizontally crossed wooden pole, see Figure 7.4) before going to climb and sleep on a *machan* (Müller-Böker, 1999b).

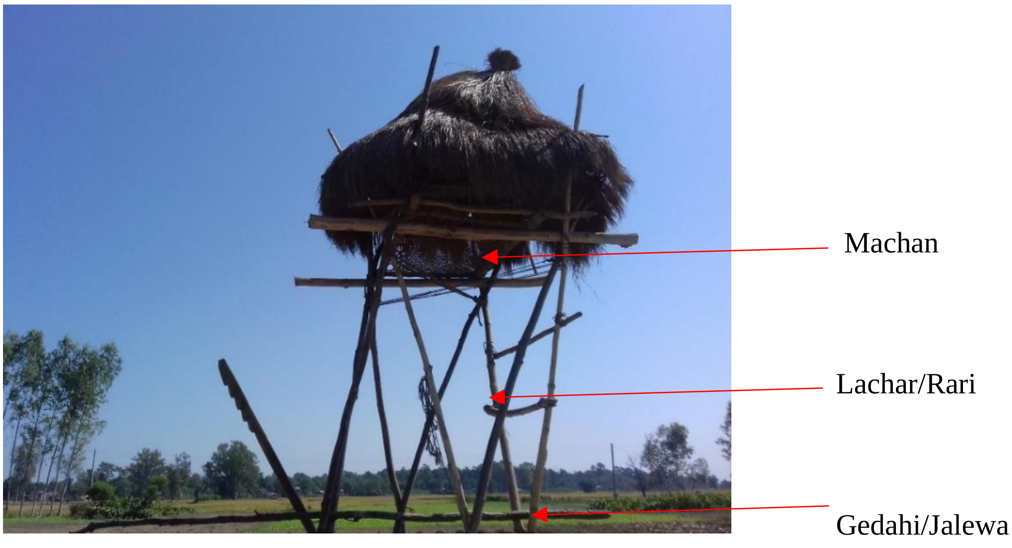


Figure 7.4 *Atwa* (watchtower) to protect crops from birds and wildlife

Thapa (2010) studied various techniques of local people (mostly Tharu) to protect their crops from wildlife in the vicinity of Bardiya National Park. She concluded that *machan* is the best way to protect crops from wildlife and birds. Using *machan* in a combination of throwing flaming sticks and group shouting is most effective for elephant and rhinoceros deterrence. *Machan* is higher than the height of maize, so it is easy to observe birds (parrots, crows) and use distraction techniques, such as crying and hitting sound-producing objects.

Jhukka (scarecrow)

Using the *jhukka* (scarecrow) is another traditional practice among the Tharu to protect crops from birds and wildlife. A scarecrow is a predator model to scare birds. Most scarecrows are made in human-form, constructed from inexpensive, unwanted and locally available materials to deter birds and animals. Placing *jhukka* in the field and tying coloured pieces of cloth are also common in the Tharu community.

Scarecrows, including flaming threads, are only effective for a short time in small areas. Birds, especially crows, quickly recognise the false human, reducing its deterrence function (Bishop, McKay, Parrott, & Allan, 2003). The effectiveness of the scarecrow can be increased by moving it within the field and keeping loose clothes/plastics, so parts flip in the air and produce sound, scaring birds (Bishop et al., 2003). Beringer, VerCauteren, and Millspaugh (2003) found that animal-activated scarecrows can be useful to protect soybean from white-tailed deer (*Odocoileus virginianus*) in the short-term in small areas. A monofilament fence was ineffective. Automated commercial scarecrows, such as inflatable plastic scarecrows with propane exploders, were effective to varying degrees and in different areas (Bishop et al., 2003).

Odra (deadfall trap)

Odra is a lethal technique to trap rats. A hard soil block is used since rock is not readily available in the Tarai of Nepal (Figure 7.5). The use of *odra* at home and in the field is a traditional Tharu practice. Apart from some specific communities, such as Mushar, *odra* is not used by other local communities because they believe that rat meat is impure. It is not only used to control the rats but also to capture field rats, as they are a culturally important meat for the Tharu community. Now, the modern rat trap and even rat poison are becoming common in households, but they are not used to capture/kill field rats.

Figure 7.5 *Odra* (deadfall trap) to capture field rats

Photo source: https://primitivelifeways.com/events/primitive-traps-and-deadfalls

Despite varying levels of efficacy of traditional practices for managing birds, wildlife and rats, these practices remain in rural farming communities. Some techniques, such as scarecrow and deadfall, have been improved, and industrial products are used. Fitzwater (1970) described the use of “trapping – the oldest profession” to capture predators. Cage traps, false floors, triggered doors, one-way doors, funnel traps, spring traps, and glue are some traditional physical trapping techniques for trapping rodents, birds and wildlife.

The *atwa* and *jhukka* function as non-chemical and non-lethal methods for managing birds and wildlife as a part of the ecosystem. The *odra* is a lethal method for controlling fast-breeding pests, such as rats. Tharu people dig field rat traps throughout the rice harvesting season; they also collect rice from the rat holes together with rats. Although there is no direct link with global warming mitigation potential, these local practices do not emit CH_4 or N_2O.

7.5 *Dehari*—Tharu Indigenous technology for seed and grain storage

7.5.1 Post-harvest storage in the Tharu community

Various post-harvest technologies are available for agricultural produce before it is marketed or stored for seed. The Tharu also have some unique foods and beverages, such as *maar* (boiled rice with soup to drink in the summer) and *jaar* (rice beer), which are part of the local food culture. The Tharu use a variety of locally made structures and technologies to store agro-produce. Table 7.7 shows a few common post-harvest structures with their typical functions. In post-harvest handling and storage, women play a leading role in grain processing, drying, storage, utilisation, and even decide how much grain and other agro-produce to sell.

Table 7.7 Common post-harvest storage structures in the western Tharu

Storage structure	**Function**	**Storage duration**
Dehari (earthen grain storage)	Storage of agricultural produce, tools and goods. Rice can be stored for 4–5 years without damage. Hulled rice storage for short-term.	Long-term storage (>1 year)
Chhitni (made from bamboo) *Jhauwa* (made from plants)	Storing onion, garlic, potato and taro for a few weeks to a season.	Short-term storage (<6 months)
Bakhari (made from bamboo, elephant grass)	Mostly used to store rice before sale and excess rice that cannot be stored in *dehari*.	Medium-term storage (up to 1 year)
Surli (hanging maize outside the house	Maize hanging in a sunny open area for sun-drying and storage. Garlic, hanging in shade and open area for storage.	Medium-term storage (up to 1 year)
Alu poka (seed potato wrapped in rice straw and plastered with cattle dung and hung in shade)	Tharu Indigenous technology for storing potato; little decay (<25%) inside the bundle.	Medium-term storage (6–9 months)
Underground storage	Taro storage underground for seed. Mixing taro with turmeric and plastering on the ground with straw and cow dung is better than the sole storage of taro.	Medium-term storage (up to six months)

Among the various post-harvest structures, *dehari* is probably one of the oldest Indigenous technologies in Tharu communities.

7.5.2 Dehari and its importance in Tharu communities

Dehari is an earthen storage structure prepared at home by Tharu women. There are different types of *dehari*, each known differently according to its shape, size and use: *dehari, kuthli,* and *jabara*. *Kuthli* is a small form of *dehari,* which is normally chest height. It is used for the temporary storage of daily use goods for the kitchen, such as hulled rice and split pulses. *Jabara* is circular, increasing gradually from bottom to the centre and decreasing from the centre to the top, making a dumb-bell shape. Unlike *dehari* and *kuthli*, it does not have an *aan* (lid). It is used to store blankets, beds, utensils and art crafts (*dhakia, gondari, suppa,* etc.).

Dehari is not only used for seed and grain storage, but also as a room separator; it has cultural importance, e.g. as a wall painting (*Astimki*) to celebrate the birthday of Lord Krishna. *Pataha dehari* (also called *altar dehari*) is one of the biggest and most important *dehari,* which separates the *deuhrar* (divinity room) and the *bhittar* (kitchen). *Pata* is the place for deities; the *Maiyak pata* (the central place for main deity) is in front of the *patha dehari* and where the holy bag (with *Guru Baba*, the first Tharu and the creator of god) and other divine tools, such as cane and sword are hung (McDonaugh, 2000). It also promotes family ties, since it is a gift from mother-in-law to daughter-in-law for her assuming post-marital residence with her husband's family.

The importance of *dehari* remains in the modern house[42], as it does in the traditional wooden house in the Tharu community. However, due to the modern concrete types of houses,

[42]Local people consider that modern houses are made of brick, cement and iron rods, which are permanent in nature, whereas local traditional houses are constructed with timber and locally available forest materials and roofed with grasses and tiles.

dehari is gradually being moved from the main house to separate subsidiary houses, such as *chhirwa*[43] and *baggar/ghari*[44]. Various alternate storage structures have been introduced in the villages, but many are unused and inferior to *dehari*. One woman at Thapuwa said,

> There is no storage better than *dehari*. You can see [showing the damaged wheat that she was drying]! When I open my wheat stored in a plastic container, it was black. I lost my seed and had to buy from the market.

Dimensions and parts of dehari

Dehari is circular to square in shape, constructed as a hollow storage structure in various shapes and sizes, usually 2 × 1.5 × 3 m (length × breadth × height). The thickness of mud in the structure is about 3–5 cm. The main parts of the *dehari* are the *pendi* (base), body, neck and *bharkan* (cover) (Figure 7.6). The *pendi* is as large as the main body. It holds the main body of *dehari* and is one of the thickest parts (~5 cm); if the *pendi* breaks, then the life of the *dehari* is over. The body part is normally made of 2–3 sections and determines the height of the *dehari*. The thickness of the clay wall of the body is 3–4 cm. The neck is slightly narrowed, and it holds the cover. The thickness of the neck is similar to the main body. The *bharkan* (cover) is circular and slightly thinner than the *pendi* (base). There are two additional parts of *dehari, aan* and legs. The hole is called *aan* from where grain is removed. It is located about 15–20 cm above the *pendi*. The entire *dehari* structure stands upon the legs (usually two), which are made of wood, brick or mud. Termite attack is unlikely with *sakhuwa* wood (*Shorea robusta*) and brick legs. The legs are generally 20–30 cm long, depending on the need, and about the width of a brick.

[43] *Chhirwa* is a house (on its own) open on both sides. This is similar to a garage and used to get rest and sleep during the warm months.
[44] *Baggar* also known as *ghari* is a cattle shed that is normally fenced with wood.

Figure 7.6 Paddy rice storage in *dehari*

Dehari construction

Since *dehari* are earthen structures, considerable care is taken in their construction. The construction takes place in a sunny place before being moved to its permanent home after complete drying (Figure 7.7). All parts of the *dehari* are constructed separately and then assembled.

Soil selection

The quality of a *dehari* depends on the quality of the soil used, with clay soil considered optimal. The place from where the soil is dug is called *garaura*. Women determine the quality of soil by making a paste. The white soil found in the bank of a river and yellow soil in the forest with no gravel, stone or other inert materials are considered appropriate.

Soil paste preparation

The soil is broken into small pieces and then soaked with water in a pit or clean ground surface bound by fresh cattle dung. When the soil is fully soft, it is mixed with soft rice straw in a 1:1 ratio to form a sticky paste. The straw anchors the soil particles that make *dehari* durable.

Sticky paste that do not break between finger gaps upon squeezing is considered a good soil paste.

Construction process

Construction of the *dehari* is an art; not everyone can build one. Only women build them, with girls trained from a young age through direct observation, helping the main artist and gradually through fostering practice. The technique of *dehari* building is shown in Figure 7.7.

Figure 7.7 A woman constructing a *dehari* at Thapuwa

After preparing the soil paste, soft rice straw is spread over clean ground so that it does not stick to the ground. An appropriate size of the first part of the body is built with 3–5 cm thickness. A certain height is built (10–15 cm) and allowed to sun-dry. The construction continues gradually each day, taking a month or more for completion. It is crucial that the *dehari* is completed before it gets fully sun-dried. Mud joints must attach to make a single piece. Firewood ash is put on top of the ongoing construction to let it dry or to separate successive parts. The parts are built separately before being assembled in a fixed place.

7.5.3 Experience with dehari use

Appropriate seed and grain drying are crucial before being stored in *dehari*. Farmers allow drying to occur pre- and post-harvest and after threshing. Sun and air drying are the common drying techniques. Women decide the appropriate moisture condition of seed for storage. The local techniques and knowledge of pre-storage indicators shared by the Tharu are summarised in Table 7.8.

Table 7.8 Local indicators for pre-storage crops

Crop	**Indicator for storage**
Rice	Harvest and left in the field to dry until green stalk completely dry. *Kharhi* (piled up drying) in the *khenhwa* (threshing yard). Undried rice breaks in milling.
Wheat	Dry as a standing crop, harvest, tie in bunches, and left in the field to dry. No need to dry after threshing.
Maize	Harvest, remove husk from cobs, sun-dry for 2–3 days, thresh and sun-dry for another 2–3 days until it produces a metallic sound during drying.
Lentil	Harvest and sun-dry for 2–3 days in the field or threshing floor and then thresh. When biting, it should produce a *kitik* (sharp sound).
Pea	Harvest and dry for 4–5 days and then either walk animals over it or manually thresh. Biting easily separates cotyledons with a sharp sound.
Mustard	Brownish seed turns to a blackish colour. On immersion in hot edible oil, cotyledons split when dry; watery burst when seed is not well-dried.
Potato	Air-dried in the shade. No moisture in the ground and the outer surface of tuber is an indicator for proper storage for the medium- and long-term.

Aluminium and plastic bin storage is promoted in the villages by government and non-government organisations, but the *dehari* remains the most common and preferred storage practice of the Tharu. A detailed comparison by women of *dehari* versus aluminium and other bins is summarised in Appendix 11. The use of aluminium and plastic bins for grain storage is a recent initiative that most of the interviewed women in the village have been trying since 2014. All the interviewees except one (Siri) have had poor experiences storing rice in bins.

Two participants (Sundari and Siri) agreed to store rice/grains for a short time (<3 months) in aluminium bins. *Dehari* is a multipurpose storage structure that the Tharu have been using for generations; hence, their attachment to *dehari* is high. All participants described that paddy could be stored for up to five years without any damage in the *dehari*.

There is low damage from storage insects in the *dehari*, thereby promoting long-term storage and contributing to food security. Women believe that there are fewer attacks of weevils and rice moths and no mould formation in *dehari*; moths even die in it, and the grain remains safe. There is a risk that termites enter from the wooden or mud legs, so termite-resistant materials, such as brick legs and plastic inserted between the legs and *pendi* (base) are desirable. *Dehari* has an essential role in food security, as it is mostly used to store unhulled rice for next year's crop or if the current crop is a failure due to extreme climatic variabilities and hazards. Tharu try to save rice for the following year, as eating older rice signifies wealth, and they believe that old rice increases in volume upon cooking.

Dehari is based on the principle of being airtight, with heat insulation. It maintains the temperature and protects from moisture absorption from the atmosphere, two essential factors for seed storage, longevity, germination, and vigour (Justice & Bass, 1978). *Dehari* is sealed and airtight, which decreases the level of oxygen and increases the level of CO_2, causing asphyxiation to weevils (Cheng, Lei, Ahn, Liu, & Zhu-Salzman, 2012). *Dehari* is semi-resistant to flooding; an extended hour of waterlogging during flooding destroys *dehari*. Improved traditional storage structures, including *dehari*, have been tested in flood-affected areas of Nepal, including raised legs and base and plastering of surfaces (Khadka, 2018). Rivera-Ferre et al. (2013) mentioned the use of *kothali* (*kuthli* in the western Tarai) for storing grain in the Tharu of eastern Tarai, Nepal, where the number and size of such storage structures (*kuthli*) reflects the economic prosperity of households.

7.6 Drivers of change in local agriculture

Agriculture is rapidly becoming an external input-based and mechanised enterprise. Farming focuses on increasing production through all possible means. In this context, local crops and landraces are being replaced and are on the verge of extinction. This section explores a broader category of factors changing in agriculture in the western Tarai of Nepal.

7.6.1 Uncertainty in production

Agriculture of the Tharu in the western Tarai remains largely traditional, subsistence-oriented, and weather-dependent. Climate variability and extreme events, such as flooding, high temperature and droughts, continue to affect agricultural production. Some crops and associated practices are highly dependent on seasonal weather. For example, lentil yields are dependent on the weather in winter. If fields receive heavy rain in winter and become waterlogged, then the plants die quickly. The untimely oversupply of water during the winter season floods lentil and pea crops, which affects production. Farmers believe that dew and cold are important for lentil, pea, and other pulses. Therefore, pulses are considered risky crops by young farmers, who prefer secure production from rice–wheat/maize farming.

Local crops and landraces are adapted to the local environment, but as mentioned earlier, many produce lower yields than improved and hybrid seeds. Therefore, cultivation of high-yielding varieties with the use of inorganic fertilisers and irrigation has increased in the study village, particularly in Thapuwa. Sellers of agriculture inputs and the extension agents encourage chemical-based production; therefore, the perception is that hybrid seed yields cannot be achieved without inorganic fertiliser. There is no doubt that the adoption of modern agricultural inputs increases maize, rice and wheat production (2–4-fold in the study villages), but also increases external inputs and decreases crop diversity.

7.6.2 Farm mechanisation in the Tarai

The use of farm power and machinery has been increasing in the Tarai, such as tractors (two- and four-wheels), tillage implements, harvesters, and threshers (Takeshima, Adhikari, Poudel, & Kumar, 2015). Farm mechanisation makes farming convenient and offers time for income diversification of smallholders.

Tractors are not owned by individual farmers but hired for particular farm tasks on a cash or in-kind basis. There are six tractors in Thapuwa and two tractors in Bikri. In general, ploughing is paid in cash on an hourly basis, while threshing is reimbursed on an in-kind basis. A tractor is used to till the land with a harrow, cultivator and field leveller. Nowadays, rotavators (combined tillage and leveller), harvesters (mainly for rice and wheat) and crop threshers (rice, wheat, maize and lentil) are also used. A few large farmers in Thapuwa also use a combine harvester (harvesting and threshing) for wheat. However, rice transplanters are not used in the area due to the need for sophisticated seedling preparation. Animal-drawn rippers and direct seeders are needed for smallholder mechanisation, as well as simple rice transplanter technology, such as the two-wheel tractor-operated machine used for strip tillage in non-puddled rice transplanting in Bangladesh (Johansen, Haque, Bell, Thierfelder, & Esdaile, 2012).

Young farmers prefer mechanisation due to the increased oppourtunity to engage in outside work. Som Prasad Tharu said,

> I earn NPR 16,000 (USD145) in a month from outside wage labour, then why should I spend one month threshing rice with the bullock. It finishes within two hours and I pay just 5 quintals of rice (equivalent to NPR 11,000 = USD 100). It saved NPR 5,000 (USD 45) to me, but I also finished a major task of farming. Now I secure food for the whole year.

Young farmers believe that older farmers used to be solely engaged in agriculture and had no alternatives to animal power; hence, they harvested crops manually, collected and placed them in *kharhi* (piles), and threshed them by bullock treading. Temporary storage of harvested rice in *kharhi* allows farmers time to cultivate wheat, potato and other pulses for the winter season.

Mechanisation has reduced the value of draft animals, such as the bullock. Local cow breeds are problematic because they are a draft breed, not for milking. There is no market value for cows; they graze crops in villages and create traffic problems in cities.

7.6.3 Small-sized land holdings

Nepali farmers are largely small landholders, with an average holding of <0.68 ha (also refer to Tables 6.2 and 6.3 of Chapter 6.3.1). The mean landholding in Thapuwa is 1.16 ha and in Bikri is 0.55 ha per household. However, a large portion of the farmers (45%) are smallholders (<0.5 ha), including 19 *mukta kamaiya* households in Thapuwa with extremely small land ownership (2 *kattha*, 0.1 ha). Landholdings and other essential household characteristics are presented in Table 6.2. The households are small landholders, with households in Bikri have smaller landholdings (0.55 ha/household) than Thapuwa (1.17 ha/household). There are 19 *mukta kamaiya* families in Thapuwa with small plots of land (0.07 ha/family). Despite the small landholdings, particularly in Bikri, the primary occupation of people in both villages is agriculture (Table 6.2).

Despite most households owning some land, the vast majority of the Tharu are tenants and agriculture is the major source of livelihood. A few people work in the village for government and private companies. Employment is limited for junior positions—police, army, and school teacher. Other communities in Nepal, particularly hill Brahmin and Chhetri, dominate government jobs, business and national politics that contribute more to the household economy than farming. Furthermore, the Tharu are farmers, so they prefer to hold agricultural land than high-valued land in city and market centres, unlike other communities in Nepal.

Landholdings have declined due to the legal inheritance of ancestral property, mostly land, by sons—all sons inherit equally with no land inheritance for daughters—which has fragmented the land into small pieces. The Tharu have large families due to their farming-based livelihoods and lack of access to birth control measures. The small-sized landholdings are insufficient for sustaining livelihoods, thus the need to diversify incomes through wage labour locally, within Nepal, and sometimes abroad.

7.6.4 Employment options

Diversification of income sources is a pressing need for small farmers. Many farmers have small pieces of land, and the changing lifestyles no longer supported by subsistence farming. Off-farm labour (skilled and unskilled) is becoming an important source of income to compensate for the low farm income.

Many farmers (41%, according to Table 6.6, chapter 6) perform at least one type of employment outside farming, including working on the farm, doing non-farm physically demanding jobs as carpenters, masons and blacksmiths. There are increasing trends of farmers seeking seasonal wage labour in India, as well as the Gulf States and Malaysia. Farmers invest their earnings from off-farm activities into farm activities. They do not much consider the cost and inputs invested in agriculture; rather, the priority is to finish the farm work as early as possible, with high crop production for household food security and partly for income.

The early engagement of youth in the job market has some negative implications for the education of boys in Thapuwa village. Schoolboys see the income made by others, so they want to engage in such work rather than going to school. As a result, many boys have left school at ages between 14 and 18 years and engage in work.

7.6.5 Unstable market pricing

The market price of many crops (rice, pulses and vegetables) depends on local production and the food import policy of the Nepali government. Vegetable prices depend largely on the Indian market. Production costs are lower in India because of the subsidy on agriculture inputs, such as seed and inorganic fertiliser. Farmers cannot compete with Indian produce in border markets, such as Gulariya.

Farmers do not have a regular source of income—earning twice a year, in November–December by selling rice and in April by selling winter crops (wheat, lentils). Food security and input timing in rice occur in August–September, so farmers often receive a loan from the local merchants, and are then obliged to sell their produce to these local money lenders, often for a low price or with a high interest rate.

This situation compels farmers to either rent land to engage fully in farming or change their profession. Tharu are in a transition phase in an attempt to move away from the social stigma (*kamaiya*), backwardness and poverty, without detaching from the farming and rural livelihood in which they have been engaged for generations.

7.6.6 Agricultural policy

Government policy, programme and strategies are focused on increasing productivity, commercialisation and modernisation. The Agriculture Perspective Plan (APP) implemented from 1995–2015, the ongoing Agriculture Development Strategy (ADS), and other agricultural policies and programs, such as Prime Minister Agriculture Modernisation Project of the government of Nepal are oriented to increasing production and productivity to reduce the national food deficit and improve household food security. Therefore, agrobiodiversity and the promotion of crop landraces and Indigenous practices/methods have low priority. Agricultural extension packages, services and training encourage chemical options rather than sustainable soil and integrated pest management practices, including most local Indigenous knowledge and practices.

The national agriculture policy relating to agriculture and biodiversity conservation includes promotion of local and Indigenous knowledge in the policy documents of government, as this is an obligation of Nepal as a state member of the United Nations, but implementation is limited to the local level.

7.7 Conclusion

Nepal has focused on increasing agricultural productivity through the transformation of subsistence agriculture, with the Tarai as the region for commercialisation and mechanisation. Tharu farmers in the western Tarai are on the verge of adopting the government's modern agriculture technologies and relinquishing traditional practices and Indigenous knowledge for some crops. Modern agriculture largely consists of improved seeds, chemical inputs, irrigation technologies and farm mechanisation. As a result, farmers have rapidly adopted modern agriculture and increased yields 2–4-fold in the major cereal crops (rice, maize and wheat). However, many local agricultural practices and methods remain prevalent, mostly in minor crops, such as lentil, pea and mustard. Mixed cropping of wheat, lentil and mustard has been practised traditionally and is popular for securing food diversity and reducing the risk of crop failure due to climate change. There is a decreasing trend of lentil relay sowing into rice due to inconsistent and lower yields than conventional tillage-based production. The labour cost-savings of zero-tillage are mostly not considered by small landholders.

However, farmers continue to conserve and cultivate landraces of rice (Andi, Karangi, Sauthyari, Tilki), maize (Raksi/Gaiji) and minor crops (lentil, pea, mustard). Landraces require particular cultivation techniques, such as direct seeding of rice in dry and wet beds (Karangi and Sauthyari) and relay sowing of lentil. A combination of landraces and traditional and

Indigenous technology has survived within contemporary commercialised agriculture. Furthermore, local knowledge, classifications (e.g. climate, seasons, and soil) and adjusted practices help farmers to make appropriate decisions and improve resiliency to climate change. Given the largely tacit nature of Indigenous knowledge, it continues to be transformed and transmitted in the Tharu community where rituals provide a platform to practice, verify and update. Ritual ceremonies are not simply outdated practices; they encompass a deep ethno-scientific knowledge of the Tharu community, such as the use of *khirbhan* in *hareri* and plant bio-pesticides in *darbandhi* and pest management (*dahiya, mahiya*). Finally, local knowledge for forecasting weather and extreme climatic events is used by the Tharu and rural farming communities, given the lack of reliable physical weather forecasts at the micro-level of regional variation.

CHAPTER 8. GENERAL DISCUSSIONS AND CONCLUSIONS

8.1 Introduction

The initial overall research question was: how do Indigenous knowledge and practices contribute to resilience in agriculture in response to climate change? The sole focus on Indigenous knowledge and traditional knowledge gradually expanded to cover related aspects of scientific knowledge for the adoption of modern agricultural technologies and practices, after a systematic literature review on the theoretical foundation of knowledge creation and transmission within communities. There are diverse interpretations of Indigenous knowledge, and the term is often interchangeably used with traditional knowledge and local knowledge. From the 1960s–1990s, many studies have endeavoured to bring consensus and understanding between traditional/Indigenous knowledge and scientific knowledge. Within its work on the conservation and sustainable use of biological resources, the Rio de Janeiro Earth Summit 1992 acknowledged and attempted to recognise and foster traditional methods and knowledge of Indigenous people through instruments, such as the Convention on Biological Diversity (CBD 1992) (UNCED, 1992). The World Bank worked on Indigenous knowledge in development programmes in the 1990s and brought it to global attention through publications dealing with Indigenous knowledge and the integration of Indigenous knowledge in development programmes (World Bank, 2004; Warren, 1991; Woytek, 1998). The CBD 1992 and the FAO UN International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA 2001) considered traditional and local knowledge (CBD, 1992; FAO, 2001), but not Indigenous knowledge, because—as the FAO noted—Indigenous knowledge is considered to only be held by Indigenous Peoples (FAO, 2004). These issues are covered in detail, including the national policies of Nepal, in Chapter 2.

Climate change has catalysed perceptions, understandings and local responses on different continents and sparked the formation of the Intergovernmental Panel on Climate

Change (IPCC), which ultimately incorporated Indigenous knowledge from the Fourth Assessment Report (AR4) 2007. With this background, it can be said that the world is convinced of the leading role of scientific knowledge, which is complemented by many local innovations, knowledge and practices that contribute to evaluating and theorising scientific facts and evidence. Not everyone in the world is convinced of the above; for example, many Indigenous rights activists see much of Western science as part of a continuing imperial project (Ellen, 2017; Sillitoe, 2002 & 2017).

My knowledge horizon and research scope widened during my PhD research. The aim was to bridge the anthropological perspective of Indigenous knowledge and the scientific orientation of agricultural practices to understand their relations and complementarity. The philosophical views and approaches vary between anthropology and agricultural science. Anthropology through ethnoscience emphasises understanding the issue from the perspective of local and Indigenous people and dealing with the issue by considering their perceptions, knowledge and skills. The Tharu—the Indigenous people focussed upon in this study—worship nature, and agriculture is their identity and the way of life. In contrast, agricultural science focuses on technology and agronomic practices for dealing with the issue of climate change. The converging point of the two disciplines is crop agronomy for cultivation, protection and post-harvest management. There is a minor issue related to research methods (qualitative and quantitative), where anthropology emphasises qualitative analysis whereas agricultural science emphasises quantitative analysis; hence, I adopted a mixed-methods approach to harness the strengths of both methods. This is also reflected in my supervision by an interdisciplinary team from anthropology and agronomy. However, many of the specific questions of this study remain valid for assessing perceptions, vulnerability, adaptive capacity, and adaptation and mitigation measures of the agricultural frontiers in two predominantly Tharu villages (Thapuwa and Bikri) in the Tarai in western Nepal.

The adoption of modern agriculture is an important adaptation strategy to respond to climate change. Modern agriculture covers technology, input, and scientific knowledge. In the study region the use of improved and hybrid seed, inorganic fertilisers, herbicides, pesticides and irrigation technology dominates, particularly in major cereal crops such as rice, maize and wheat, whereas mostly local methods prevail in the case of minor crops, such as lentils, peas, and mustard. Rice, wheat and maize are globally important crops, with many options available in terms of varieties and cultivation technologies, compared to the minor crops. Rice is the most important staple crop in Nepal, including among the Tharu. The main reason for growing hybrid rice is for its yield advantage. Rice is culturally important in the rice-eating culture of Asia. Rice consumption an indicator of food security in many communities, including those of the Tharu. Rice is so dominant in Nepali culture that inhabitants expect rice for lunch and dinner. Maize and wheat are two other staple crops that have been modernised with the use of improved and hybrid seeds and chemical inputs.

The distinction between Indigenous and local agricultural practices is a fuzzy one in practice. Therefore, specific Indigenous knowledge explicitly relating to the Tharu, such as *dehari*, is considered as Tharu Indigenous knowledge. There are other various knowledges, which are are not specifically related to the Tharu and and are practiced in the wider community, which are considered as traditional knowledge. Local knowledge is a combination of Indigenous, traditional and scientific knowledge, so it is described as “hybrid knowledge” through out the thesis**.** The Indigenous knowledge claim is made based on the engagement of the Tharu in agriculture in the Tarai region of Nepal. Historical evidence shows that the Tharu were the first settlers in the Tarai during the era of malaria outbreaks until its eradication in the 1950s, during which time the Tarai became the most populated region of Nepal and the Tharu were marginalised (Chaudhary, 2008; Krauskopff, 1995, 2000; Panjiyar, 2000; Regmi, 1977). The Tharu are agricultural pioneers who played an important role in developing agriculture and associated knowledge in the region. Thus, agricultural knowledge and the practices associated with the Tharu have developed over time, as the Tharu have sought to improve and consolidate their agricultural livelihoods.

To illustrate the links between knowledge systems, climate adaptation and mitigation, and yield/profitability, on the advice of my supervisors[45] I developed a framework to compare the various agricultural practices used by Tharu farmers (Figure 8.1). Succeeding sections present a description of components of the model, agricultural practices, and their contribution to mitigation/adaptation and yield/profitability.

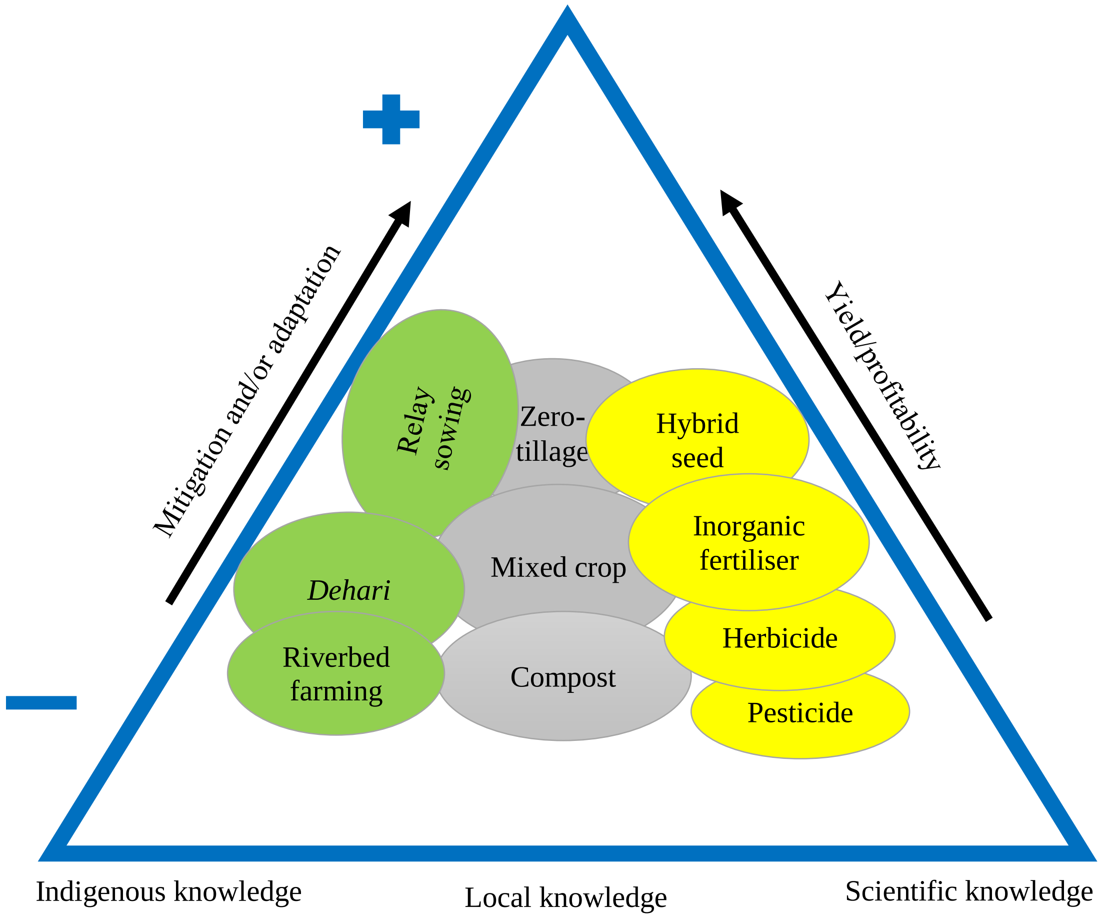


Figure 8.1 Role of knowledge systems in climate change adaptation and mitigation

[45] The initial form of this figure was first suggested by Professor Willie Erskine in a supervision consultation.

The framework is presented in the form of a triangle with the sides illustrating interrelationships among different knowledge-based agricultural practices for adaptation and mitigation and yield/profitability. Agricultural practices that have been adopted in and adapted to the local environment to produce low emissions and competitive yields have led to more climate-resilient agriculture. The axis along the base reflects knowledge across a spectrum from scientific knowledge at one end to Indigenous knowledge at the other end, with local knowledge often a synthesis of those two extremes, as the basis of agricultural practices. The left axis of the triangle represents the contribution to adaptation/mitigation, and the right axis represents yield/profitability. Various agricultural practices prevalent in the Tharu community are shown in ellipses with different colours and positions (distance) from the base of the triangle. The relative size of the ellipse represents its prevalence in farming, while colour represents the form of knowledge (yellow—scientific, grey—local, and green—Indigenous); the vertical position on each ellipse indicates the level of contribution to adaptation/mitigation and profitability dimensions in agriculture. Complementarily, the horizontal position of practices implies that the practice belongs primarily to or is most related to one of the three knowledge systems along the horizontal axis. The upward direction of the black arrows, along with the signs (+ and –), indicates the direction of contribution to adaptation and mitigation and profit, with a larger contribution signified by a position towards the apex of the triangle.

To the left side of the triangle, the first group of knowledge/practices includes relay sowing, *dehari* (Tharu technology for storage structures), and riverbed farming, which are considered Tharu Indigenous agricultural practices, as they are largely exclusively practised by the Tharu in the region. In the middle of the triangle are zero-tillage, mixed cropping, and compost use, all of which are used locally, but integrate scientific knowledge and are used in other Nepalese communities and elsewhere; therefore, these practices are considered as derived from local knowledge. The final group (use of hybrid seed, inorganic fertiliser, pesticide, and herbicide) on the right side of the triangle, are categorised as scientific knowledge, as their use is mostly derived from science and is widespread.

8.2 How Tharu perceive climate change is increasing their vulnerability

Perception of climate change is based on vulnerability, which in turn is largely determined by climatic shocks and impacts under low adaptive capacity. Climatic hazards can severely impact agriculture and livelihoods. The Tharu have perceived climatic changes, including hotter summers, and cold waves during winter due to sudden decreases in temperature with extended hour-days of thick fogs. They are experiencing delayed onset of the monsoon and decreased rainfall during the monsoon, and increased rainfall after rice transplantation (post-monsoon), which has caused flooding in their villages. However, rice is transplanted on time or even 7–10 days earlier than the traditional crop calendar due to irrigation facilities, particularly in Thapuwa village.

The perception of climatic hazards differs according to geography, sociocultural structure, and adaptive capacity. The Tharu ranked flooding as the number one hazard, followed by drought in Bikri and storms in Thapuwa as the second most impactful hazard. The third most important hazard was cold waves in both villages. The hazard ranking was based on the hazard's impact on forms of livelihood capital—natural, physical, social/cultural, human and financial—identified from the hazard matrix ranking derived from participatory focus group discussions. The impact was rated on its frequency, level of loss and damage, and future risks. The Tharu perceive an increased frequency and intensity of various hazards, such as floods, droughts, cold waves. They believe that human interventions and resource exploitation, including forests, are contributing to the changing climate and environment. The villagers have developed coping and adaptation strategies based on the ranking of the hazard. They use their observations and experiences to assess hazard severity and apply a combination of both traditional and scientific knowledge in response. The strategies and activities in response to climate change mostly focus on adjusting to the change (adaptation), of which many of the adjustments also reduce and prevent emissions, thereby helping with the mitigation aspect of climate change.

Temperature and rainfall are the two most-perceived variables related to climate change. Extreme levels of temperature and rainfall lead to drought, flooding, and cold/heat waves that increase vulnerability. The perceptions of the Tharu of increased temperatures matched the physical climatic data trends in the district, but the decreased rainfall pattern could not verified due to the large inter-annual variations. The perceptions also differed by age group, education, and availability of facilities. Formal education and access to information play a critical role in the perceptions of climate change. The middle-aged group perceived climate change more readily than others and most ready to adopt scientific practices. Similarly, the young generation was inclined to access science and technology for information.

The Tharu have complex understandings of natural disasters and environmental change. Some of the climate extremes and natural hazards can be predicted, whereas others are difficult using Indigenous knowledge of various physical and biological indicators. The prediction of rainfall and droughts is commonly practiced, as it is most related to farming. Other hazards, such as storms, hail and their combination are difficult to predict and are perceived as regular climatic phenomena. However, the understanding of Tharu in regard to the overall climate system, environment and biodiversity is connected with the above-mentioned human interventions. Casimir (2008) argued that traditional culture and faith shape the perceptions of climate change in relation to God more than to human beings. A comparative study between Germans and Tongans showed that a Tongan believes that God is involved, while a German blames human interventions for climate change (Nerb, Bender, & Spada, 2008). Furthermore, the perceptions of people with a formal education and Tongans isolated from their culture were linked to scientific knowledge (Nerb et al., 2008). Tharu people did not express anger about environmental changes while I was in the field and were rather concerned about conserving and protecting biodiversity at the local level.

The application and role of Indigenous knowledge to predict weather/climate and natural disasters has declined with the increasing use of scientific technology and methods. However, the integration of Indigenous knowledge with scientific methods for disaster prediction increases the relevance and adoption in the community. There are many examples of the advantages of integrating Indigenous knowledge with scientific methods, including cyclone prediction in a coastal community in Bangladesh (Paul & Routray, 2013), drought in Kenya (Masinde & Bagula, 2011) and different hazards (flooding, drought, diseases) in Ethiopia (Iticha & Husen, 2019). Tharu farmers use various physical and biological indicators for weather forecasting, such as wind direction and the behaviour of insects and other animals. Indigenous knowledge is not limited to the prediction of bad weather and disasters, but worshipping deities involves rituals for their amelioration. Like the "rainmaking" rituals in Africa and Asia, the Tharu perform *gaiya berhna* and *magha lotna* as rainmaking rituals in the western Tarai (see Appendix 10). The Tharu believe that the god of rain *Mahadeva* listens to the voice of people performed in *gaiya berhna* and children's rain requests in the form of producing the sound of a frog in *magha lotna*. There is a deep belief that the crying frog brings rain. Older people have stronger beliefs than the youth and the educated. Many rituals in the Tharu community are performed as an apotropaic tradition since the Tharu fear that the *deuta* (deities) will do something bad to them. Ritual ceremonies relating to agriculture are one of the strongest ways for knowledge presentation, facilitating its transmission to younger generations.

While there may be no scientific basis for the efficacy of rainmaking ceremonies, they have cultural significance in the bringing together of people for Indigenous knowledge education and planning to cope with unusual situations. The customary practices of Indigenous Peoples in governing the village and community function improve the adaptive capacity of communities. The Tharu have the *barghar* system for village governance and community work and the *guruwa* system to protect villagers and agriculture from wild animals, diseases and spirits. Similarly, *kulapani* Chaudhari is a traditional practice of irrigation management using voluntary labour in the Rajapur Irrigation Project in Bardiya (Howarth & Lal, 2002; Pun, 2000). A traditional practice of the Tharu encourages the contribution of free labour for community work; as such, the Tharu were exploited through the *begari* (free compulsory work) for the *jimidar* in Dang of the western Tarai, Nepal (Krauskopff, 1999).

The use of scientific weather information is becoming important for agriculture and disaster risks reduction, but Indigenous knowledge remains the basis of many agricultural practices. Digital technology in agriculture is increasingly used to forecast climatic hazards and the possible incidence of insects and diseases. In Nepal, farmers have limited access to weather information through local FM radio stations and television, and such information is considered unreliable at the micro-level in the specific geographical area studied. Some scientific technologies, such as the flooding early warning system, fit well with the Tharu *barghar* governance system. Through the *khayala/kachehri* (village meeting under the *barghar* system), every household head is responsible for disseminating information to household members on the risks of hazards and coping strategies. Additionally, the *chaukidar* (village watchman) send alerts through a message called *hak parna*. This is an effective mechanism for participatory community decision, information flow and the execution of decisions for adaptation and mitigation in Tharu villages.

Overall, the perceptions of climate change are complex, varying with different sociocultural factors, particularly education and access to information. Young farmers are inclined to use scientific weather forecasting and strategies to reduce the impact of climatic extremes and hazards. However, traditional ways to predict climate and weather are an indispensable part of decision making among older and middle-aged farmers in their daily life and agriculture. They prioritise the hazard based on its impact on overall livelihood capital, particularly loss of and damage to houses, food and standing crops. High-risk hazards, such as flooding, are prioritised and planned for in mitigation and adaptation using local experience-based knowledge and modern technology and practices. The adoption and implementation of resilient technology and practices depend on the adaptive capacity of individual households and the community.

8.3 Can the Tharu deal with the perceived climate changes?

The capacities to adapt to and mitigate climate change are determined by various factors. The livelihoods approach provided the framework for a comprehensive capacity assessment by integrating livelihood capital and their interrelationships for adaptation and mitigation. The participatory group rating showed that the Tharu people had intermediate levels (two out of four) for adaptive capacity, which was insufficient for coping with and adapting to existing floods, droughts and other climatic hazards. The focus group discussion participants identified and selected the five most important indicators for each livelihood capital and rated each indicator (1–4, where 1 is the weakest and 4 is the strongest situation) based on their existing contexts and experience, such as membership in forest user groups, access to government services, membership in saving groups, the *barghar* system, and youth education for assessing social capital in Bikri village. Their knowledge, experiences and practices can reduce vulnerability to tolerable limits, but they require external support during disasters such as flooding. The participatory adaptive capacity rating provides rapid and broad information on the constraints to adaptive capacity, but requires a household level evaluation for individual capacity determination (van de Sand, 2012). Therefore, a binary logistic regression was used to complement the understanding of adaptive capacity factors, which showed that education, access to extension services, and land ownership significantly affect adaptive capacity.

Education, extension services, and land ownership are influenced by social structure and stratification that ultimately determine the adaptive capacity of an individual and the community. Local social stratification is based on various characteristics, such as caste, occupation, economy and education. Tharu people were classified as *matwali* (liquor-drinking) and enslavable in the Nepali caste system and at the bottom of the pyramid in the Hindu *Varna* system that remains influential in the determination of social position and status in the Tarai region. In Nepal, ethnic groups are categorised as *aadibasi janjati* (Indigenous nationalities), like *adivasi* and scheduled tribes in India. The *kamaiya* system (bonded labour in agriculture) in western Nepal further marginalised the Tharu and impacted their social/cultural identity (Chaudhary, 2012). Cultural and caste domination also influence access to information and services from the local government. Many marginalised and excluded groups/communities, such as the *dalit* (so-called ‘untouchables’) and Tharu, could not access disaster relief support or projects to reduce hazards in the western Tarai due to social exclusion and the lack of social and political influences (Jones & Boyd, 2011).

Education and training improve the understanding, knowledge and consideration of adaptation measures. The national education system has a largely western education focus that changes the perception, understanding, and beliefs of people, orienting them towards scientific knowledge. The decision making of educated households to plan and implement adaptation measures were more oriented towards modern agriculture than that of illiterate farmers. Educated farmers can improve their resilience by diversifying income and accessing agricultural inputs and services from governmental and non-governmental agencies. This study showed that education and access to extension services has a significant positive role with regard to adaptive capacity, as reported elsewhere (Ndamani & Watanabe, 2016; Tiwari et al., 2014).

From a gendered perspective, women are more vulnerable to climate change than men because of gender discrimination in society. Women have fewer entitlements to land, financial control, education and human resource development. Furthermore, women have a higher workload than men because of their household chores and farm work, which limits their access and exposure to the outer world. Cultural barriers restrict the mobility of women and their decision making. In the Tharu community, gender discrimination persists, which was reflected in the consistently lower adaptive capacity in regard to livelihood endowment than men in both villages, except for social/cultural and financial forms of capital. . The lower adaptive capacity of women compared to men echoes findings elsewhere. Sugden et al. (2014) found that social stratification based on caste, economy (land, income) and gender determines the vulnerability and adaptation in agrarian livelihoods in the eastern Tarai (Dhanusha and Morang districts) of Nepal. Outmigration (mostly male) adds an extra burden to women due to their expanded role in agriculture, as well as social and community engagement, on top of regular productive (household chores) and reproductive roles (caring for children). This scenario also reflects the context of the Tharu at Thapuwa and Bikri in the Bardiya district. Women left at home, who live in joint families, are supported by family members, but women living in nuclear families are at greater risk during the flooding and other hazards. Furthermore, single women and spouses of migrant workers lack their male counterpart's labour to perform agricultural activities on time because women have certain cultural restrictions related to their work tasks, such as tillage and rice field bund construction in the Tharu community.

The agricultural extension model of Nepal favours modern agriculture. The agricultural policies and programs of the government and projects of NGOs focus on high-yielding crop varieties and the use of chemical inputs, with a low priority given to landraces and local agricultural practices. The Agriculture Perspective Plan (APP) from 1995–2015 and the Agriculture Development Strategy (ADS) 2015–2035 extensively focus on scientific and commercial agriculture in Nepal (MoAD, 2015). However, the agriculture sub-sectoral policies, such as the agrobiodiversity policy 2063 BS (2006 AD) and seed vision 2013–2025, have considered the conservation of biological resources and their sustainable use (MoAD, 2006; SQCC, 2013). The agrobiodiversity policy is based on CBD 1992 and ITPGRFA 2001; therefore, it is more progressive than the ADS in terms of traditional knowledge and skills used in agriculture. However, agricultural policymakers, researchers and extension workers put little emphasis on Indigenous and local knowledge and innovations, which needs to change. Ellen (2007, p. 10) suggested changing the mind-set on local agricultural knowledge from "unnecessary and old-fashioned instead, [to] better against uncertainty." He gave clear evidence of how local agricultural knowledge was replaced in Southeast Asia in the post-1945 period through the influence of capital-intensive modern projects, including the Green Revolution, where farmers could hardly resist the programs. In Nepal, a balanced approach using modern and traditional agriculture is practised, where the Tarai is designated for commercial agriculture to increase production, and traditional farming relegated to hills and mountains due to geographical remoteness and limited infrastructure.

The land is a valuable livelihood capital that is considered natural and physical in nature, but its ownership is linked to the sociocultural context. In Nepali societies, the land also determines wealth and social status (Chaudhary, 2008; Regmi, 1977). Farmers owning land, especially large land holdings (>2 ha), had greater adaptive capacity than sharecroppers and tenants. The sharecropper has to share the harvested product with the landowner or must pay the agreed amount of cash to the landowner irrespective of production. Sugden et al. (2014) found that land is a critical factor for reducing climatic and non-climatic vulnerability in agrarian economies in the eastern Tarai, Nepal. Large landowners lease some of their land and cultivate the rest themselves to reduce the risks, whereas small and medium landowners rent extra land to cultivate despite limited financial capacity for technology and inputs, such as irrigation pumps; as a result, they rely on large landowners for their livelihood. Land can be used for multiple purposes to access credit, finance, production and social wellbeing for farming communities. Smallholders and tenants are compelled to migrate in search of work, which adds to the drudgery of women left at home. Sugden et al. (2014) argued that government strategies and programme for improving adaptive capacity only work in the short-term, but in long-run it is essential to reduce land inequalities and poverty through a transformative adaptation approach for climate justice.

In short, the perception of climate change is important for adaptation and mitigation responses. Based on the perceptions and associated risks, farmers direct their available options, resources, and income diversification to enhance their agricultural resilience to climate change. With the changing social context, income diversification from off-farm work relating to skilled and non-skilled wage labour or even long-term/permanent migration (>1 year) is becoming the choice of youth and middle-aged farmers. A diversified income reduces household vulnerability and can invest on implementation of adaptation strategies, thus improves resilience to climate change. This study provides evidence of how Tharu farmers in the Tarai are exposed to climatic hazards and extremes and how they are reducing their vulnerability through resilient agriculture and livelihoods.

8.4 Adaptation to climate change: strategies and practices

Farmers consider multiple strategies related to agriculture and off-farm to adapt to climate change. In the agricultural sector, the adoption of modern technologies and agronomic practices are the most prevalent climate adaptation strategies in the western Tarai of Nepal. Regarding off-farm adaptation strategies, income diversification through domestic and foreign migrant labour work prevailed, particularly among smallholders. Other studies argue that income from remittances can improve food security and social resilience in the short-term, but increase food dependency and social inequality over time (Adger et al., 2002; Sunam & Adhikari, 2016).

Modern scientific agricultural technology includes irrigation pumps, farm tools and machinery, and information and communication technology. Similarly, modern agriculture practices include the use of inputs—seeds, inorganic fertilisers, herbicides and pesticides—and cultivation and management techniques. While the adoption of modern agricultural inputs and production technology started in Nepal (around 2000 AD), it is confined to the major staple crops (rice, maize and wheat). Traditional agricultural knowledge, practices, and local innovations are strong components in existing farming systems. For example, the use of improved and hybrid seed is a strong indicator of the adoption of modern agriculture, which remains very low in Nepal (<10%) and the study villages. The overall local seed replacement rate with improved and hybrid seed was about 9%, 7%, and 10% for rice, maize and wheat, respectively in 2010/2011 (Pokhrel, 2012). Many farmers are using improved seeds and other inputs, but they remain limited in terms of crop type, proportion and quantity.

The major reasons to use hybrid and improved seed are availability, high yields, short growing season, and resistance to biophysical constraints, such as heat and drought stress. Crop productivity is the major concern of small farmers for household food security and maximising household income. Even large farmers grow fine-grain local rice for self-consumption but use hybrid rice to increase farm income. In the study villages, farmers produce 2–4 times higher yields from hybrid rice and maize than from landraces. The higher yields of hybrid varieties are partially due to a combination of inorganic fertiliser, irrigation facilities, and cultivation techniques. Tharu women, who are mostly responsible for rice transplantation, prefer hybrid rice because it is transplanted at a wider distance between seedlings and with a single seedling per hill, which accelerates manual transplantation and requires fewer seeds. The short growing season of hybrid varieties allows early harvesting of rice, thereby permitting the timely sowing of wheat and other winter crops. It also allows more time for non-agricultural pursuits, such as off-farm occupations.

The adjustment of sowing and harvesting dates of crops to escape the weather and cultivation constraints is another important local adaptation strategy in agriculture. Early sowing and harvesting of crops and associated changes in the crop growing period are supported by new crop varieties and irrigation technology. Rice can be transplanted about two weeks earlier because of the irrigation facilities. Thanks to irrigation, summer maize cultivation has been replaced with rice cultivation, with maize cultivated during the winter-spring season.

Farmers have maintained agrobiodiversity through their continued cultivation of landraces, which not only conserves agrobiodiversity, but more importantly, conserves traditional knowledge and practices that are often climate-smart (adaptive, low emissions and sustainable). Farmers have been cultivating certain landraces of rice (Andi, Karangi, and Sauthyari) and maize (Raksi/Guinji) for generations. Pulses, vegetables, oilseeds, spices and condiments are large groups of crops that have been traditionally cultivated with a large number of landraces. Farmers' knowledge continues through selection, processing and storage of seed and planting materials. Landraces of such crops are adapted to the local environment, use low inputs, and emit low GHGs. Tharu employ Indigenous technology to store grain in *dehari* (earthen grain storage bin) and to preserve unhusked maize in the open (*surli*) and seed potato in rice straw (*alu poka*). This study identified two important rationales for cultivating landraces using traditional methods. The first reason is low availability or complete lack of improved varieties; therefore, farmers continue using traditional methods, which are adapted to the local environment. Many crop landraces are adapted to the local environment, are less attacked by insects/disease and produce consistent yields with preferred quality. There is limited research at the global and national level on minor crops, even pulses and mustard. For example, lentil is Nepal's number one pulse crop (about 60%) in terms of area and production, but productivity is less than 1 t/ha, and many farmers cultivate landraces (Shrestha, Neupane, & Adhikari, 2011). Consistently low yields of lentil (<1 t/ha) were reported in Nepal, India, and Bangladesh, compared to Canada and the USA (>1 t/ha) from 1990–2006 (McNeil, Hill, Materne, & McKenzie, 2007). The second reason is the cultural requirements and taste of landraces. The food culture and taste of local food influences farmers to cultivate local crops and landraces. Andi rice is culturally important for making *chichar* (sticky rice cooked in steam, a typical Tharu cultural food) and *jaar* (sweet rice beer) for *Maghi*—the biggest festival of the Tharu. Similarly, *dal* (soup made from pulses) is required to complement rice; therefore, farmers continue lentil and pea cultivation, even if the yields are lower than winter maize. Rice consumption is becoming increasingly important in Nepal, including among the Tharu. Two decades ago, maize was the most important staple crop after rice and used to be consumed in a variety of ways; now, maize is only consumed when rice is unavailable. There is a risk of declining food diversity in Nepal due to the increasing dominance of rice culture in the mid-hills and mountain regions, replacing local crops such as finger millet, buckwheat and potato.

Indigenous knowledge and local agricultural practices are less applicable, but are consistently being practiced in minor crops. Farmers often practice Indigenous and scientific knowledge and practices together for the crops to cope with local challenges. Thus, different knowledge and practices complement each other for climate adaptation and resilient agriculture. Figure 8.1 presents some of the Tharu Indigenous and local agriculture practices that contribute to a consistent and sustainable production system. Relay sowing (lentil, grass pea, linseed), zero-tillage/no-tillage (pea, garlic), and mixed cropping (any combination of lentil, pea, wheat and mustard) are some of the Indigenous and local crop production methods practised in the western Tarai. The yield and profitability of these practices are not consistent, and yields are normally on par or lower than conventional tillage-based production. However, Indigenous and local agricultural management, mainly in minor crops, rarely use chemical inputs, require low energy use for cultivation, and safeguard from crop failures. The traditional way to store grain also saves energy and reduces emissions.

The cultivation of hybrid crop varieties has increased the application of inorganic fertilisers, pesticides and herbicides in agriculture. The increased use of inorganic fertiliser also has implications for the declining population of manure-producing cattle in the region. The use of pesticides is a last resort for controlling insects and diseases. However, the use of herbicides is increasing, mainly among larger landholders (>2 ha) in Thapuwa village due to the increased cost-effectiveness compared to manual weed removal. Herbicide use has reduced the amount of grass available for fodder, so farmers cultivate berseem clover (*Trifolium alexandrinum*) during the winter-spring season for animal fodder. Although most farmers use inorganic fertiliser, the amount of application per unit area is low (<0.3 t/ha). The increased use of inorganic fertiliser in Bardiya district was verified from the record of sales, which increased seven-fold from 1017 t in 2009/2010 to 7629 t in 2014/2015 (DADO, 2015). The use of inorganic fertiliser has contributed directly to climate change through N_2O emissions, and pesticides and herbicides have indirect implications for emissions and a negative impact on ecology and the environment.

Indigenous and local knowledge and practices may not always contribute to low carbon emissions. In such cases scientific knowledge and technology can improve Indigenous and traditional practices. For example, CH_4 emissions can be reduced from paddy rice cultivation through alternate wetting and drying (Islam et al., 2018; Yang et al., 2012). The traditional practice of composting manure and its subsequent application in the field results in high CH_4 and N_2O emissions, which can be improved through the supply of oxygen to reduce anaerobic bacterial fermentation in manure piled on the land surface or in a pit. Manure needs to be incorporated immediately into the soil after spreading in the field to reduce emissions and nutrient losses (Schilke-Gartley & Sims, 1993).

In conclusion, many Indigenous and local agricultural practices are better adapted in local environment and contribute more to the mitigation of climate change than scientific knowledge-based modern agricultural practices. The modern agriculture technology and inputs have specific traits to adapt to climatic variability (heat/cold, droughts), insect pest and diseases, thereby the adoption is increasing. Hybrid crop varieties, in combination with chemical inputs and irrigation, produce higher yields than Indigenous and local practices, but concurrently increase GHGs emissions from agriculture and energy use in the supply chain in terms of per ha of land. However, emissions are often lower when measured per ton of yield as compared to traditional agriculture. The adoption of hybrid crop varieties increases productivity with increased use of inorganic inputs that ultimately. It also promotes intensive agriculture, which is replacing the pulse crop rotation in the rice system, thereby system may well reduces soil fertility and ultimately creating an unsustainable production system. Some of the traditional agricultural practices, such as relay sowing, zero/reduced tillage and the incorporation of legumes in the farming system contribute to scientific/modern agriculture, allowing it to adapt to climate change and reduce emissions from agriculture. Mitigation is a complementary by-product of adaptation measures by farmers; however, if it is to continue, it cannot be compromised by low yields for the sake of mitigation. Climate-smart agricultural technologies that can adapt to climatic and biological stresses and have low carbon footprints but produce higher yields than landraces and traditional practices could be the choice of farmers. Therefore, farmers use the most productive and profitable agricultural practices not withstanding whether they are scientific, local or even Indigenous practices adapted to the local environment and cultural context.

A limitation of this research is the justification of local agricultural practices in the mitigation of climate change. The study did not focus on the quantitative calculation of emission reductions and mitigation potentials of local agricultural practices and technologies. Estimation at the local level is possible, using the mitigation potential of similar studies as a reference. The figures from two small villages would be too small to generalise for the district and the country. It would be valuable to calculate the mitigation potential at a sub-national and national level using a suitable model that offers a low emissions scenario.

8.5 Significance of the research

The research findings are useful for farming communities and policymakers. At the community level, the research traces the perceptions of local people on climate change that would benefit local farming communities in the design and implementation of coping and adapting strategies for climate variability and extreme events, such as flooding and droughts. Furthermore, given the accuracy of their perceptions, research participants and other members in the village can assess vulnerability and adaptive capacity and request support from local government to improve capacity, protect agrobiodiversity and promote local innovations and practices.

In terms of policy, the research has various implications and practical uses. Firstly, the research has documented various Indigenous knowledge, rituals traditions and practices for climate predictions and hazard management of the Tharu in the western Tarai, Nepal, which is resource material for researchers, development workers, and Indigenous rights activists for environmental conservation, developing climate-smart agriculture and improving farmer wellbeing. Secondly, the research output can be used by local government agencies (Gulariya municipality and others in Bardiya district) in the revision or design of a Local Adaptation Plan of Action (LAPA) to reduce the impact of climate change and improve adaptive capacity.

The research has contributed to the theoretical discourse of climate change adaptation in contemporary research. The value of an integrated (biophysical and socioeconomic) approach of studying vulnerability and the impact of climate change has been extensively argued for (Adger, 2006; Chaudhary et al., 2011; Deressa et al., 2009; Piya et al., 2016) after criticism of the biophysical focus on physical loss and damage and the socioeconomic approach focus on human behaviour and politics/governance. This study contributes to the philosophical and theoretical discourse on knowledge systems by demonstrating how Indigenous knowledge and scientific knowledge may converge in local agriculture to develop climate-smart and sustainable food production. This study should also help to narrow the intellectual debate of knowledge inferiority on ethnoscience and Western science. Moreover, the research insights are based on an interdisciplinary perspective to improve the resilience of vulnerable communities by contributing to types of livelihood capital.

8.6 Thesis conclusions

This study moved from an exclusive focus on Indigenous knowledge to a consideration as well of scientific knowledge and local knowledge and then towards “hybrid knowledge” by integrating Indigenous and local knowledge with scientific knowledge and technology.. The application of Indigenous knowledge (e.g. old climate rules) for weather predictions and practices (e.g. local pest control) has been decreasing due to access to scientific information and technology. It is not so much that traditional knowledge is declining, but rather that it is evolving and in some cases integtrating with scientific knowledge in hybrid forms as the climate changes and other sources of knowledge become accessible. As an Indigenous institution in every Tharu village in western Nepal, the *barghar* local leadership system governs village social, cultural, quasi-judicial and agriculture-related communal work through such institutions as *begari* (free labour contributions). Linked with the *barghar*, the *guruwa* system of shamanic practice also functions to protect and promote the wellbeing of villagers and their agriculture.

Tharu farmers perceive that flooding is the most important hazard in both study villages (Thapuwa and Bikri), while other hazard ratings differed between village location and economic activities. Storms are important for people in Thapuwa as they occur in the spring maize growing season, whereas drought is a bigger issue for people in Bikri due to the inaccessibility to irrigation. These perceptions are built on the direct experiences of shocks in terms of frequency and intensity of impact. Tharu farmers use various traditional techniques for climate and weather forecasting in addition to the meteorological weather forecast. Their disaster preparedness and responses combine various locally available resources and techniques, including early warning systems for hazards, such as flooding. Smallholders, sharecroppers and tenant farmers had higher vulnerability than large landholders and economically strong farmers; this relative vulnerability has driven them to off-farm activities, mostly labour in both domestic and overseas contexts.

The adaptive capacity of Tharu was adequate in the past to cope with and adapt to floods and drought, though not to thrive when having to engage with the losses these hazards caused. However, the frequency of risks of climate hazards are increasing, rendering past adaptations inadequate in the future in the absence of interventions to reduce risks. The frequency of flooding is increasing. The proximity of the study villages to the Babai River has subjected them frequently to floods in the absence of adequate flood protection. The vulnerability to drought has been reduced with irrigation technology and agronomic practices. Among various livelihood-based factors, land entitlements and ownership, formal education and agricultural extension services have significantly affected the adaptive capacity of Tharu farmers. Land ownership is extremely important for the Tharu since most of their livelihoods are dependent on agriculture. Therefore, small landowners rent land for farming; in the absence of farming land, they diversify themselves in off-farm and migrant labour work. In general, the average landholding of the Tharu is larger than the national average, but it is their only source of livelihood and income, unlike the multiple sources of income (e.g. jobs and business) for other social castes in Nepal. Similarly, education has contributed to their access to information and services and diversified incomes. Informal knowledge sharing, training and village traditional rituals and practices also contribute to knowledge generation and transformation in the Tharu community. The agricultural extension service provides inputs, technical services and market information. The government agency, private sector, as well as farmer-to-farmer extension play a role in improving the adaptive capacity of Tharu farmers.

The adoption of modern agriculture technologies, inputs and methods is increasing within the Tharu community. Adoption has been limited largely to major staple crops (rice, wheat and maize) in terms of the cultivation of hybrid and improved seeds and the use of chemical inputs and irrigation technology that boost yields. Modern agriculture is comparatively energy-intensive, with higher emissions of greenhouse gases though the emissions are lower in terms of per tonnes of crop yield than traditional and local methods. There are several local agricultural practices, such as mixed cropping, relay sowing, riverbed farming, and post-harvest technology, that the Tharu Indigenous people continue to use, along with landraces, farmyard manure, and integrated crop protection measures. Relay sowing and riverbed farming are traditional agricultural practices common among many farmers in Tarai, Nepal, so it does not an exclusively belong to the Tharu. The practices integrate modern agricultural techniques and inputs, so they constitute a local innovation in agriculture. Such agricultural practices are adapted to the local environment and cultural system, and their contribution to climate mitigation is higher than modern practices.

Despite the advantages regarding the adaptation and mitigation provided by Indigenous and local agricultural practices, their application has been decreasing mainly due to their low yields and profitability. Farmers have adopted modern technologies and practices in agriculture that improve yields with the added cost of chemical inputs and exclusion of sustainable cropping practices, such as the replacement of pulse crops (lentil, pea) in rice fields. These practices support small farmers to improve food security and household economy, but modern agriculture also increases dependency on production inputs (seeds, inorganic fertilisers, herbicides) as well as decreasing crop diversity. That dependency does not mean that agriculture should remains traditional; such modern introductions as irrigation technology (canal and underground water) play a crucial role to increase the yield of improved crops in conjunction with improved seeds and inorganic fertiliser.

In conclusion, neither Indigenous knowledge nor scientific knowledge alone is sufficient to improve the resilience of Tharu farming communities. The Tharu have embraced “hybrid knowledge”—a combination of Indigenous and scientific knowledge, technology and practice to increase yield and maximise profit as well as decrease vulnerability to extreme weather events. This hybridity is evident in the complementarity of the employment of modern varieties and scientific agricultural practices for the major grains and the continuing use of landraces for minor crops such as lentils, peas and mustard. In addition, the traditional pest management strategies, which often have a ritual component, are used in conjunction with botanical and chemical pesticides. Indigenous knowledge-based agriculture encourages the use of local resources, low-energy intensive practices and the conservation of crop biodiversity, which can provide options of the diversity of knowledge for decision making and policy options in national and global levels.

Four interventions could reduce the anticipated increased vulnerability of the Tharu specifically and the Tarai in general: first, providing skill enhancement and vocational training, particularly for youth, to diversify the income of smallholders through off-farm related activities; second, continued infrastructure development for improved safety and accessibility; third, strengthening agricultural extension for resilient agriculture. Local adaptations based on hybrid knowledge can help mitigate these trends by contributing to the improved management of water and its associated hazards. Fourth there is a need for the government of Nepal to recognise and to promote the continuing value of traditional practices for at least some crops and thus to base extension on this recognition of the value of hybrid practices.

To sum up, this thesis has demonstrated—using a case study of agricultural practices among the Tharu of two villages in the Tarai of Nepal—how the adoption of modern agriculture and preservation of traditional practices based on local and Indigenous knowledge are continuing in the contemporary practice of hybrid agriculture amid efforts to adapt to and mitigate climate change.

REFERENCES

Acciaioli, G. (2017, October 27). [Ethnography is changing its form as a mesography in a short-duration of fieldwork]. *Personal Communication*.

Acciaioli, G. (2020, May 29). [Swidden agriculture in Indonesia]. *Personal Communication*.

Adesina, A. A., Mbila, D., Nkamleu, G. B., & Endamana, D. (2000). Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of southwest Cameroon. *Agriculture, Ecosystems & Environment, 80*(3), 255-265.

Adger, W. N. (1999). Social vulnerability to climate change and extremes in coastal Vietnam. *World Development, 27*(2), 249-269.

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in Human Geography, 24*(3), 347-364.

Adger, W. N. (2006). Vulnerability. *Global Environmental Change, 16*(3), 268-281.

Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., o'Brien, K., Pulhin, J., . . . Takahashi, K. (2007). Assessment of adaptation practices, options, constraints and capacity. In *Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change.* (pp. 717-743). M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (Eds.). Cambridge, UK: Cambridge University Press.

Adger, W. N., Barnett, J., Brown, K., Marshall, N., & O'Brien, K. (2013). Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change, 3*(2), 112-117.

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., . . . Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic Change, 93*(3), 335-354.

Adger, W. N., & Kelly, P. M. (1999). Social vulnerability to climate change and the architecture of entitlements. *Mitigation and Adaptation Strategies for Global Change, 4*(3), 253-266.

Adger, W. N., Kelly, P. M., Winkels, A., Huy, L. Q., & Locke, C. (2002). Migration, remittances, livelihood trajectories, and social resilience. *AMBIO: A Journal of the Human Environment, 31*(4), 358-367.

Aggarwal, P. K., & Sivakumar, M. V. K. (2011). Global climate change and food security in South Asia: an adaptation and mitigation framework. In R. Lal, M. V. K. Sivakumar, M. A. Faiz, A. H. M. Mustafizur Rahman, & K. R. Islam (Eds.), *Climate change and food security in South Asia*: Springer, Dordrecht.

Agrawal, A. (1995). Indigenous and scientific knowledge: some critical comments. *Indigenous Knowledge and Development Monitor, 3*(3), 3-6.

Agresti, A. (1996). *An introduction to categorical data analysis*. USA: John Wiley & Sons.

Ahmed, A., Rahman, A., & Kelley, T. G. (1987). Study on the mixed cropping of wheat and lentil at varying seeding ratios under different levels of fertility. *Bangladesh Journal of Agricultural Research, 12*(1), 53-59.

AIPP. (2012). *Indigenous peoples and climate change adaptation in Asia*. Retrieved from Chiang Mai, Thailand. Retrieved from https://www.iwgia.org/images/publications/0656_IPs_and_Climate_Change_Adaptation_in_Asia.pdf

Alam, M. K., Bell, R. W., & Biswas, W. K. (2019). Decreasing the carbon footprint of an intensive rice-based cropping system using conservation agriculture on the Eastern Gangetic Plains. *Journal of Cleaner Production, 218*, 259-272.

Alam, M. K., Biswas, W. K., & Bell, R. W. (2016). Greenhouse gas implications of novel and conventional rice production technologies in the Eastern-Gangetic plains. *Journal of Cleaner Production, 112*, 3977-3987.

Albuquerque, P. U., & Alves, A. G. C. (2016). What is ethnobiology? In U. P. Albuquerque & R. R. Nóbrega Alves (Eds.), *Introduction to ethnobiology* (pp. 3-7). Cham: Springer International Publishing.

Amon, B., Amon, T., Boxberger, J., & Alt, C. (2001). Emissions of NH_3, N_2O and CH_4 from dairy cows housed in a farmyard manure tying stall (housing, manure storage, manure spreading). *Nutrient Cycling in Agroecosystems, 60*(1-3), 103-113.

Andersen, A. N., Cook, G. D., Corbett, L. K., Douglas, M. M., Eager, R. W., Russell-Smith, J., . . . Woinarski, J. C. Z. (2005). Fire frequency and biodiversity conservation in Australian tropical savannas: implications from the Kapalga fire experiment. *Austral Ecology, 30*(2), 155-167.

Anderson, J., & Bausch, C. (2006). *Climate change and natural disasters: scientific evidence of a possible relation between recent natural disasters and climate change*: Policy brief for the EP Environment Committee (IP/A/ENVI/FWC/2005-35), Brief number 02a, Institute of European Environment Policy and eco logic.

Arbuckle, J. G., Morton, L. W., & Hobbs, J. (2013). Farmer beliefs and concerns about climate change and attitudes toward adaptation and mitigation: Evidence from Iowa. *Climatic Change, 118*(3-4), 551-563.

Asseng, S., Jamieson, P., Kimball, B., Pinter, P., Sayre, K., Bowden, J., & Howden, S. (2004). Simulated wheat growth affected by rising temperature, increased water deficit and elevated atmospheric CO2. *Field Crops Research, 85*(2-3), 85-102.

Ayers, J. M., & Huq, S. (2009). Supporting adaptation to climate change: what role for official development assistance? *Development Policy Review, 27*(6), 675-692.

Barrera-Bassols, N., & Toledo, V. M. (2005). Ethnoecology of the Yucatec Maya: symbolism, knowledge and management of natural resources. *Journal of Latin American Geography, 4*(1), 9-41.

Bates, J., Brophy, N., Harfoot, M., & Webb, J. (2009). *Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC). Agriculture: methane and nitrous oxide*. Retrieved from The Netherlands. Retrieved from https://www.ecofys.com/files/files/serpec_agriculture_report.pdf

Bell, R. W., Haque, M., Jahiruddin, M., Rahman, M., Begum, M., Miah, M., . . . Zahan, T. (2019). Conservation agriculture for rice-based intensive cropping by smallholders in the Eastern Gangetic Plain. *Agriculture, 9*(1), 5.

Bellarby, J., Tirado, R., Leip, A., Weiss, F., Lesschen, J. P., & Smith, P. (2013). Livestock greenhouse gas emissions and mitigation potential in Europe. *Global Change Biology, 19*(1), 3-18.

Beringer, J., VerCauteren, K. C., & Millspaugh, J. J. (2003). Evaluation of an animal-activated scarecrow and a monofilament fence for reducing deer use of soybean fields. *Wildlife Society Bulletin*, 492-498.

Berners-Lee, M., Hoolohan, C., Cammack, H., & Hewitt, C. N. (2012). The relative greenhouse gas impacts of realistic dietary choices. *Energy Policy, 43*, 184-190.

Bhatta, G. D., & Aggarwal, P. K. (2015). Coping with weather adversity and adaptation to climatic variability: a cross-country study of smallholder farmers in South Asia. *Climate and Development, 8*(2), 145-157.

Bhattacharyya, P., Sinhababu, D. P., Roy, K. S., Dash, P. K., Sahu, P. K., Dandapat, R., . . . Mohanty, S. (2013). Effect of fish species on methane and nitrous oxide emission in relation to soil C, N pools and enzymatic activities in rainfed shallow lowland rice-fish farming system. *Agriculture, Ecosystems & Environment, 176*, 53-62.

Bhushan, L., Ladha, J. K., Gupta, R. K., Singh, S., Tirol-Padre, A., Saharawat, Y., . . . Pathak, H. (2007). Saving of water and labor in a rice-wheat system with no-tillage and direct seeding technologies. *Agronomy Journal, 99*(5), 1288-1296.

Bishop, J., McKay, H., Parrott, D., & Allan, J. (2003). *Review of international research literature regarding the effectiveness of auditory bird scaring techniques and potential alternatives*. Retrieved from London, UK. Retrieved from https://canadianbirdstrike.ca/wp-content/uploads/2018/02/Bishop_et_al_2003.pdf

Bista, D. B. (1972). *Peoples of Nepal*. Kathmandu, Nepal: Ratna Pustak Bhandar.

Böhm, A. (2004). Theoretical coding: text analysis in grounded theory. In U. Flick, E. v. Kardorff, & I. Steinke (Eds.), A companion to qualitative research (pp. 270-275). London: SAGE Publications Ltd.

Borjas, G. J. (1987). Self-selection and the earnings of immigrants. *The American Economic Review, 77*(4), 531-553.

Borjas, G. J. (2008). Labor outflows and labor inflows in Puerto Rico. *Journal of Human Capital, 2*(1), 32-68.

Bowen, A., Cochrane, S., & Fankhauser, S. (2012). Climate change, adaptation and economic growth. *Climatic Change, 113*(2), 95-106.

Briggs, J. (2005). The use of indigenous knowledge in development: problems and challenges. *Progress in Development Studies, 5*(2), 99-114.

Briggs, J. (2013). Indigenous knowledge: a false dawn for development theory and practice? *Progress in Development Studies, 13*(3), 231-243.

Bruun, T. B., De Neergaard, A., Lawrence, D., & Ziegler, A. D. (2009). Environmental consequences of the demise in swidden cultivation in Southeast Asia: carbon storage and soil quality. *Human Ecology, 37*(3), 375-388.

Cannon, R. J. (1998). The implications of predicted climate change for insect pests in the UK, with emphasis on non-indigenous species. *Global Change Biology, 4*(7), 785-796.

CARE International. (2009). *Climate vulnerability and capacity analysis: a handbook* (1st ed.): CARE International.

Caritas. (2016). *Approaching resilience: practices and innovations supporting smallholder climate change adaptation*. New Delhi: Caritas India.

Casimir, M. J. (2008). The mutual dynamics of cultural and environmental change: an introductory essay. In M. J. Casimir (Ed.), *Culture and the changing environment: uncertainty, cognition, and risk management in cross-cultural perspective* (pp. 1-60): Berghahn Books.

CBD. (1992). The Convention on Biological Diversity. Retrieved from https://www.cbd.int/doc/legal/cbd-en.pdf

CBS. (2007). *National census 2001 (population and caste/ethnicity)*. Kathmandu, Nepal: Central Bureau of Statistics (CBS), Government of Nepal.

CBS. (2011a). *Nepal in figure*. Kathmandu, Nepal: Central Bureau of Statistics (CBS), Government of Nepal.

CBS. (2011b). *A summary report of national agriculture census 2011*. Kathmandu, Nepal: Central Bureau of Statistics (CBS), Government of Nepal.

CBS. (2014a). *Population atlas of Nepal*. Kathmandu, Nepal: Central Bureau of Statistics (CBS), Government of Nepal.

CBS. (2014b). *Population monograph of Nepal* (Vol. II). Kathmandu, Nepal: Central Bureau of Statistics (CBS), Government of Nepal.

Chakraborty, D., Ladha, J. K., Rana, D. S., Jat, M. L., Gathala, M. K., Yadav, S., . . . Raman, A. (2017). A global analysis of alternative tillage and crop establishment practices for economically and environmentally efficient rice production. *Scientific Reports, 7*(9342).

Chakraborty, S., Tiedemann, A. V., & Teng, P. S. (2000). Climate change: potential impact on plant diseases. *Environmental Pollution*, *108*(3), 317-326.

Chalise, S., & Naranpanawa, A. (2016). Climate change adaptation in agriculture: a computable general equilibrium analysis of land-use change in Nepal. *Land Use Policy, 59*, 241-250.

Chaudhary, B. R. (2012). Socio-economic status of freed-bonded Labourers (*mukta kamaiya*) in Nepal. *Sudasien*, *Zeitschrift des Sudasienburo. Journal of Right to Food*, *Special Issue 'Nepal'*, *32*(3-4), 94-97.

Chaudhary, B. R., Acciaioli, G., Erskine, W., & Chaudhary, P. (2018). *Vulnerability of the Tharu indigenous people to climate change in western Tarai of Nepal.*, Proceedings of International Scientific Conference. Towards sustainable development: climate change response for sustainability and security. Vitnam National University, Hanoi, Vietnam.

Chaudhary, M. (2008). *The Tarai of Nepal and its landowners [In Nepali: Nepal ko Tarai tatha yeska bhumiputraharu]*. Dang, Nepal: Shanti Chaudhary, Rural Women Development Organization.

Chaudhary, P., & Bawa, K. S. (2011). Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biology Letters, 7*, 767-770.

Chaudhary, P., Rai, S., Wangdi, S., Mao, A., Rehman, N., Chettri, S., & Bawa, K. S. (2011). Consistency of local perceptions of climate change in the Kangchenjunga Himalaya landscape. *Current Science*, 504-513.

Chaudhary, S. L. (2003). *Tharus: the pioneer of civilization of Nepal*. Kathmandu, Nepal: Muna Press.

Cheng, W., Lei, J., Ahn, J.-E., Liu, T.-X., & Zhu-Salzman, K. (2012). Effects of decreased O_2 and elevated CO_2 on survival, development, and gene expression in cowpea bruchids. *Journal of Insect Physiology, 58*(6), 792-800.

Chhetri, N., Chaudhary, P., Tiwari, P. R., & Yadaw, R. B. (2012). Institutional and technological innovation: understanding agricultural adaptation to climate change in Nepal. *Applied Geography, 33*, 142-150.

Coakley, S. M., Scherm, H., & Chakraborty, S. (1999). Climate change and plant disease management. *Annual Review of Phytopathology, 37*(1), 399-426.

Conklin, H. C. (1957). *Hanunoo agriculture. A report on an integral system of shifting cultivation in the Philippines*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Conklin, H. C. (1980). *Ethnographic atlas of Efugao*. New Haven and London: Yale University Press.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Los Angeles: SAGE

DADO Bardiya. (2015). *Annual agriculture development programme and statistics book*. Gulariya, Bardiya, Nepal: District Agriculture Development Office (DADO), Government of Nepal

Dahit, G. (2005). *An introduction to Tharu culture*. Kathmandu, Nepal: National Foundation for Development of Indigenous Nationalities (NFDIN), Government of Nepal.

Dahit, G. (2008). *Tharu indigenous knowledge and practices*. Kathmandu, Nepal: National Foundation for Development of Indigenous Nationalities (NFDIN), Government of Nepal.

Dalzell, V. M. (2015). *Freedom, margins and music: musical discourses of Tharu ethnicity in Nepal*. (Doctoral dissertation), University of California, Riverside. Retrieved from https://escholarship.org/uc/item/0vg8n6pg

Dangol, D. R. (2008). Traditional uses of plants of commonland habitats in western Chitwan, Nepal. *Journal of Institute of Agriculture and Animal Science, 29*, 71-78.

Datta, A., Santra, S. C., & Adhya, T. K. (2013). Effect of inorganic fertilizers (N, P, K) on methane emission from tropical rice field of India. *Atmospheric Environment, 66*, 123-130.

DDC Bardiya. (2013). *District profile and resource map [In Nepali: Jilla bastugat bibaran, 2071 V.S.]* Gulariya, Bardiya, Nepal: District Development Committee (DDC) Bardiya, Government of Nepal.

de Vries, M., & de Boer, I. J. M. (2010). Comparing environmental impacts for livestock products: a review of life cycle assessments. *Livestock Science, 128*(1), 1-11.

DoFRS, (Cartographer). (2019). Gulariya Nagarpalika, Bardiya, Province-5. Department of Forest Research and Survey (DoFRS), Ministry of Forest and Environment, Government of Nepal.

Deressa, T., Hassan, R. M., & Ringler, C. (2008). *Measuring Ethiopian farmers' vulnerability to climate change across regional states*: Intl Food Policy Res Inst.

Deressa, T. T., Hassan, R. M., & Ringler, C. (2011). Perception of and adaptation to climate change by farmers in the Nile Basin of Ethiopia. *The Journal of Agricultural Science, 149*(1), 23-31.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., & Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, *19*(2), 248-255.

DesInventar. (2018). Composition of disasters in Nepal. Retrieved from https://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=npl&continue=y

Devkota, R. P., Bajracharya, B., Maraseni, T. N., Cockfield, G., & Upadhyay, B. P. (2011). The perception of Nepal's Tharu community in regard to climate change and its impacts on their livelihoods. *International Journal of Environmental Studies*, *68*(6), 937-946.

Dewalt, B. (1994). Using indigenous knowledge to improve agriculture and natural resource management. *Human Organization, 53*(2), 123.

Dhakal, S., Rai, J., Chemchong, D., Pradhan, P., Maharjan, J., & Chaudhary, S. (2000). *Isues and experiences: kamaiya system, Kanra aandolan and Tharus in Bardiya*. Retrieved from www.spacenepal.org

Dhama, K., Rathore, R., Chauhan, R., & Tomar, S. (2005). Panchagavy (Cowpathy): an overview. *Intrnal Journal of Cow Science, 1*(1), 1-15.

DHM. (2015). *Study of climate and climatic variation over Nepal (final draft report)*. Retrieved from Kathmandu, Nepal. Retrieved from https://www.dhm.gov.np/uploads/climatic/47171194Climate%20and%20Climatic%20variability%20of%20Nepal-2015.pdf

DHM. (2017). *Observed climate trend analysis in the districts and physiographic regions of Nepal (1971-2014)*. Kathmandu, Nepal: Department of Hydrology and Meteorology (DHM), Ministry of Population and Environment, Government of Nepal.

Diederen, P., Van Meijl, H., Wolters, A., & Bijak, K. (2003). Innovation adoption in agriculture: innovators, early adopters and laggards. *Cahiers d'Economie et Wociologie Rurales, 67*, 29-50.

Dilley, M., Chen, R. S., Deichmann, U., Lerner-lam, A. L., Arnold, M., Agwe, j., . . . Yetman, G. (2005). *Natural disaster hotspots: a global risk analysis*. Washington, DC: The World Bank, Hazard Management Unit.

Dutfield, G. (2001). Trips-related aspects of traditional knowledge. *J. Int'l L.*, 233-276.

Ellis, F. (2000). *Rural livelihoods and diversity in developing countries*: Oxford university press.

Ellen, R. (2007). Introduction. In R. Ellen (Ed.), *Modern crises and traditional strategies: local ecological knowledge in Island Southeast Asia* (Vol. Studies in Environmental Anthropology and Ethnobiology,). New York: Berghahn Books.

Ellison, D., Morris, C. E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., . . . Pokorny, J. (2017). Trees, forests and water: Cool insights for a hot world. *Global Environmental Change, 43*, 51-61.

EPA. (n.d.). Understanding global warming potentials. from United States Environmental Protection Agency (EPA). Retrieved from https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

FAO. (2001). International Treaty on Plant Genetic Resource for Food and Agricuture (ITPGRFA) 2001. Retrieved from http://www.fao.org/plant-treaty/overview/texts-treaty/en/

FAO. (2004). What is local knowledge. Retrieved 24/11/2017, from Food and Agriculture Organization of the United Nations (FAO). Retrieved from http://www.fao.org/tempref/docrep/fao/007/y5610e/y5610e00.pdf

Farooq, M., Siddique, K. H. M., Rehman, H., Aziz, T., Lee, D. J., & Wahid, A. (2011). Rice direct seeding: experiences, challenges and opportunities. *Soil & Tillage Research, 111*(2), 87-98.

Finucane, M. (2009). *Why science alone won't solve the climate crisis: managing climate risks in the Pacific*. Retrieved from http://hdl.handle.net/10125/11545

Fitzwater, W. D. (1970). Trapping-the oldest profession. *Proceedings of the 4th Vertebrate Pest Conference (1970)*, 101-108.

Flick, U. (2004). Triangulation in qualitative research. In U. Flicks, E. v. Kardorff, & I. Steinke (Eds.), *A companion to qualitative research* (pp. 178-183). London: SAGE Pulblications.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change, 16*(3), 253-267.

Foster, G. (1979). Fieldwork in Tzintzuntzan. In G. M. Foster, G. Scudder, D. Colson, & R. V. Kemper (Eds.), *Long-term field research in social anthropology* (pp. 165-184). New York: Academic.

Fowler, C. S. (1977). Ethnoecology. In D. L. Hardesty (Ed.), *Ecological anthropology* (pp. 215-243). New York: John Wiley & Sons.

Fox, J., Fujita, Y., Ngidang, D., Peluso, N., Potter, L., Sakuntaladewi, N., . . . Thomas, D. (2009). Policies, political-economy, and swidden in Southeast Asia. *Human Ecology, 37*(3), 305-322.

Fujisawa, M., & Kobayashi, K. (2010). Apple (*Malus pumila var. domestica*) phenology is advancing due to rising air temperature in northern Japan. *Global Change Biology, 16*(10), 2651-2660.

Galloway McLean, K. (2009). *Advanced guard: climate change impacts, adaptation, mitigation and indigenous peoples – a compendium of case studies* (UNU-IAS Ed.). Darwin, Australia: United Nations University (UNU) - Institute of Advanced Studies (IAS), Traditional Knowledge Initiative.

Ganguli, P. (2001). *Intellectual property rights: unleashing the knowledge economy*: Tata McGraw-Hill Publishing Company.

Gartaula, H. N., Niehof, A., & Visser, L. (2010). Feminisation of agriculture as an effect of male out-migration: unexpected outcomes from Jhapa District, Eastern Nepal. *International Journal of Interdisciplinary Social Sciences, 5*(2), 565-577.

Gartaula, H. N., Visser, L., & Niehof, A. (2012). Socio-cultural dispositions and wellbeing of the women left behind: A case of migrant households in Nepal. *Social Indicators Research, 108*(3), 401-420.

Gathala, M. K., Timsina, J., Islam, M. S., Rahman, M. M., Hossain, M. I., Harun-Ar-Rashid, M., . . . McDonald, A. (2015). Conservation agriculture based tillage and crop establishment options can maintain farmers' yields and increase profits in South Asia's rice–maize systems: evidence from Bangladesh. *Field Crops Research, 172*, 85-98.

Gbetibouo, G. A. (2009). Understanding farmers' perceptions and adaptations to climate change and variability: the case of the Limpopo Basin, South Africa. *IFPRI Discussion Paper 00849*, 36.

Geertz, C. (1963). *Agricultural involution: the process of ecological change in Indonesia*. Berkley and Los Angeles, California: Univ of California Press.

Gellner, D. N. (2018, January 20). Politics of Buddhism in Nepal. *Economic and Political Weekly*.

Gentle, P., & Maraseni, T. N. (2012). Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental Science and Policy, 21*, 24-34.

Ghimire, S. K., Shrestha, A. K., Shrestha, K. K., & Jha, P. K. (2000). Plant resources use and human impact around Royal Bardia National Park, Nepal. *Journal of Natural History Museum, 19*, 3-26.

Ghorbani, E., Khodamoradi, M., Bozorgmanesh, M., & Emami, A. (2012). Indigenous knowledge in agriculture. *World Rural Observation, 4*(4), 88-92.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., . . . Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. *Science, 327*(5967), 812-818.

Gooding, M., Ellis, R., Shewry, P., & Schofield, J. (2003). Effects of restricted water availability and increased temperature on the grain filling, drying and quality of winter wheat. *Journal of Cereal Science, 37*(3), 295-309.

Government of Nepal, & UNDP. (2014). *Nepal human development report 2014: beyond geography, unlocking human potential*. Kathmandu, Nepal: National Planninjg Commission (NPC)/ Government of Nepal, United Nations Development Programme (UNDP).

Grab, S., & Craparo, A. (2011). Advance of apple and pear tree full bloom dates in response to climate change in the southwestern Cape, South Africa: 1973–2009. *Agricultural and Forest Meteorology, 151*(3), 406-413.

Gumo, S. (2017). Praying for Rain: Indigenous Systems of Rainmaking in Kenya. *The Ecumenical Review, 69*(3), 386-397.

Guneratne, A. (1998). Modernization, the state, and the construction of a Tharu identity in Nepal. *Journal of Asian Studies, 57*(3), 749-773.

Guneratne, A. (1999). The shaman and the priest: ghosts, death and ritual specialists in Tharu society. *HIMALAYA, the Journal of the Association for Nepal and Himalayan Studies, 19*(2), 9-20.

Guneratne, A. (2002). *Many tongues, one people: the making of Tharu identity in Nepal*. Ithaca and London: Cornell University Press

Guneratne, A. (2007). The Tharu of Chitwan, Nepal. In B. Brower & B. R. Johnston (Eds.), *Disappearing peoples?: Indigenous groups and ethnic minorities in South and Central Asia* (pp. 91-106). California: Taylor & Francis Group.

Guneratne, A. (2010). Tharu-state relations in Nepal and India. *HIMALAYA, the Journal of the Association for Nepal and Himalayan Studies, 29*(1), 19-28.

Gurung, G. B., Pande, D. P., & Khanal, N. P. (2014). Riverbed vegetable farming for enhancing livelihoods of people: a case study in the Tarai region of Nepal. In K. L. Maharjan (Ed.), *Communities and livelihood strategies in developing countries*. Tokyo: Springer.

Haden, V. R., Niles, M. T., Lubell, M., Perlman, J., & Jackson, L. E. (2012). Global and local concerns: what attitudes and beliefs motivate farmers to mitigate and adapt to climate change? *PLoS ONE, 7*(12), e52882.

Hamilton, F. (1819). *An account of the kingdom of Nepal and of the territories annexed to this dominion by the house of Gorkha*. New Delhi: Manjusri Pub. House.

Hamilton, J. G., Dermody, O., Aldea, M., Zangerl, A. R., Rogers, A., Berenbaum, M. R., & Delucia, E. H. (2005). Anthropogenic changes in tropospheric composition increase susceptibility of soybean to insect herbivory. *Environmental Entomology, 34*(2), 479-485.

Handelman, D. (2004). Introduction: why rituals in Its own right? How so? *Social Analysis, 48*(2), 1-32.

Handelman, D. (2008). Afterword: returning to cosmology – thoughts on the positioning of belief. *The International Journal of Social and Cultural Practice, 52*(1), 181-195.

Haque, M., Bell, R., Islam, M., & Rahman, M. (2016). Minimum tillage unpuddled transplanting: an alternative crop establishment strategy for rice in conservation agriculture cropping systems. *Field Crops Research, 185*, 31-39.

Harness, D. M. (2000). *The nakshastras: the lunar mansions of vedic astrology* (First Indian Edition ed.). Delhi: Motilal Banarsidass Publ.

Helvetas Nepal. (2011). *Nepal's climate change polices and plans: local communities' perspective*. Retrieved from Kathmandu, Nepal. Retrieved from https://www.eda.admin.ch/dam/countries/countries-content/nepal/en/resource_en_208677.pdf

Hiler, E. A., & Howell, T. A. (1983). Irrigation options to avoid critical stress: an overview. In H. M. Taylor, W. R. Jordan, & T. R. Sinclair (Eds.), *Limitations to efficient water use in crop production* (pp. 479-497). USA: Americal Society of Agronomy.

Hobbs, P. R., & Giri, G. S. (1997). Reduced and zero-tillage options for establishment of wheat after rice in South Asia. In Braun HJ., Altay F., Kronstad W.E., Beniwal S.P.S., & M. A. (Eds.), *Wheat: prospects for global improvement. Developments in plant breeding* (Vol. 6, pp. 455-465): Springer, Dordrecht.

Hodges, R. J., Buzby, J. C., & Bennett, B. (2011). Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. *The Journal of Agricultural Science, 149*(S1), 37-45.

Hou, H., Peng, S., Xu, J., Yang, S., & Mao, Z. (2012). Seasonal variations of CH_4 and N_2O emissions in response to water management of paddy fields located in Southeast China. *Chemosphere, 89*(7), 884-892.

Howarth, S. E., & Lal, N. K. (2002). Irrigation and participation: rehabilitation of the Rajapur project in Nepal. *Irrigation and Drainage Systems, 16*(2), 111-138.

Howden, S. M., Soussana, J.-F., Tubiello, F. N., Chhetri, N., Dunlop, M., & Meinke, H. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences, 104*(50), 19691-19696.

Hufschmidt, G. (2011). A comparative analysis of several vulnerability concepts. *Natural hazards, 58*(2), 621-643.

Hunn, E. (2007). Ethnobiology in four phases. *Journal of Ethnobiology, 27*(1), 1-10.

Hunn, E. (2014). To know them is to love them. *Ethnobiology Letters, 5*, 146-150.

IFRC. (2018). Types of disasters: Definition of hazard. Retrieved from http://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/

IPCC. (1996). *Climate change 1995: impacts, adaptations and mitigation of climate change: scientific-technical analyses* (R. T. Watson, M. C. Zinyowera, R. H. Moss, & D. J. Dokken Eds.). Contribution of working group II to the second assessment report of the intergovernmental pannel on climate change. New York & Melbourne: Cambridge University Press.

IPCC. (2001). *Climate change 2001: impacts, adaptation, and vulnerability. A report of working group II of the intergovernmental panel on climate change*. Contribution to working group II to the third assessment report of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press.

IPCC. (2007). *Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change* (M. Parry, O. Canziani, J. Palutikof, P. v. d. Linden, & C. Hanson Eds.). Cambridge, UK: Cambridge University Press.

IPCC. (2012). Smmary for policymakers. In C. B. Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, a. M. Tignor, & P. M. Midgley (Eds.), *Managing the risks of extreme events and disasters to advance climate change adaptation* (pp. 3-21). A special report of working groups I and II of the intergovernmental panel on climate change. Cambridge, UK and New York, USA: Cambridge University Press.

IPCC. (2014a). *Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change* (C. B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, & L. L. White Eds.). Cambridge, UK and New York, USA: Cambridge University Press.

IPCC. (2014b). *Climate change 2014: mitigation of climate change. Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change* (O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K.Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx Eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

IPCC. (2014c). *Climate change 2014: synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change* (Core writing team, R. K. Pachauri, & L. A. Meyer Eds.). Geneva, Switzerland.

ISET International. (2014). Climate resilience framework. Retrieved from https://www.i-s-e-t.org/climate-resilience-framework

Islam, S. F. U., van Groenigen, J. W., Jensen, L. S., Sander, B. O., & de Neergaard, A. (2018). The effective mitigation of greenhouse gas emissions from rice paddies without compromising yield by early-season drainage. *Science of the Total Environment, 612*, 1329-1339.

Iticha, B., & Husen, A. (2019). Adaptation to climate change using indigenous weather forecasting systems in Borana pastoralists of southern Ethiopia. *Climate and Development, 11*(7), 564-573.

Jagadish, S. V. K., Craufurd, P. Q., & Wheeler, T. R. (2007). High temperature stress and spikelet fertility in rice (Oryza sativa L.). *Journal of Experimental Botany, 58*(7), 1627-1635.

Jain, S. K. (2001). Ethnobotany in modern India. *Phytomorphology, 51*(3-4), 39-54.

Jat, R. K., Sapkota, T. B., Singh, R. G., Jat, M. L., Kumar, M., & Gupta, R. K. (2014). Seven years of conservation agriculture in a rice–wheat rotation of Eastern Gangetic Plains of South Asia: yield trends and economic profitability. *Field Crops Research, 164*, 199-210.

Johansen, C., Haque, M., Bell, R., Thierfelder, C., & Esdaile, R. (2012). Conservation agriculture for small holder rainfed farming: opportunities and constraints of new mechanized seeding systems. *Field Crops Research, 132*, 18-32.

Jones, L., & Boyd, E. (2011). Exploring social barriers to adaptation: insights from Western Nepal. *Global Environmental Change, 21*(4), 1262-1274.

Jordan, J. (2009). *Rethinking community resilience to climate change: does a social capital lens help.* Paper presented at the Development Studies Association Conference.

JOSHUA Project. (2018). Tharu. Retrieved from https://joshuaproject.net/people_groups/15464

Justice, O. L., & Bass, L. N. (1978). *Principles and practices of seed storage* (Vol. Agriculture Handbook No. 506). Washington, DC: US Department of Agriculture

Kabir, M. A., Rahim, M. A., & Majumder, D. A. N. (2016). Productivity of garlic under different tillage methods and mulches in organic condition. *Bangladesh Journal of Agricultural Research, 41*(1), 53-66.

Karna, P. K. (2014). *Impact of climate change in rice production of Nepal*. Kathmandu, Nepal: South Asian Network for Development and Environmental Economics (SANDEE).

Kesheng, S., & Zhen, L. (1997). Effect of rice cultivars and fertilizer management on methane emission in a rice paddy in Beijing. *Nutrient Cycling in Agroecosystems, 49*(1), 139-146.

Khadka, N. B. (2016). *Tharu brghar-mukhiya indigenous model: a case study of Tharu community of Nepal.* (Doctoral dissertation), Nova Southeastern University, (ProQuest Number 10256356)

Khadka, R. (2018). *Safe grain storage in flood-prone area*. Retrieved from http://repo.floodalliance.net/jspui/handle/44111/3005

Kimber, R. (1983). Black lightning: Aborigines and fire in central Australia and the western desert. *Archaeology in Oceania, 18*(1), 38-45.

Klein, R., Midgley, G., Preston, B., Alam, M., Berkhout, F., Dow, K., & Shaw, M. (2014). Adaptation opportunities, constraints and limits. In *Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change.* (pp. 899-943). [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R. C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S.S. MacCracken, P.R. Mastradrea, and L.L. White (Eds.)]. Cambridge, UK and New York, USA: Cambridge University Press.

Klein, R. J. T. (2010). Linking adaptation and development finance: A policy dilemma not addressed in Copenhagen. *Climate and Development*, *2*(3), 203-206.

Krauskopff, G. (1995). The Anthropology of the Tharus: An Annoted Bibliography. *Kailash, 17*(3-5), 185-213.

Krauskopff, G. (1999). Curvees (Begaari) in Dang: ethno-historical Notes. In O. Herald (Ed.), *Tharu and Tarai Neigbour* (Vol. 16, pp. 63-83). Kathmandu: Babliotheca Hymalayica.

Krauskopff, G. (2000). From jungle to farms: a look at Tharu history. In G. M. Krauskopff (Ed.), *The Kings of Nepal and the Tharu of the Terai* (Vol. 2, pp. 25-48). Kirtipur, Nepal: Center for Nepalese and Asian Studies (CNAS).

Kumar, S., Singh, R. G., Piggin, C., Haddad, A., Ahmed, S., & Kumar, R. (2011). No-till lentil: an option for profitable harvest in dry areas. *Grain Legumes, 57*, 39-42.

Kumar, V., & Ladha, J. K. (2011). Direct seeding of rice: recent developments and future research needs. In D. L. Sparks (Ed.), *Advances in Agronomy* (Vol. 111, pp. 297-413): Academic Press.

Ladha, J. K., Rao, A. N., Raman, A. K., Padre, A. T., Dobermann, A., Gathala, M., . . . Piepho, H. P. (2016). Agronomic improvements can make future cereal systems in South Asia far more productive and result in a lower environmental footprint. *Global Change Biology, 22*(3), 1054-1074.

Lal, M. (2003). Global climate change: India's monsoon and its variability. *Journal of Environmental Studies and Policy, 6*(1), 1-34.

Lal, R. (2011). Climate of South Asia and the Human Wellbeing. In R. Lal, M. V. K. Sivakumar, M. A. Faiz, A. H. M. Mustafizur Rahman, & K. R. Islam (Eds.), *Climate change and food security in South Asia*: Springer, Dordrecht.

Lal, R. (2016). Potential and challenges of conservation agriculture in sequestration of atmospheric CO2 for enhancing climate-resilience and improving productivity of soil of small landholder farms. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 11*(009), 1-16.

Lamsal, K., Chaudhary, P., & Bhandari, K. H. (2014). *Climate change policy in Nepal: challenges, opportunities and imperative.* Pokhara, Nepal: Local Initiatives for Biodiversity Research and Development (LI-BIRD).

Langness, L. L. (1965). *The life history in anthropological science*. New York: Holt, Rinehart and Winston.

Lemos, M. C., Agrawal, A., Eakin, H., Nelson, D. R., Engle, N. L., & Johns, O. (2013). Building adaptive capacity to climate change in less developed countries. In G. Ansar & J. Hurrell (Eds.), *Climate science for serving society* (pp. 437-457): Springer, Dordrecht.

Lenton, T. M., Livina, V. N., Dakos, V., Van Nes, E. H., & Scheffer, M. (2012). Early warning of climate tipping points from critical slowing down: comparing methods to improve robustness. *Phil. Trans. R. Soc. A, 370*(1962), 1185-1204.

Letizia, C. (2014). Buddhist activism, new sanghas, and the politics of belongining among some Tharu and Magar communities of Southern Nepal. In G. Toffin & J. Pfaff-Czarnecka (Eds.), Facing globalization in the Himalayas: belonging and the politics of the self (Vol. Governance, Conflict, and Civic Action, Volume 5, pp. 298-325). New Delhi: SAGE

Li, C., Qiu, J., Frolking, S., Xiao, X., Salas, W., Moore, B., . . . Sass, R. (2002). Reduced methane emissions from large-scale changes in water management of China's rice paddies during 1980–2000. *Geophysical Research Letters, 29*(20), 33.31-33.34.

Lithourgidis, A., Dordas, C., Damalas, C. A., & Vlachostergios, D. (2011). Annual intercrops: an alternative pathway for sustainable agriculture. *Australian Journal of Crop Science, 5*(4), 396.

Lobell, D. B., Hammer, G. L., McLean, G., Messina, C., Roberts, M. J., & Schlenker, W. (2013). The critical role of extreme heat for maize production in the United States. *Nature Climate Change, 3*(5), 497-501.

Lobell, D. B., Sibley, A., & Ortiz-Monasterio, J. I. (2012). Extreme heat effects on wheat senescence in India. *Nature Climate Change*, *2*(3), 186-189.

Locke, P. (2011). The ethnography of captive elephant management in Nepal: a synopsis. *Gajah, 34*(1), 32-40.

Lodhi, S., & Mikulecky, P. (2010). Management of indigenous knowledge for developing countries. *Communication and Management in Technological Innovation and Academic Globalization*, 94-98.

Long, J. S., & Freese, J. (2006). *Regression models for categorical dependent variables using Stata* (2nd ed.). College Station, Tex: Stata press.

Luedeling, E., Girvetz, E. H., Semenov, M. A., & Brown, P. H. (2011). Climate change affects winter chill for temperate fruit and nut trees. *PLoS ONE, 6*(5), e20155.

Maharjan, S. K., Maharjan, K. L., Tiwari, U., & Sen, N. P. (2017). Participatory vulnerability assessment of climate vulnerabilities and impacts in Madi Valley of Chitwan district, Nepal. *Cogent Food & Agriculture*, *3*(1), 1310078.

Maharjan, S. K., Sigdel, E. R., Sthapit, B. R., & Regmi, B. R. (2011). Tharu community's perception on climate changes and their adaptive initiations to withstand its impacts in Western Terai of Nepal. *International NGO Journal*, *6*(2), 35-42.

Malik, A. I., Ali, M. O., Zaman, M. S., Flower, K., Rahman, M. M., & Erskine, W. (2016). Relay sowing of lentil (Lens culinaris subsp. culinaris) to intensify rice-based cropping. *The Journal of Agricultural Science, 154*(5), 850-857.

Malla, G. (2009). Climate change and its impact on Nepalese agriculture. *Journal of Agriculture and Environment, 9*, 62-71.

Manandhar, N. P. (1985). Ethnobotanical notes on certain medicinal plants used by Tharus of Dang-Deokhuri District, Nepal. *International Journal of Crude Drug Research, 23*(4), 153-159.

Manandhar, S., Vogt, D., Perret, S., & Kazama, F. (2011). Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices. *Regional Environmental Change, 11*(2), 335-348.

Manea, A., Leishman, M., & Downey, P. (2011). Exotic C4 grasses have increased tolerance to glyphosate under elevated carbon dioxide. *Weed Science, 59*(1), 28-36.

Marsh, D., & Furlong, P. (2002). A skin not a sweater: ontology and epistemology in political science. In V. Lowndes, D. Marsh, & G. Stoker (Eds.), *Theory and methods in political science* (Fourth edition, pp. 177-198). London: PALGRAVE.

Marvin, H. J. P., Kleter, G. A., Noordam, M. Y., Franz, E., Willems, D. J. M., & Boxall, A. (2013). Proactive systems for early warning of potential impacts of natural disasters on food safety: climate-change-induced extreme events as case in point. *Food Control, 34*(2), 444-456.

Masinde, M., & Bagula, A. (2011). ITIKI: bridge between African indigenous knowledge and modern science of drought prediction. *Knowledge Management for Development Journal, 7*(3), 274-290.

Maslak, M. A. (2003). *Daughters of the Tharu: gender, ethnicity, religion, and the education of Nepali girls*. New York & London: RoutledgeFalmer.

McDonald, A., Riha, S., & Ditommaso, A. (2010). Early season height differences as robust predictors of weed growth potential in maize: new avenues for adaptive management? *Weed Research, 50*(2), 110-119.

McDonald, A., Riha, S., DiTommaso, A., & DeGaetano, A. (2009). Climate change and the geography of weed damage: analysis of US maize systems suggests the potential for significant range transformations. *Agriculture, Ecosystems & Environment, 130*(3-4), 131-140.

McDonaugh, C. (2000). Spirit, substance, vehicle. Kinship and cosmology among the Dangaura Tharu, Nepal. *Social Anthropology, 8*(1), 19-32.

McLeman, R., & Smit, B. (2006). Migration as an adaptation to climate change. *Climatic Change, 76*(1-2), 31-53.

McNamara, K. E., Westoby, R., & Smithers, S. G. (2017). Identification of limits and barriers to climate change adaptation: case study of two islands in Torres Strait, Australia. *Geographical Research, 55*(4), 438-455.

McNeil, D. L., Hill, G. D., Materne, M., & McKenzie, B. A. (2007). Global Production and World Trade. In Shyam S. Yadav, David McNeil, & P. C. Stevenson (Eds.), *Lentil: an ancient crop for modern times* (pp. 95-106). The Netherlands: Springer.

Mendoza Zuany, R. G. (2009). Building hybrid knowledge at the Intercultural University of Veracruz, Mexico: an anthropological study of indigenous contexts. *Intercultural Education, 20*(3), 211-218.

Mishra, A. K., Khanal, A. R., & Pede, V. O. (2017). Is direct seeded rice a boon for economic performance? Empirical evidence from India. *Food Policy, 73*, 10-18.

Mishra, J. S., & Singh, V. P. (2012). Tillage and weed control effects on productivity of a dry seeded rice–wheat system on a Vertisol in Central India. *Soil and Tillage Research, 123*, 11-20.

MoAD. (2006). *National agro-biodiversty policy 2063 BS (2006 AD), first amendment 2071 BS (2014 AD)*. Kathmandu, Nepal: Ministry of Agricultural Development (MoAD), Government of Nepal.

MoAD. (2015). *Agriculture Development Strategy (ADS) 2015 to 2035 (Part: 1)*. Kathmandu, Nepal: Ministry of Agricultual Development (MoAD), Government of Nepal.

Modiano, G., Terrenato, G., Novelletto, L., Di Rienzo, A., Colombo, A., Purpura, B., . . . Modiano, L. (1991). Protection against malaria morbidity: Near-fixation of the α-thalassemia gene in a Nepalese population. *American Journal of Human Genetics, 48*(2), 390-397.

MoE. (2010a). *National Adaptation Programme of Action (NAPA) to Climate Change*. Kathmandu, Nepal: Ministry of Environment (MoE), Government of Nepal.

MoE. (2010b). *National framework on Local Adaptation Plans for Action (LAPA)*. Kathmandu, Nepal: Ministry of Environment (MoE), Government of Nepal.

MoE. (2011). *Climate change policy of Nepal 2011*. Kathmandu, Nepal: Ministry of Environment (MoE), Government of Nepal.

MoF. (2019). *Economic survey 2018/19*. Kathmandu, Nepal: Ministry of Finance (MoF), Government of Nepal.

MoFE. (2019a). *National environment policy 2019*. Kathmandu, Nepal: Ministry of Forest and Environment (MoFE), Government of Nepal.

MoFE. (2019b). *Climate change scenarios for Nepal for national adaptation plan (NAP)* Kathmandu, Nepal: Ministry of Forest and Environment (MoFE), Government of Nepal.

MoFSC. (2015). *Nepal REDD+ strategy, Part I: operational summary*. Kathmandu, Nepal: REDD Implementation Center, Ministry of Forests and Soil Conservation (MOFSC), Government of Nepal.

MoHA. (n.d.). *Comparative information on flood victims 2068-2072 (2011-2016) in Nepal*. Ministry of Home Affairs (MoHA), Government of Nepal. Retrieved from http://www.drrportal.gov.np/document

MoHA, & DPNet-Nepal. (2015). *Nepal disaster report 2015*. Retrieved from http://www.drrportal.gov.np/uploads/document/329.pdf

MoPE. (2016). *Renewable energy subsidy policy 2073 VS* Kathmandu, Nepal: Ministry of Population and Environment (MoPE), Government of Nepal.

Morgan, C. L. (2011). *Vulnerability assessments: a review of approaches*. Gland, Switzerland. Retrieved from http://www.iucn.org/building-coastal-resilience

Mosse, D., Gupta, S., & Shah, V. (2005). On the margins in the city: *adivasi* seasonal labour migration in western India. *Economic and Political weekly*, 3025-3038.

Müller-Böker, U. (1999a). *The chitwan Tharus in southern Nepal: an ethno ecological approach*. Stuttgart: Franz Steiner Verlag.

Müller-Böker, U. (1999b). The voices from Chitwan: some examples of the Tharus' oral tradition. *HIMALAYA, the Journal of the Association for Nepal and Himalayan Studies, 19*(2), 45-48.

Müller-Böker, U.. (1997). Tharus and Pahariyas in Chitawan: observations on the multi-ethnic constellation in southern Nepal. In I Stellrecht, & Winiger, M. (eds.) *Perspectives on history and change in the Karakorum, Hindukush, and Himalaya* (Vol. 3, pp. 157-169). Koln: Culture Area Karakorum, Scientific Studies, *3,:*157-169. .

Müller-Böker, U. (1993). Ethnobotanical studies among the Chitawan Tharus. *Journal of the Nepal Research Centre*, *9*, 17-56.

Müller, A. (2009). *Benefits of organic agriculture as a climate change adaptation and mitigation strategy in developing countries*. Retrieved from https://gupea.ub.gu.se/handle/2077/19131

Murgueitio, E., Calle, Z., Uribe, F., Calle, A., & Solorio, B. (2011). Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands. *Forest Ecology and Management*, *261*(10), 1654-1663.

Nader, L. (2011). Ethnography as theory. *HAU: Journal of Ethnographic Theory*, *1*(1), 211-219.

Nakashima, D. J., McLean, K.G., Thulstrup, H.D., Castillo, A.R. & Ruis, J.T. (2012). *Weathering uncertainty: traditional knowledge for climate change assessment and adaptation* (D. McDonald Ed.): United Nations Education, Scientific and Cultural Organisation (UNESCO) and The United Nations University (UNU).

Nakicenovic, N., Alcamo, J., Grubler, A., Riahi, K., Roehrl, R., Rogner, H.-H., & Victor, N. (2000). *Special report on emissions scenarios (SRES), a special report of working group III of the intergovernmental panel on climate change*: Cambridge University Press.

Ndamani, F., & Watanabe, T. (2016). Determinants of farmers' adaptation to climate change: a micro level analysis in Ghana. *Scientia Agricola*, *73*(3), 201-208.

Nelson, G., Rosegrant, M., Koo, J., Robertson, R., Sulser, T., Zhu, T., . . . Lee, D. (2009). Climate change: impact on agriculture and costs of adaptation. *IDEAS Working Paper Series from RePEc*.

Nelson, R., Kokic, P., Crimp, S., Meinke, H., & Howden, S. M. (2010). The vulnerability of Australian rural communities to climate variability and change: Part I—Conceptualising and measuring vulnerability. *Environmental Science & Policy, 13*(1), 8-17.

Nerb, J., Bender, A., & Spada, H. (2008). Attributed causes of environmental problems: a cross-cultural study of coping strategies. In M. J. Casimir (Ed.), *Culture and the changing environment: uncertainty, cognition and risk management in cross-cultural perspective* (pp. 107-123).

Neuman, W. L. (2004). *Basics of social research: qualitative and quantitative approaches* (2nd Ed.). Boston: Pearson Education, Inc.

NFDIN. (2002). *National Foundation for Development of Indigenous Nationalities Act, 2058 (2002)*. Kathmandu, Nepal: National Foundation for Development of Indigenous Nationalities (NFDIN), Government of Nepal. Retrieved from http://www.nfdin.gov.np/uploads/ck/5df9de0c60dda.pdf.

Nhemachena, C., & Hassan, R. M. (2008). Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. *IFPRI Research Brief*, 5-7.

Noble, I. R., Huq, S., Anokhin, Y. A., Carmin, J., Goudou, D., Lansigan, F. P., . . . Villamizar, A. (2014). Adaptation needs and options. In C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, & L. L. White (Eds.), *Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change* (pp. 833-868). Cambridge, UK and New York, USA: Cambridge Universit Press.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: how Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

NPC. (2011). *National living standard survey 2010/11* (Vol. 2). Kathmandu, Nepal: National Planning Commission (NPC), Government of Nepal

Oo, A. Z., Sudo, S., Inubushi, K., Mano, M., Yamamoto, A., Ono, K., . . . Ravi, V. (2018). Methane and nitrous oxide emissions from conventional and modified rice cultivation systems in South India. *Agriculture, Ecosystems and Environment, 252*, 148-158.

Otto-Banaszak, I., Matczak, P., Wesseler, J., & Wechsung, F. (2011). Different perceptions of adaptation to climate change: a mental model approach applied to the evidence from expert interviews. *Regional Environmental Change, 11*(2), 217-228.

Pandey, A., Mai, V. T., Vu, D. Q., Bui, T. P. L., Mai, T. L. A., Jensen, L. S., & de Neergaard, A. (2014). Organic matter and water management strategies to reduce methane and nitrous oxide emissions from rice paddies in Vietnam. *Agriculture, Ecosystems and Environment, 196*, 137-146.

Panjiyar, T. N. (2000). In my own words: In search of the Tharu past. In G. Krauskopff & P. Myer (Eds.), *The King of Nepal and the Tharu of the Tarai* (Vol. 2, pp. 49-55). Kirtipur, Kathmandu, Nepal: The Center for Nepalese and Asian Studies (CNAS), Tribhuvan University (TU).

Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains: quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1554), 3065-3081.

Pasteur, K. (2011). *From vulnerability to resilience, a framework for analysis and action to build community resilience*. UK: Practical Action Publishing.

Pathak, H., Jain, N., Bhatia, A., Patel, J., & Aggarwal, P. K. (2010). Carbon footprints of Indian food items. *Agriculture, Ecosystems & Environment, 139*(1), 66-73.

Paul, S. K., & Routray, J. K. (2013). An analysis of the causes of non-responses to cyclone warnings and the use of indigenous knowledge for cyclone forecasting in Bangladesh. In *Climate change and disaster risk management* (pp. 15-39): Springer.

Peng, S., Hou, H., Xu, J., Mao, Z., Abudu, S., & Luo, Y. (2011). Nitrous oxide emissions from paddy fields under different water managements in southeast China. *Paddy and Water Environment, 9*(4), 403-411.

Peng, S., Huang, J., Sheehy, J. E., Laza, R. C., Visperas, R. M., Zhong, X., . . . Cassman, K. G. (2004). Rice yields decline with higher night temperature from global warming. *Proceedings of the National Academy of Sciences, 101*(27), 9971-9975.

Perch-Nielsen, S. L., Bättig, M. B., & Imboden, D. (2008). Exploring the link between climate change and migration. *Climatic Change, 91*(3-4), 375.

Phillips, R. E., Thomas, G. W., Blevins, R. L., Frye, W. W., & Phillips, S. H. (1980). No-tillage agriculture. *Science, 208*(4448), 1108-1113.

Piya, L., Joshi, N. P., & Maharjan, K. L. (2016). Vulnerability of Chepang households to climate change and extremes in the Mid-Hills of Nepal. *Climatic Change, 135*(3-4), 521-537.

Piya, L., Maharjan, K. L., & Joshi, N. P. (2012a). Comparison of adaptive capacity and adaptation practices in response to climate change and extremes among the Chepang households in rural Mid-Hills of Nepal. *Journal of International Development and Cooperation, 18*(4), 55-75.

Piya, L., Maharjan, K. L., & Joshi, N. P. (2012b). Perceptions and realities of climate change among the Chepang communities in rural Mid-Hills of Nepal. *Journal of Contemporary India Studies: Space and Society, Hiroshima University, 2,* 35-50.

Pokhrel, A., & Soni, P. (2018). An investigation into a resource and environmentally sustainable system: zero-tillage lentil and garlic production in Nepal. *Agroecology and Sustainable Food Systems, 42*(9), 982-1002.

Pokhrel, S. (2012). Role of DISSPRO and CBSP on current seed supply situation in Nepal. *Journal of Agriculture and Environment, 13,* 53-59.

Polanyi, M. (1958). *Personal knowledge: towards a post-critical philosophy*. London Routledge & Kegan Paul.

Porter, J., Parry, M., & Carter, T. (1991). The potential effects of climatic change on agricultural insect pests. *Agricultural and Forest Meteorology, 57*(1-3), 221-240.

Porter, J. R., Xie, L., Challinor, A. J., Cochrane, K., Howden, S. M., Iqbal, M. M., . . . Travasso, M. I. (2014). Food security and food production systems. In C. B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, & L. L. White (Eds.), *Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change*. Cambridge, UK and New York, USA: Cambridge University Press.

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., & Kunin, W. E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology & Evolution, 25*(6), 345-353.

Poudel, S., & Kotani, K. (2013). Climatic impacts on crop yield and its variability in Nepal: do they vary across seasons and altitudes? *Climatic Change, 116*(2), 327-355.

Powlson, D. S., Stirling, C. M., Thierfelder, C., White, R. P., & Jat, M. L. (2016). Does conservation agriculture deliver climate change mitigation through soil carbon sequestration in tropical agro-ecosystems? *Agriculture, Ecosystems and Environment, 220*, 164-174.

Practical Action. (2009). *Temporal and spatial variability of climate change over Nepal (1976–2005)*. Kathmandu, Nepal: Practical Action Nepal Office.

Practical Action. (2017). *Developing national disaster risk reduction policy and strategic action plan in Nepal, 2016- 2030: lessons learned from recent major disasters in Nepal*. Practical Action Consulting Pvt Ltd. Kathmandu. Retrieved from http://drrportal.gov.np/uploads/document/917.pdf

Pradhan, B., Sharma, P., & Pradhan, P. K. (2019). Impact of cold wave on vulnerable people of Tarai region, Nepal. In *Climate Change and Global Warming*: IntechOpen.

Pradhan, B. B., Shrestha, R. M., Hoa, N. T., & Matsuoka, Y. (2017). Carbon prices and greenhouse gases abatement from agriculture, forestry and land use in Nepal. *Global Environmental Change, 43*, 26-36.

Pradhan, B. K. (2007). *Disaster preparedness for natural hazards: current status in Nepal*. Kathmandu, Nepal: International Centre for Integrated Mountain Development (ICIMOD).

Pradhan, R., Pradhan, U., Meinzen-Dick, R., & Bruns, B. (1997). Negotiating access and rights: a case study of disputes over rights to an irrigation water source in Nepal. In *Negotiating water rights* (pp. 221-247).

Pratibha, G., Srinivas, I., Rao, K. V., Shanker, A. K., Raju, B. M. K., Choudhary, D. K., . . . Maheswari, M. (2016). Net global warming potential and greenhouse gas intensity of conventional and conservation agriculture system in rainfed semi arid tropics of India. *Atmospheric Environment, 145*, 239-250.

Pun, S. (2000). *Gender, land and irrigation management in Rajapur.* Paper presented at the Water, Land and Law: Legal Anthropological Perspectives, 18-20 March 1998, Kathmandu, Nepal.

Quinn, M. A. (2009). Biological nitrogen fixation and soil health improvement. In F. J. M. W. Erskine, A. Sarker, B. Sharma (Ed.), *The lentil - botany, production and uses* (pp. 229-247). Wallingford: Comm Agric Bureau Int.

Rajaure, D. P. (1981a). *The Tharu women of Sukhrwar.* (Vol. II: Field Studies, Part 3). Kathmandu, Nepal: Center for Economic Development and Administration (CEDA), Tribhuvan University (TU).

Rajaure, D. P. (1981b). Tharus of Dang: the people and the social context. *Kailash, 8*(3-4), 155-181.

Rajaure, D. P. (1982a). Tharus of Dang: rites de passage and festivals. *Kailash, 9*(2-3), 177-258.

Rajaure, D. P. (1982b). Tharus of Dang: Tharu religion. *Kailash, 9*(1), 61-96.

Rao, A. N., Johnson, D. E., Sivaprasad, B., Ladha, J. K., & Mortimer, A. M. (2007). Weed management in direct-seeded rice. In D. L. Sparks (Ed.), *Advances in agronomy* (Vol. 93, pp. 153-255).

Regmi, M. C. (1977). *Land ownership in Nepal*. Delhi: Adroit Publisher.

Reicosky, D. C. (2015). Conservation tillage is not conservation agriculture. *Journal of Soil and Water Conservation, 70*(5), 103A-108A.

Resilience Alliance. (2018). Resilience. Retrieved from https://www.resalliance.org/index.php/resilience

Rhoades, R. E. (1984). *Breaking new ground: anthropology in agricultural research*. Lima, Peru: International Potato Center

Rivera-Ferre, M., Di Masso, M., Mailhost, M., López-i-Gelats, F., Gallar, D., Vara, I., & Cuellar, M. (2013). *Understanding the role of local and traditional agricultural knowledge in a changing world climate: the case of the Indo-Gangetic Plains*: CGIAR-CCAFS Program, Nepal.

RKJS/Practical Action. (2013). *Participatory vulnerability and adaptation capacity analysis*. Radhakrishna Tharu Jansewa Kendra (RKJS) and Practical Action. Gulariya, Bardiya, Nepal.

Rogers, E. M. (1958). Categorizing the adopters of agricultural practices. *Rural Sociology, 23*(4), 346-354.

Royce, A. P., & Kemper, R. V. (2002). Long-term field research: metaphors, paradigms, and themes. *Chronicling cultures: long-term field research in anthropology*.

Sandstrom, A. R., & Sandstrom, P. E. (2011). The long and the short of ethnographic research among the Nahua of Northern Veracruz, Mexico. *Anthropology and Humanism, 36*(1), 25-35.

Sapkota, M. (2014). Contested identity politics in Nepal: implications from Tharu movement. *IOSR Journal of Humanities and Social Science*, *19*(7), 16-25

Sapkota, T. B., Jat, M. L., Aryal, J. P., Jat, R. K., & Khatri-Chhetri, A. (2015). Climate change adaptation, greenhouse gas mitigation and economic profitability of conservation agriculture: some examples from cereal systems of Indo-Gangetic Plains. *Journal of Integrative Agriculture, 14*(8), 1524-1533.

Sarbahari, K. (2016). *Tharu gurwa: parmparagat upchar pranali (Tharu shaman and traditional medicine techniques)*. Kathmandu: Nepal Foundation for Development of Indigenous Nationalities (NFDIN), Government of Nepal.

Sarker, A., Erskine, W., Abu Bakr, M., Matiur Rahman, M., Ali Afzal, M., & Saxena, M. C. (2004). Lentil improvement in Bangladesh. *A success story of fruitful partnership between the Bangladesh Agricultural Research Institute and the International Center for Agricultural Research in the Dry Areas. APAARI Publication, 1*, 1-38.

Schaefer, B. D. (2017, March 15). Ignore the critics: If Trump withdraws from Paris Climate Agreement, he will demonstrate US leadership. *Fox News*. Retrieved from http://www.foxnews.com/opinion/2017/03/15/ignore-critics-if-trump-withdraws-from-paris-climate-agreement-will-demonstrate-us-leadership.html

Schilke-Gartley, K. L., & Sims, J. T. (1993). Ammonia volatilization from poultry manure-amended soil. *Biology and Fertility of Soils, 16*(1), 5-10.

Schiller, K. (2014). *Assessing the sustainability of leasehold riverbed vegetable farming for landless and land-poor households in the Terai of Nepal.* (Master's thesis), University of Hohenheim, Hohenheim, Germany.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proceedings of the National Academy of Sciences, 106*(37), 15594-15598.

Scialabba, N. E. H., & Mller-Lindenlauf, M. (2010). Organic agriculture and climate change. *Renewable Agriculture and Food Systems, 25*(2), 158-169.

Seddon, D., Adhikari, J., & Gurung, G. (2002). Foreign labor migration and the remittance economy of Nepal. *Critical Asian Studies, 34*(1), 19-40.

Sekhon, H. S., Singh, G., & Ram, H. (2007). Lentil-based cropping systems. In S. S. Yadav, D. McNeil, & P. C. Stevension (Eds.), *Lentil: an anicient crop for modern times* (pp. 123-142). The Netherlands: Springer.

Seufert, V., Ramankutty, N., & Foley, J. A. (2012). Comparing the yields of organic and conventional agriculture. *Nature, 485*, 229.

Sharma, M. D., Shrestha, S., & Chaudhary, B. R. (2010). *Training manual of riverbed farming: targeted to local resource person [In Nepali: Bagarma tarkai kheti talim pustika: sthaniya shrot byaktiharulai lakshit]*. Kathmandu, Nepal: Helvetas – Swiss Intercooperation.

Shaw, J. (2002, November–December). The great global experiment: as climate change accelerates, how will we adapt to a changed earth? *Harvard Magazine*. Retrieved from https://harvardmagazine.com/sites/default/files/pdf/2002/11-pdfs/1102-34.pdf

Shen, S., Basist, A., & Howard, A. (2010). Structure of a digital agriculture system and agricultural risks due to climate changes. *Agriculture and Agricultural Science Procedia, 1*, 42-51.

Shivakoti, G. P., & Ostrom, E. (2002). *Improving irrigation governance and management in Nepal*. Oakland, California: ICS Press.

Shrestha, A. B., Wake, C. P., Mayewski, P. A., & Dibb, J. E. (1999). Maximum temperature trends in the Himalaya and its vicinity: an analysis based on temperature records from Nepal for the period 1971–94. *Journal of Climate, 12*(9), 2775-2786.

Shrestha, B. G. (2015). To use or not to use: Nepal samvat, the national era of Nepal. *HIMALAYA, the Journal of the Association for Nepal and Himalayan Studies, 35*(1), 117-128.

Shrestha, R., Neupane, R., & Adhikari, N. (2011). *Status and future prospects of pulses in Nepal.* Paper presented at the Regional Workshop on Pulse Production held at Nepal Agricultural Research Council (NARC), Kathmandu, Nepal.

Shrestha, S., Moore, G. A., & Peel, M. C. (2018). Trends in winter fog events in the Terai region of Nepal. *Agricultural and Forest Meteorology, 259*, 118-130.

Shrestha, S., Pandey, V. P., Chanamai, C., & Ghosh, D. K. (2013). Green, blue and grey water footprints of primary crops production in Nepal. *Water Resources Management, 27*(15), 5223-5243.

Shrestha, S. L. (2014). *Climate change resilience and vulnerability of farmers in Nepal.* (Doctoral dissertation), Hiroshima University, Japan, Retrieved from https://ci.nii.ac.jp/naid/500000920390/

Sidhu, H., Humphreys, E., Dhillon, S., Blackwell, J., & Bector, V. (2007). The Happy Seeder enables direct drilling of wheat into rice stubble. *Australian Journal of Experimental Agriculture, 47*(7), 844-854.

Sigdel, M., & Ikeda, M. (2010). Spatial and temporal analysis of drought in Nepal using standardized precipitation index and its relationship with climate indices. *Journal of Hydrology and Meteorology, 7*(1), 59-74.

Sillitoe, P. (2007). Local vs global science: an overview. In P. Sillotoe (Ed.), *Local science vs globa science: approaches to indigenous knowledge in international development* (Vol. Studies in environmental anthropology and ethnobiology, pp. 1-22).

Sillitoe, P. (2017). *Indigenous knowledge: enhancing its contribution to natural resources management*. Wallingford, Oxfordshire: CABI.

Singh, S., Angadi, S. V., Grover, K. K., Hilaire, R. S., & Begna, S. (2016). Effect of growth stage based irrigation on soil water extraction and water use efficiency of spring safflower cultivars. *Agricultural Water Management, 177*, 432-439.

Singh, S., & Singh, D. (2010). *Recent fog trends and its impact on wheat productivity in NW plains in India*. Paper presented at the 5th International Conference on Fog, Fog Collection and Dew, Münster, Germany.

Smith, P., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E. A., . . . Tubiello, F. N. (2014). Agriculture, forestry and other land use (AFOLU). In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, J.C. Minx Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (Eds.), *Climate change 2014: mitigation of climate change. contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change*. Cambridge, UK and New York, USA: Cambridge University Press.

Soora, N. K., Aggarwal, P. K., Saxena, R., Rani, S., Jain, S., & Chauhan, N. (2013). An assessment of regional vulnerability of rice to climate change in India. *Climatic Change, 118*(3-4), 683-699.

Speranza, C. I. (2010). *Resilient adaptation to climate change in African agriculture*. Bonn: German Development Institute/Deutsches Institut für Entwicklungspolitik (DIE). Retrived from http://hdl.handle.net/10419/199179

Spradley, J. P. (1979). *The ethnographic interview*. New York: Holt, Rinehart and Winston.

Spradley, J. P. (1980). *Participant observation*. New York: Holt, Rinehart and Winston.

SQCC. (2013). *National seed vision 2013-2025 (Seed sector sevelopment strategy)*. Lalitpur, Nepal: Seed Quality Control Centre (SQCC), Government of Nepal.

Srivastava, S. (1999). Cultural dynamics among the Rana Tharus: the past in the the present. In K. O. Skar (Ed.), *Nepal: the Tharu and Tarai neighbours* (Vol. 16). Kathmandu, Nepal: Babliotheca Himalaya.

Sterrett, C. (2011). *Review of climate change adaptation practices in South Asia*. Retrieved from https://www-cdn.oxfam.org/s3fs-public/file_attachments/rr-climate-change-adaptation-south-asia-161111-en_3.pdf

Steward, P. R., Dougill, A. J., Thierfelder, C., Pittelkow, C. M., Stringer, L. C., Kudzala, M., & Shackelford, G. E. (2018). The adaptive capacity of maize-based conservation agriculture systems to climate stress in tropical and subtropical environments: A meta-regression of yields. *Agriculture, Ecosystems & Environment, 251*, 194-202.

Sugden, F., Maskey, N., Clement, F., Ramesh, V., Philip, A., & Rai, A. (2014). Agrarian stress and climate change in the Eastern Gangetic Plains: gendered vulnerability in a stratified social formation. *Global Environmental Change, 29*, 258-269.

Sunam, R., & Adhikari, J. (2016). How does transnational labour migration shape food security and sood sovereignty? Evidence from Nepal. *Anthropological Forum, 26*, 248-261.

Sustainnet EA. (2010). *Technical manual for farmers and field extension service providers: conservation agriculture*. Nairobi, Kenya: Sustainable Agricultural Information Initiative (Sustainnet EA).

Swiderska, K., Song, Y., Li, J., Reid, H., & Mutta, D. (2011). Adapting agriculture with traditional knowledge. Retrieved from https://www.osti.gov/etdeweb/biblio/22041080

Takeshima, H., Adhikari, R. P., Poudel, M. N., & Kumar, A. (2015). Farm household typologies and mechanization patterns in Nepal Terai. *International Food Policy Research Institute Discussion Paper*, 1-56.

Tamang, S., Paudel, K. P., & Shrestha, K. K. (2014). Feminization of agriculture and its implications for food security in rural Nepal. *Journal of Forest and Livelihood, 12*(1), 20-32.

Technology Need Assessment. (2017). *From needs to implementation: stories from the Technology Needs Assessments* (S. Bee, S. Traeru, & V. Hecl Eds.). Copenhagen, Denmark: United nations Energy Programme (UNEP DTU Parthership).

Thapa, S. (2010). Effectiveness of crop protection methods against wildlife damage: a case study of two villages at Bardia National Park, Nepal. *Crop Protection, 29*(11), 1297-1304.

Thomas, D., & Twyman, C. (2004). Good or bad rangeland? Hybrid knowledge, science, and local understandings of vegetation dynamics in the Kalahari. *Land Degradation & Development, 15*(3), 215-231.

Thurston, H. D. (1990). Plant disease management practices of traditional farmers. *Plant Disease, 74*(2), 96-102.

Tiwari, K. R., Rayamajhi, S., Pokharel, R. K., & Balla, M. K. (2014). Determinants of the climate change adaptation in rural farming in Nepal Himalaya. *International Journal of Multidisciplinary and Current Research, 2*, 234-240.

Trewavas, A. (2001). Urban myths of organic farming. *Nature, 410*, 409.

UNCED. (1992). Agenda 21. Retrieved from https://sustainabledevelopment.un.org/outcomedocuments/agenda21

UNESCO. (2002). *Best practices on indigenous knowledge*. The Hague and Paris: United Nations Educational, Scientific and Cultural Organisation (UNESCO) and the Centre for Internal Research and Advisory Networks (CIRAN).

UNFCCC. (1997). What is the Kyoto Protocol? Retrieved from https://unfccc.int/kyoto_protocol

UNFCCC. (2015). What is the Paris Agreement? Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement

UNRCO. (2017). *Nepal: flood 2017. Office of the Resident Coordinator Situation Report No. 9 (as of 20 September 2017).* Retrieved from https://reliefweb.int/sites/reliefweb.int/files/resources/Nepal%20Flood%20Sitrep%2022%20September%202017.pdf

Uprety, Y., Boon, E. K., Poudel, R. C., Shrestha, K. K., Rajbhandary, S., Ahenkan, A., & Tiwari, N. N. (2010). Non-timber forest products in Bardiya district of Nepal: Indigenous use, trade and conservation. *Journal of Human Ecology, 30*(3), 143-158.

Uprety, Y., Poudel, R. C., Shrestha, K. K., Rajbhandary, S., Tiwari, N. N., Shrestha, U. B., & Asselin, H. (2012). Diversity of use and local knowledge of wild edible plant resources in Nepal. *Journal of Ethnobiology and Ethnomedicine, 8*(1), 16.

Van de Sand, I. (2012). *Assessing vulnerability to climate variability and change: Participatory assessment approach and Kenyan case study*. Retrieved from http://edoc.vifapol.de/opus/volltexte/2013/4403/pdf/Studies_65.pdf

Van Vliet, N., Mertz, O., Heinimann, A., Langanke, T., Pascual, U., Schmook, B., . . . Leisz, S. (2012). Trends, drivers and impacts of changes in swidden cultivation in tropical forest-agriculture frontiers: a global assessment. *Global Environmental Change, 22*(2), 418-429.

Wachinger, G., Renn, O., Bianchizza, C., Coates, T., De Marchi, B., Domènech, L., . . . Pellizzoni, L. (2010). *Risk perception and natural hazards*. Retrieved from http://www.caphaz-net.org

Wang, L., Gruber, S., & Claupein, W. (2012). Optimizing lentil-based mixed cropping with different companion crops and plant densities in terms of crop yield and weed control. *Organic Agriculture, 2*(2), 79-87.

Wang, S.-Y., Yoon, J.-H., Gillies, R. R., & Cho, C. (2013). What caused the winter drought in western Nepal during recent years? *Journal of Climate, 26*(21), 8241-8256.

Warner, K. (2007). *Agroecology in action: extending alternative agriculture through social networks*. Cambridge, Massachusetts and London, England: MIT Press.

Warner, K., Ehrhart, C., de Sherbinin, A., Adamo, S., & Chai-Onn, T. (2009). *In search of shelter: mapping the effects of climate change on human migration and displacement*. Retrieved from http://www.ciesin.columbia.edu/documents/clim-migr-report-june09_media.pdf

Warren, D. M. (1991). *Using indigenous knowledge in agricultural development*. Washington, DC: The World Bank.

Webb, L. B., Whetton, P. H., & Barlow, E. W. R. (2011). Observed trends in winegrape maturity in Australia. *Global Change Biology, 17*(8), 2707-2719.

Webster, C., & Wilson, P. (1966). *Agriculture in the tropics*: London: Longmans, Oreen & Co. Ltd.

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C. (2009). Agroecology as a science, a movement and a practice. A review. *Agronomy for Sustainable Development, 29*(4), 503-515.

Wheeler, T. (2017). Climate change and agriculture: risks and opportunities to food and farming systems in the tropics. *Agriculture for Development*, 58-60.

Wilhite, D. A. (2000). *Drought as a natural hazard: concepts and definitions*. Nebraska - Lincoln: Drought Mitigation Center Faculty Publications, 69.

Willey, R., & Osiru, D. (1972). Studies on mixtures of maize and beans (Phaseolus vulgaris) with particular reference to plant population. *The Journal of Agricultural Science, 79*(3), 517-529.

Wiraguna, E., Malik, A. I., & Erskine, W. (2017). Waterlogging tolerance in lentil (Lens culinaris Medik. subsp. culinaris) germplasm associated with geographic origin. *Genetic Resources and Crop Evolution, 64*(3), 579-586.

Wolf, K., Herrera, I., Tomich, T. P., & Scow, K. M. (2017). Long-term agricultural experiments inform the development of climate-smart agricultural practices. *California Agriculture, 71*(3), 120-124.

Wolfe, D. W., Ziska, L., Petzoldt, C., Seaman, A., Chase, L., & Hayhoe, K. (2008). Projected change in climate thresholds in the Northeastern US: implications for crops, pests, livestock, and farmers. *Mitigation and Adaptation Strategies for Global Change, 13*(5-6), 555-575.

World Bank. (2004). *Indigenous knowledge: local pathways to global development - marking five years of the World Bank indigenous knowledge for development program*. Washington, DC: The World Bank.

Woytek, R. (1998). *Indigenous knowledge for development: a framework for action*. Washington DC: Knowledge and Learning Center, African Region, The World Bank.

Yamane, K., Garcia, R., Imayoshi, K., Mabesa-Telosa, R. C., Banayo, N. P. M. C., Vergara, G., . . . Kato, Y. (2018). Seed vigour contributes to yield improvement in dry direct-seeded rainfed lowland rice. *Annals of Applied Biology, 172*(1), 100-110.

Yang, S., Peng, S., Xu, J., Luo, Y., & Li, D. (2012). Methane and nitrous oxide emissions from paddy field as affected by water-saving irrigation. *Physics and Chemistry of the Earth, 53-54*, 30-37.

Zahan, T., Hashem, A., Rahman, M., Bell, R. W., & Begum, M. (2018). Efficacy of herbicides in non-puddled transplanted rice under conservation agriculture systems and their effect on establishment of the succeeding crops. *Acta Sci. Malays, 2*, 17-25.

Zaman, M. S., Malik, A. I., Kaur, P., & Erskine, W. (2018). Waterlogging tolerance of pea at germination. *Journal of Agronomy and Crop Science, 204*(2), 155-164.

Zhang, T., Zhu, J., & Wassmann, R. (2010). Responses of rice yields to recent climate change in China: an empirical assessment based on long-term observations at different spatial scales (1981–2005). *Agricultural and Forest Meteorology, 150*(7), 1128-1137.

Zhang, Y. F., Liu, H. J., Guo, Z., Zhang, C. S., Sheng, J., Chen, L. G., . . . Zheng, J. C. (2018). Direct-seeded rice increases nitrogen runoff losses in southeastern China. *Agriculture Ecosystems & Environment, 251*, 149-157.

Zhao, X., Liu, S. L., Pu, C., Zhang, X. Q., Xue, J. F., Zhang, R., . . . Chen, F. (2016). Methane and nitrous oxide emissions under no-till farming in China: a meta-analysis. *Global Change Biology, 22*(4), 1372-1384.

Zilberman, D., Zhao, J., & Heiman, A. (2012). Adoption versus adaptation, with emphasis on climate change. *Annu. Rev. Resour. Econ., 4*(1), 27-53.

Ziska, L. H., & Goins, E. W. (2006). Elevated atmospheric carbon dioxide and weed populations in glyphosate treated soybean. *Crop Science, 46*(3), 1354-1359.

APPENDICES

Appendix 1. Population of Tharu in the census of Nepal (1981–2011)

District	1981 (Language)		1991 (Ethnicity)		2001 (Ethnicity)		2011 (Ethnicity)	
	Number	%	Number	%	Number	%	Number	%
Jhapa	1,461	0.30	9,600	1.62	9,588	1.51	9,983	1.23
Morang	33,772	6.32	60,391	8.95	63,673	7.55	60,566	6.27
Sunsari	44,704	12.97	75,079	16.20	87,523	13.99	91,500	11.98
Udaypur	11,341	7.10	18,369	8.30	22,323	7.76	24,240	7.63
Saptari	35,511	9.37	61,640	13.24	73,161	12.83	73,697	11.53
Siraha	3,541	0.94	20,617	4.47	27,252	4.78	26,386	4.14
Dhanusha	33	0.01	1,697	0.31	3,909	0.58	4,422	0.59
Mahottari	1,144	0.32	7,522	1.71	9,025	1.63	9,909	1.58
Sarlahi	7,941	1.99	15,359	3.12	20,225	3.18	21,778	2.83
Rautahat	6,337	1.91	21,821	5.27	27,502	5.05	30,811	7.33
Bara	16,356	5.13	49,389	11.88	63,259	11.31	71,993	10.47
Parsa	246	0.09	32,701	8.78	40,970	8.24	45,620	7.59
Chitwan	31,179	12.01	45,392	12.80	60,121	12.74	63,359	10.92
Nawalparasi	15,710	5.09	73,494	16.85	92,779	16.48	97,275	15.11
Rupandehi	482	0.13	55,803	10.69	74,888	10.57	84,788	9.63
Kapilvastu	13,431	4.97	43,709	11.76	60,574	12.57	70,096	12.26
Dang	84,061	31.56	111,574	31.48	147,328	31.86	163,116	29.52
Banke	17,519	8.53	45,564	15.95	63,344	16.42	76,879	15.65
Bardiya	73,876	37.12	153,322	52.81	201,276	52.60	226,089	53.00
Surkhet	1,610	0.97	4,941	2.19	5,631	2.09	6,890	1.96
Kailali	120,534	46.74	206,933	49.52	269,521	43.70	322,120	41.53
Kanchanpur	22,369	13.24	70,544	27.35	88,155	23.33	115,876	25.68
Total	543,158	3.63	1,185,461	6.45	1,512,027	6.53	1,737,470	6.67

Sources: CBS 1981 and 1991 (as cited in Guneratne, 2002, p. 165; CBS, 2007, 2014a)

Note: The sum of Tharu in the districts listed in the table does not equal the figure for total Tharu, which excludes Tharu living in Kathmandu and other hilly and mountain districts of Nepal. The decreasing percentage of the Tharu in many districts in 2011 is because of the recording of individuals based on their physical presence.

Appendix 2. Household survey questionnaire form—English version

Household ID ------------- Respondent ID ----------------

Interview Schedule for Household Survey

Dear respondents,
I am Buddhi Chaudhary, a PhD student at the University of Western Australia. As a part of my study, I have to prepare a thesis for which I am doing my research on the climate change adaptation of Tharu Community in Nepal. For this purpose, I would like to request your kind cooperation and time to fill the questionnaire. Also, I would like to request you that your name will be kept confidential and all the information you provide will be used only for my research purposes. Thank you very much!

Date …………………/2018 (dd/mm/yyyy)

Given name of the informant …………………… Surname …..…………... Gender …… Age ……… Mobile number ……………

Name of the Household Head (HHH) ……………………… Gender of the HHH …………

District ………………… Municipality ………………… Ward No. ………… Village ………………

PART A: AGRONOMIC PRACTICES AND FOOD SECURITY

1. What are the top FIVE Crops for you?

Practices/Crop	**Rice**	**Maize**	**Wheat**	**Crop 4: …..**	**Crop 5: ...**
Cultivated area (local unit)					
Main varieties (at least 3)					
Seed rate per unit area					
Seed cost per unit					
Tillage method **[Code 1]**					
Tillage number					
Tillage source **[Code 2]**					
Cropping method **[Code 3]**					

CODE 1 (Tillage method)	**CODE 2 (Tillage Power)**	**CODE 3 (Cropping method)**
1=No/zero-tillage, 2= Minimum tillage, 3=Tillage	1= Bullock 2= Two-wheel tractor 3= Four-wheel tractor, 4= Others ……..	1=Single cropping, 2=Mixed, 3=Intercropping, 4=Relay, 5=Agroforestry

If you are using any hybrid crop varieties then what crops? …………………….. From what year? …………..

If practicing No/minimum tillage then since when? ----------------- Why? ---------------------------------

If practicing mixed/relay and intercropping then since when? -------------------- Why? ------------------------------

1.1 Use of Agricultural inputs (previous year) in top five crops

Inputs/Crops	Rice	Maize	Wheat	Crop4:…	Crop 5: …
Compost/FYM use (mt/ha)					
Fertilizer use (kg/ha) -Urea -DAP -MoP -Micronutrients (specify)					
Pesticides cost (specify)					
Herbicides cost (Specify)					
Irrigation - Source and cost - Interval (days) - Critical crop stage					
Labour (# days) Land preparation, cultivation, weeding, harvesting					

Have you tested your soil ever? [ ] No [ ] Yes, if Yes, then any treatment? ----------------

Why don't you use chemical fertilizer?
…………………………………………………………………………………….

Why don't you use pesticides?
……………………………………………………………………………………………….

Why don't you use hybrid crop varieties?
…………………………………………………………………………………………

1.2 Do you cultivate any **local varieties**? [ ] Yes [ ] No If Yes then,

Crop	Variety	Area in local unit	Using since year	Reasons of using?
Rice				
Wheat				
Maize				
Crop 4: …				
Crop 5: ….				

1.3 Disposal pattern of five top crops in last year

Disposal/Crops	Rice	Maize	Wheat	Crop 4: …..	Crop 5: …..
Production (local unit)					
Saved for seeds (kg)					
Quantity Sold (local unit)					

- Market price - Month sold - Transport cost					
Consumption (local unit)					
Exchanged (local unit)					
Gift/donation (local unit)					
Storage for next year (mt)					

2. Energy in Kitchen (Firewood)

What is energy source in kitchen? Tick applicable, 1) Firewood, 2) LPG/Kerosene, 3) Biogas, 4) Dung

How many *bharis* of firewood do you need each week? ………………………………………

Which months do you usually gather firewood from forests? ……………………………………

Do you sell firewood? [ ] Yes [ ] No

If yes, qty sold per day/week/month ……………………………

Price ………………………………………………

3. Food Security

i. How many months do your own farm products feed your family? ………….

ii. Which are the months you face food deficit situation? ………………

iii. What are the reasons for deficit in that particular month/s? ……………………………

iv. How did you manage the food shortage during the last one year?

[ ] Less preferred food [ ] Reduced meal [ ] Collect from forests
[ ] Grain loan [ ] Cash loan [ ] Labor sale
[ ] Small animal sale [ ] Sale of assets [ ] Others (specify)

a) In case of less preferred food, what is less preferred food for you? …………………………

How often do you consume less preferred food? Please denote times per week if possible.

[ ] Rarely [ ] Frequently [ ] Sometimes

b) In case of reduced meal, who is/are the one to do so?

[ ] Girl [ ] Boy [ ] Adult Male
[ ] Adult Female [ ] Aged Male [ ] Aged Female

How often? Please denote times per week if possible.

[ ] Rarely [ ] Frequently [ ] Sometimes

c) In case if you collected food from forests (last year), give the following details?

Wild food name	Month of collection	From where?	Quantity collected	Quantity Sold	Unit Price (cash or kind)	Parts used	Availability 1-3 (1 decrease)
Fish							
Crab							
Snail (*Ghongi*)							
Veggies (specify)							
Fruits (specify)							
Others (specify)							

d) In case of grain loan
Whom did you take the loan from? ……………………………………………………….
What was the interest rate? …………………………………………………………...
How did you repay? ……………………………………………………………………
e) In case of labor sale
Which months do you and your family members rely more on wage labor? ……………
Where do you and your family members go for wage labor? ……………………………

PART B: INFORMATION ON CLIMATE CHANGE PERCEPTION, IMPACT AND ADAPTATION

4. Perception of climate change

4.1 Have you heard about "climate change"? [ ] Yes [ ] No
If YES, who/from where do you learn about this?
……………………………………………………………..

4.2 Do you think the summers are getting hotter or cooler?

[ ] Hotter [ ] Cooler [ ] No change

If hotter or cooler, since when (which year) did you observe the change? ……………………..

Do you have to make any adjustments for the changing temperature? If yes, explain
…………………………………….

4.3 Do you think the winters are getting warmer or cooler?

[ ] Warmer [ ] Cooler [ ] No change

If warmer or cooler, since when (which year) did you observe the change? ……………………..

Do you have to make any adjustments for the changing temperature? If yes, explain
……………………………………………….

4.4 Have you observed changes in the rainfall pattern? If possible give specific year of changes observed.

Time period	Onset of monsoon	End of monsoon	Total rainy days during monsoon	Total rainy days during winter
Last year				
10 years ago				
20 years ago				

5. Impact and Adaptation to climate change

5.1 Change in Farming/Agriculture practices

Indicators of land/farming	**Current/last year**	**10 years ago**	**20 years ago**	**Reasons of change**
Cow - female				
Cow - male				
Buffalo (male/female)				
Small livestock number (goat, sheep)				
Pig				

What crop area subsequently increased or decreased (ha)? -Crop A …… -Crop B …… -Crop C ……				
Yield increase/decrease (quantify)? - Crop A ……. - Crop B ……. - Crop C …….				
Chemical fertilizer, pesticides, weedicides [0=No, 1=little bit, 2=Yes]				
Use of compost [0=Fertilizer only, 1=Compost only, 2= Compost + Fertilizer]				
Tillage power [0=No-tillage, 1=Animal, 2=Tractor, 3=Both]				
Crop insect/disease prevalence? [1=Increase, 2=Decrease]				

5.1.1 If you have suffered from infestation of insect, disease and weeds, what were the protection measures taken?

Name of Insect/ disease/weed	**Main affected crop**	**Protection measures taken**	**From what year**

5.1.2 Are there any crops that you have completely stopped cultivating in the last 10 years? [ ] Yes [ ] No

If YES, What are those crops (specify year if you remember) ……………………………………………………………….

Why did you stop cultivating these? ………………………………………………………………………………………

5.2 Climate-induced hazards

Hazard's name: ……………..	**Current/Last year**	**10 years ago**	**20 years ago**
Human death/lost			
Badly injured/ loss of body parts			

House damaged (Value NRs)			
Livestock killed (Value NRs)			
Stored food damaged (Value NRs)			

6. Decision making and Adaptation barriers

What is the source of weather information? Tick one or more, Radio/TV/Mobile/Internet/Friends and relatives/ Others (specify) ……..

Are they on time?[ ] Yes [ ] No

Are they continuous? [ ] Yes [ ] No

Are they useful? [ ] Yes [ ] No, if NOT why? ……………………….

Do you have early warning system of flood in the River? [ ] Yes [ ] No, if Yes then

Do you follow the warnings? [ ] Yes [ ] No, if No, Why? ………………………………..

What is the basis of crop variety selection? Yield / Price / Taste / Other (specify)

PART C: INFORMATION ON CURRENT LIVELIHOOD STATUS

7. Information on family members

S. No.	Name of member	Gender	Age (completed years)	Formal education (years)	Primary Occupation	Labor contribution to farm 2017#	Remarks*
1	Respondent						
2							
3							

1= Full time, 2=Part-time/partly, 3=No labour contribution in agriculture

* Denote if the member is out of home (job, temporary migration) or if handicapped

8. Livelihood assets

8.1 Landholding (ha)

Type of land	Own holding	Registered	Unregistered	Rented out	Rented in	Mortgaged out	Mortgaged in
Lowland (*Khet*)							
Irrigated							
Unirrigated							
Upland (*Bari*)							
Irrigated							
Unirrigated							
Riverbed							
Others (Specify)							

Do you have land in the city area? [ ] Yes [ ] No,
Where? ------------------------ Area? ----------------
How are you using the land? [ ] Fallow [ ] Agriculture [ ] House
If you have house, [ ] Using yourself [ ] Rented out Monthly rent? ………………..

8.2 Livestock ownership, marketing and production costs in the last 12 months

Animal type	Type 1= Local 2= Cross 3= Exotic	No. Owned	Value of each NRs	Marketing		Production cost NRs			Who is responsible for raising? 1=Husband, 2=Wife and 3=Both	Who decides to buying and selling of [.....]? 1= Husband, 2=Wife, 3= Both
				Quantity sold (No /kg/lit)	Average selling price NRs	Feed	Labor	Veterinary care		
Cow										
Bullock		x								
Buffalo		x								
Pig										
She goat										
He goat										
Sheep		x								
Poultry		x								
Bee hives										

8.2.1 Animal products and selling in last 12 months?

Products	Production	Quantity sold	Selling Price	Remarks
Milk/Yogurt (kg per week)				How many months? …………
Butter (kg per week)				
Manures (mt per year)				
Hair/skin (NRs per year)				

8.3 Physical assets

Infrastructure: Public facilities

Availability of electricity [] Yes [ ] No

Infrastructure	Walking distance from home (hrs)	Place
Nearest all season road		
Nearest school		
Nearest sub/health post		
Nearest agriculture service centre		
Nearest livestock service centre		
Nearest agro-vet centre		
Nearest market centre		

Other physical assets: Individual/personal

Assets	Mark as applicable	Assets	Mark as applicable
House		Solar/Biogas	
Radio		Boring/ Pump set	
Computer/laptop		Agriculture equipment trolley, harrows, threshers	
Television		Hand pump	
Phone/mobile phone		Timber trees	
Bike/Motorbike		Vehicle (specify) …………..	

House: Roofing materials: …………………………… Floor materials:
Wall materials: ……………………………… Number of storeys and rooms: …………….
Do you have a toilet? [ ] Yes, [ ] No, If Yes, type of toilet:

8.4 Financial assets

Do you have a bank account? [ ] Yes [ ] No

What are the other forms of Savings?

[ ] Bank [ ] saving groups [ ] Cooperatives

[ ] Credited for interest [ ] Shares [ ] Jewelleries

Credits/loan

Do you have any debts/loans that you have to repay? [ ] Yes [ ] No

Source of credit/loan	Name of institution	Interest rate	Purpose of credit/loan	Any remarks?
Relatives	x			
Friends	x			
Neighbours	x			
Local money lenders	x			
Cooperatives				
Bank				
Other sources				

If no, why?

[ ] No need of credit [ ] Need credit, but no one willing to give (no source)

[ ] Need credit, but lack collateral [ ] Need credit, but interest rate too high

[ ] Others (specify)

Insurance

Insurance type	Name of institution	Donors/Sponsors if any	Since when?	Details (premium, instalment amounts, instalment periods)
Crop insurance				
Livestock insurance				
Own/family members life insurance				
Others (specify)				

8.5 Human assets

Source of income	Type of job	Where?	Income
Salaried job in the country			Per month
Remittance from abroad			Per month
Pension			Per month
Old age/ disable allowance			Per month
Trade/skill job			Per month
Others (specify)			

8.6 Social assets

Social Networks in the community	Membership (Mark x or ☑)	Who is member from the family?	Position	How much input do you have in making decisions in this [GROUP]? CODE 1
Community forestry				
Cooperative				
Saving and credit association				
Agricultural group				
Labour network				

Social Networks in the community	Membership (Mark x or ☑)	Who is member from the family?	Position	How much input do you have in making decisions in this [GROUP]? CODE 1
Irrigation/water users group				
Women's group/association				
Youth association				
Religious association				
Road maintenance				
School committee				
Political position				
Others (specify)				

1. No input 2. input into some decisions	3. Input into most decision 4. Input into all decisions

8.6.1 Extension services given by government agencies

Sector	Services received	Rating of service (1-5)? 1 Best, 5 Worst	Why?
Agriculture			
Livestock			
Education			
Health			
Irrigation			
Red Cross			
Forest/soil conservation			
VC/Ward/City office			
Others (specify)			

Do you have to add anything that I have not asked to you?

Name, signature and date of Interviewer:

--- THE END, Thank You for your Cooperation! --

Appendix 3. Word cloud of qualitative data used in the SQR NVivo analysis

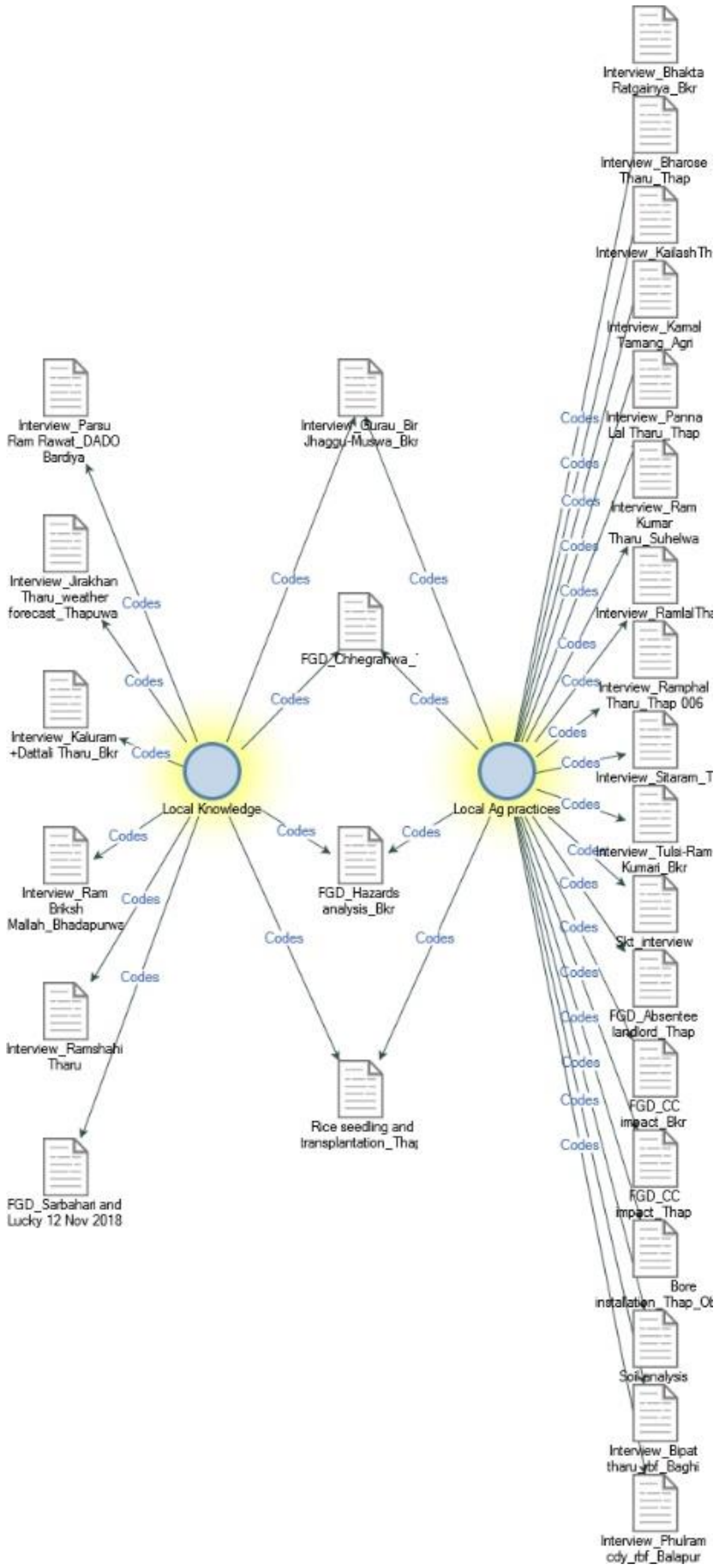
Appendix 4. Nodes list for qualitative information analysis in the SQR NVivo

Nodes

Search Project

Name	Files	References	Created On	Created By	Modified On	Modified By
Future Uncertainty	0	0	4/02/2020 11:16 AM	BRCT	4/02/2020 11:16 AM	BRCT
Future risks	2	2	4/02/2020 11:29 AM	BRCT	4/02/2020 3:55 PM	BRCT
Risk perception	3	5	4/02/2020 11:28 AM	BRCT	4/02/2020 3:18 PM	BRCT
Governance	0	0	4/02/2020 11:15 AM	BRCT	4/02/2020 11:15 AM	BRCT
Govt. Inst. gov.	7	9	4/02/2020 11:25 AM	BRCT	4/02/2020 4:04 PM	BRCT
Group gov.	1	5	4/02/2020 11:24 AM	BRCT	4/02/2020 3:29 PM	BRCT
Village gov.	1	5	4/02/2020 11:25 AM	BRCT	4/02/2020 11:51 AM	BRCT
Hazards and Stresses	0	0	4/02/2020 11:15 AM	BRCT	4/02/2020 11:15 AM	BRCT
Bio-hazards	4	4	4/02/2020 11:27 AM	BRCT	4/02/2020 12:51 PM	BRCT
Drought	3	5	4/02/2020 11:26 AM	BRCT	4/02/2020 3:54 PM	BRCT
Extreme climate	3	6	4/02/2020 11:31 AM	BRCT	4/02/2020 3:59 PM	BRCT
Flooding	5	12	4/02/2020 11:26 AM	BRCT	4/02/2020 3:54 PM	BRCT
Livelihood Asset	0	0	4/02/2020 11:14 AM	BRCT	4/02/2020 11:32 AM	BRCT
Financial	5	5	4/02/2020 11:23 AM	BRCT	4/02/2020 4:20 PM	BRCT
Human	4	7	4/02/2020 11:22 AM	BRCT	4/02/2020 4:19 PM	BRCT
Natural	2	2	4/02/2020 11:18 AM	BRCT	4/02/2020 12:36 PM	BRCT
Physical	7	7	4/02/2020 11:20 AM	BRCT	4/02/2020 4:23 PM	BRCT
Social	10	14	4/02/2020 11:21 AM	BRCT	4/02/2020 4:24 PM	BRCT
Local Ag practices	22	71	6/03/2019 8:46 AM	BRCT	4/02/2020 12:25 PM	BRCT
Direct seeding	1	1	4/02/2020 11:07 AM	BRCT	4/02/2020 12:41 PM	BRCT
Mixed cropping	1	1	4/02/2020 11:05 AM	BRCT	4/02/2020 12:23 PM	BRCT
Relay sowing	3	3	4/02/2020 11:06 AM	BRCT	4/02/2020 12:50 PM	BRCT
River-bed farming	3	12	4/02/2020 11:08 AM	BRCT	4/02/2020 3:58 PM	BRCT
Zero-tillage	2	3	4/02/2020 11:06 AM	BRCT	4/02/2020 12:42 PM	BRCT
Local Knowledge	10	22	6/03/2019 8:44 AM	BRCT	4/02/2020 11:08 AM	BRCT
Climate and weather	5	6	4/02/2020 11:09 AM	BRCT	4/02/2020 3:06 PM	BRCT
Crop production	16	31	4/02/2020 11:11 AM	BRCT	4/02/2020 3:19 PM	BRCT
Crop protection	9	12	4/02/2020 11:11 AM	BRCT	4/02/2020 3:26 PM	BRCT

Appendix 5. Comparison of nodes: local knowledge vs practices



Appendix 6. Climate change impact on agriculture and reasons of change

Crop	**10 years ago**	**20-30 years ago**	**Reason of change**	**Relation to climate change**
RICE				
Land preparation Puddling of rice field without wait period. The number of tillage is also reduced because of sandy fields and use of harrow and tractor.	Wooden and Mould Board plough used for tillage. Animal-drawn six blades harrow used.	Only wooden plough. Land preparation starts after the onset of rain in *Jeth/Asar (chirna)*, 2nd ploughing after rainfall and left for 7-10 days to decay weeds. 3rd ploughing *'lewa'* for transplantation.	The land is flooding more frequently than earlier. So, sand deposition reduced tillage number. Tillage equipment makes easy to cultivate. Direct puddling does need the removal of weeds at least one time.	Delay monsoon, drought
Seedling preparation 12–24 hr soaking in water and 24 hr piling in heap covering, with moist jute bag or plastic	24 hr soaking in water and 24 hr piling and pressing on the floor	24 hr soaked seed in water in wooden *dodwa*. Piling and covering with leaves, *khar* and pressing with weight for at least 24 hr	Faster and higher germination of hybrid varieties than improving and the local one. No change in process of seedling germination.	Piling and pressing seeds during germination grow hardy rice seedlings.
Transplantation 15–20 cm spacing One seedling per hill	Hybrid rice was started but local varieties were also common 8–10 cm spacing, 3–4 seedling per hill	8–10 cm spacing with 3–4 seedlings per hill Local var: Radha–4, Kumaliya, Sugapankhi, Burma, Latera, Sohawat were common	Wider spacing because of high tillering, less seed/seedling is required in hybrid. So it is faster to transplant and 2–3 times higher yield than the local one.	Wider spacing, tall plants cause lodging during post-monsoon.
Intercultural operation Inorganic fertiliser and weed removal are compulsory	No de-weeding Both farmyard manure and inorganic fertiliser in use	Compost and farmyard manure use only, No weed removal needed	Now direct puddling, wider spacing and use of chemical fertilizer need weed removal (normally twice)	Weeds infestation increased.
Harvesting, threshing, and storage Manual harvesting is common, but tractor	Manual harvesting, tractor run threshing was common.	Manual harvesting with a sickle Spread in *nihna* (row) for drying;	Harvesting is still manually, but threshing is done by tractor to save time, availability	No relation to climate change

harvesting is started in Thapuwa. Threshing is by tractor-operated thresher and many farmers sell rice directly from the field.	Threshing with bullock was also there	Transport by the cart, manual on head and shoulders and made *kharhi* (pile) at *khenhwa* (yard). Threshing with the bullock. Storage for next year in *dehari*	of technology, nuclear family and scarcity of farm labour	
MAIZE				
Land preparation Monsoon maize is almost completely replaced by rice. Instead, hybrid maize becomes the spring crop. Bullock, tractor and use of rotavator (tillage, breaking clods and levelling) at Thapuwa	Local Raksi maize was common. Broadcasting by 2–3 times tilling at the end of *Jeth* (May-June)	Local Raksi maize was common. Broadcasting for 2–3 times tilling at the end of *Jeth* (May-June).	Local maize farming is considerably decreased because of 2–3 times more production from hybrid maize. Line sowing, one seed per hill reduces the seed rate.	Maize cannot grow in waterlogged condition.
Intercultural operation 8–9 times irrigation, 3 times inorganic fertiliser application, 1 time weed removal	1 time weed removal. No need for irrigation as it grows in monsoon (Jun–Sep). Both compost and inorganic fertiliser are used.	1 time weed removal. No need for irrigation as it grows in the rainy season. Farmyard manure use only.	Frequent irrigation is needed for spring maize. Farmyard manure use is replaced by chemical fertilizer.	Weeds infestation increased.
Harvesting, Threshing, and storage Only the cob is harvested and the upper portion of the stalk is used for animals, and the lower portion of stalk mixed in the soil for compost. Machine threshing, followed by drying and sold.	Either the whole plant or only cob is harvested. Stalk used as hay for livestock. Manual de-husking and threshing by machine.	Either whole maize plant or only cob is harvested. Stalk used as hay for livestock. Manual de-husking and threshing.	Manual threshing is replaced with a machine, cob husk removal is still manually. Hybrid maize cultivation is basically for selling and local one for human consumption.	No relation to climate change

WHEAT				
Land preparation 1-time tractor harrowing, second-time seed sowing followed harrowing and levelling or using rotavator	2-3 times tillage with tractor harrow, bullock harrow, MB plough	6-8 times tillage with the wooden plough Moisture trapping – dew by ploughing at evening and night and levelling in the next day morning	Reduced number of rounds of tillage passes because of harrow and rotavator	Post-monsoon delays wheat sowing
Intercultural operation 1–2 times irrigation, urea top dressing, and herbicide use	1–2 times irrigation, urea top dressing and no herbicides	No irrigation facility	Irrigation and inorganic fertiliser top dressing is common nowadays	New/weeds increased
Harvesting and Threshing Manual harvesting and threshing with a tractor-operated thresher. In Thapuwa, combine harvester is also used	Manual harvesting and threshing with a tractor	Manual harvesting and threshing with the bullock	Manual harvesting is dominant but harvesting is by the thresher. Combine harvester is also introduced at Thapuwa	No relation to climate change
MUSTARD/LENTIL /PEA				
Cultivation practice Both relay and tilled sowing are practiced. Relay cropping is either in upland to trap soil moisture or low land where tillage is not possible because of high soil moisture. Mixed cropping is common	Lentil relay in rice field but in pea mostly after at least one-time tillage	Lentil, grass pea, linseed relay in the rice field. Mustard cultivation mostly in the upland field (*dihwa*) after harvest of monsoon maize	Relay cropping is decreased, but mixed cropping is increased.	Mixed cropping reduces risks of complete failure
Harvesting and Threshing Manual harvesting, threshing with tractor except for peas because it splits seed cotyledons	Manual harvesting, threshing with both bullock and tractor	Manual harvesting and threshing by a bullock	Manual harvesting is common practice from the beginning. Bullock walking threshing is replaced by the tractor-operated thresher	No relation to climate change

Appendix 7. Wild food use and associated local knowledge of the Tharu

Species name, family and growth habit	**Vernacular name** **(Th= Tharu; Np= Nepali)**	**Local use (parts used and edible only)**	**Collection period**
Aegle marmelos L. Rutaceae, Tree	Bel (Np); Ber (Th)	Ripened fruits, Fodder, ritual importance	March–June
Antidesma acidum Retz. Euphorbiaceae, Tree	Dakhi (Th)	Fruits, young leaves as a vegetable and pickle	September–May
Asparagus racemosus Willd Liliaceae, Herb	Kurilo (Np); Kurla (Th)	Tender shoots as a vegetable and pickle	June–July
Bauhinia vahlii Wight & Arn. Leguminosae, Climber	Bhorla (Np); Namarain, Moharain (Th)	Pods as a fruit, leaves for traditional plates (*dona*, *tepari*) and umbrella Bark for rope	August–February
Bauhinia variegata L. Leguminosae, Tree	Koiralo (Np); Koilar (Th)	Young shoots and leaves as a vegetable. Matured leave for fodder.	March–May
Buchanania latifolia Roxb. M.R. Almeida Anacardiaceae, Tree	Piyar, Piyari (Th)	Fruits as a vegetable, leaves fodder	May–June
Carissa carandas L. Apocynaceae, Shrub	Chutro (Np); Karaudi (Th)	Ripened fruits	June–July
Colocasia esculenta L. Schott Araceae, Herb	Karkalo (Np), Gabda (Th)	Leaves and tuber for vegetable	Whole year
Diospyros malabarica Desr. Kostel Ebenaceae, Tree	Tendu, Tendak (Th)	Ripened fruit, Leaves to make bidi (cigarettes) Stem for stick (*paina*)	April–May
Diplazium esculentum (Retz.) Sw. Woodsiaceae, Herb	Neuro (Np); Kochiya (Th)	Young shoot for vegetable	April–June
Ficus racemosa L. Moraceae, Tree	Dumri (Np); Daurai, Gullar (Th)	Ripe fresh fruits, Leaves for fodder	July–September
Madhuca longifolia (J. König ex L.) J.F. Macbr. Sapotaceae, Tree	Mahuwa (Th)	Succulent fruits edible and liquor preparation	

Momordica dioica Roxb. Cucurbitaceae, Climber	Ban karela (Np); Ban kareli (Th)	Fruits– vegetable	August–November
Murraya koenigii L. Spreng. Rutaceae, Shrub	Karipatta, Boke (Np); Binbinveria (Th)	Leaves as a spice Ripened fresh fruit	June–August
Ophioglossum reticulatum L. Ophioglossaceae, Herb	Jibre saag (Np); Ek patiya (Th)	Young leaf– vegetable	March–April
Schleichera oleosa (Lour.) Merr. Sapindaceae, Tree	Kusum (Np); Kosam (Th)	The pulp of ripe fruits, twig/leaf– fodder	June–August
Spondias pinnata L. f. Kurz Anacardiaceae, Tree	Amora (Np); Amar (Th)	Fruits- fresh and pickle	November–March
Syzygium cumini L. Skeels Myrtaceae, Tree	Jamun (Np); Jam, Jamuni (Th)	Ripe fruits Bark and young leaves to control diarrhoea	May–August
Tamilnadia uliginosa (Retz.) Tirveng. & Sastre Rubiaceae, Tree	Perar (Th)	Fruits used as vegetables	May–September
Terminalia bellirica (Gaertn.) Roxb. Combretaceae, Tree	Barro (Np); Bahare (Th)	Seed pulp edible	November–January
Zizyphus mauritiana Lam. Rhamnaceae, Shrub	Bayer (Np)	Fruits are eaten raw or used to make pickles	October–March
Lithasia geniculata, Pleuroceridae, geniculate river snail	Ghonghi (Th)	Escargot, internal parts	September–May
Freshwater shellfish (mollusc)	Sutahi (Th)	Internal parts	Nov–May
Geothelpusa dahaani, freshwater crab	Gangata (Np), Gengta (Th)	whole crab, internal muscle of large crab	August–May
Rattus argentiventer, rice field rat	Musa (Np), Muswa (Th)	Meat	October–December

Note: Wild food use was collected from the household survey. Scientific name, parts used and collection period are referred from Uprety et al. (2012) whose two research sites are also focused on the Tharu in Bardiya and Kailali.

Appendix 8. Selected livelihood indicators and current status of the community to adapt to climatic variability in Thapuwa

Physical Assets	Natural	Financial	Social	Human
Road **1** 1	Land **2** 4	Farming **4** 4	Religion/culture **2** 3	Education **4** 3
House **3** 4	River **1** 1	Saving **4** 3	*Barghar* **4** 4	Skill **2** 2
Electricity **3** 3	Orchard **4** 4	Employment **4** 2	Saving group **2** 4	Dedication **3** 4
Irrigation **3** 4	Livestock **3** 3	Loan **3** 3	Sadhu faith **1** 1	Leadership **3** 1
School **1** 2	Riverbed **1** 2	Insurance **2** 1	Access to service **3** 2	Game **1** 1
Women 11	**11**	**17**	**14**	**13**
Men 14	14	13	12	11
Avg. women 2.2	2.2	3.4	2.4	2.6
Avg. men 2.8	2.8	2.6	2.8	2.2
Ranking 12.5	12.5	15	13	12

Note: Views of the participants were rated on the scale, 1–4 (1 is the weakest and 4 is the strongest). The views of female are shown in bold font. The ranking is based on the average of male and female; higher the rank value means indicates a higher capacity of the specific livelihood capital to ultimately improve adaptive capacity in regard to climate change.

Appendix 9. Selected livelihood indicators and current status of the community to adapt to climatic variability in Bikri

Physical assets	**Natural**	**Financial**	**Social**	**Human**
House **3** 3	Land **3** 4	Skill **3** 4	Forest user group **3** 4	Health worker **1** 3
Bridge **2** 1	Orchard **4** 3	Saving **4** 2	Access to services **3** 3	Education **2** 4
River embankment **3** 2	Draft livestock **3** 3	Veg farming **3** 3	Saving group **4** 3	Skill **2** 2
Motorbike **3** 1	Irrigation canal **1** 2	Foreign labour **1** 3	*Barghar* system **3** 1	Business **2** 2
Mobile network **2** 3	River **3** 1	Agri. cooperative **1** 1	Youth education **3** 2	Leadership **3** 1
Women 13	**14**	**12**	**16**	**10**
Men 10	13	13	13	12
Avg. women 2.6	2.8	2.4	3.2	2.0
Avg. men 2.0	2.6	2.6	2.6	2.4
Ranking 11.5	13.5	12.5	14.5	11

Note: Views of the participants were rated on the scale, 1–4 (1 is the weakest and 4 is the strongest). The views of female are shown in bold font. The ranking is based on the average of male and female; higher the rank value means indicates a higher capacity of the specific livelihood capital to ultimately improve adaptive capacity in regard to climate change.

Appendix 10. Traditional agriculture rituals of the Tharu in the western Tarai, Nepal

1. *Hareri*

There is a belief that the deity Gaura Parvati created the *gandhi* insect to bring back her husband Mahadeva from the rice field. *Kesauka* Bir Bahadur Ratgainya shared a story about this.

> Latau Mahadeva left his home to enjoy his beautiful rice field. Gaura Parvati created the *gandhi* insect (*Leptocorisa* spp.) to destroy the rice field so her husband, Isru (Latau) Mahadeva, would return home and stay with her. Once Mahadeva returned to Gaura Parvati, she removed the pest and taught the populace how to remove *gandhi* bug. *Kesauka* Ratgainya described various types of *gandhi* bug: *Lamthori gandhi, Sonya gandhi*, *Rupan gandhi*, *Kaili gandhi*, and *Bhaisa gandhi*. *Gandhi* insects can be sent back to the forest area with the spiritual power of the shaman (*Jaha hara ban jungle ba uha jak baithaho, hamar khetbari chhod deu*). Guruwa creates smoke by firing old straw and says the above *gandhi* insect removal *mantar* (Shaman's songs). This is the tradition, as taught by Gura Parvati, that we are still performing to remove *gandhi* from our rice field.

The *hareri* ceremony is performed after the completion of rice transplantation in the village. It usually falls in *Sawan–Bhadau*[46] (August/September). The primary purpose of *hareri* is to pray for green and healthy crops. The Tharu wish for the crops to be free from insects, especially *gandhi* bugs, grasshoppers and diseases, such as *khaira* (Zinc deficiency), and *dahiya*[47], and they seek to promote well-running irrigation canals. A change to a new cycle (*pirhi*) occurs every five years in which the *dhak* (large musical drum) is played throughout the night and the *'marich'* ghost is worshipped by offering a black male goat (Sarbahari, 2016). However, in most of the village, the *dhak bajaina* ceremony is performed during the *lawang*i *puja* through the month of *Aghan* (November–December).

[46] There are 12 months in the Hindu Nepali calendar. The *Vikram Samvat (VS)* calendar is 56.7 years ahead of the Gregorian calendar. The *VS* is named after name of King Vikramaditya of India during medieval period. Shrestha (2015) mentioned that the VS is imposed in Nepali official calendar during the Rana period in 1903.

[47] Tharu people said *dahiya* is a disease, but according to their description it is more likely to be insects eating chlorophyll through rolling leaves during the tillering stage when there is a rainfall gap. Blight disease also causes white circular to elongated spots, causing foliage drying of plants. It can convert plants into straw, so the local Tharu also called it *paira rog* (straw disease).

Process of *hareri*

The household head of each house meets at the *marwa/thanhwa* (village shrine place). *Chiraki* (assistant of the *guruwa*) cleans the *marwa*, plasters the ground with cow dung and collects materials for the worship (corn plant, water, *daru* (homemade liquor), *kajara* (black powder), *sendur* (red powder), and others). Villagers collect money if poultry and small livestock are needed for slaughter. Villagers cook *khichadi* mixed rice. The ingredients of *khichadi* are rice, vine spinach (*poe)*, whole black gram, barbequed corn, *bhauri* (cooked bread), and cow butter. *Kichadi* is eaten as *prasad* (food offered after worship) by the village heads and also distributed to the children in the village who come to the *marwa*.

The *guruwa* and *kesauka* (assistant *guruwa*) sit together. *Guruwa* starts reciting *mantar* to protect crops, livestock and villages and the *kesauka* shakes his body (*suswaina*). After the *kesauka* produces a few times the sound '*su su suu*……', the performance is completed. Both *guruwa* and *kesauka* give *jal* (water), milk, liquor, and *kajra* and *sendur* (red powder) to all deities. Part of the *mantar* said by Lalji Rajbanshi *Guruwa* is, as follows:

> *Guruwa – Khusi bato ki dukhi bato? Mahiya, ganjar, ganji (gandhi), guja ke bhagae, ke bhakshi?*
> *Kesauka – Hamre bhachab. Lammedar hareri pati hamre lagab.*
> *Guruwa – E bakhari, e kothari k bhari? E barghar ke nagari ke Sau kotharia, 9 bakhari k bharpur kari? Dahiya, mahiya, gunji eka k bhagae?*
> *Kesauka – Hamre bharab. Hamre bhagab.*
> [English translation:
> Guruwa – Are you happy or sad? Who controls *mahiya* (aphids) and *gandhi* (rice bug)?
> Kesauka – We control, we perform the *hareri* rituals.
> Guruwa – Who fills the *bakhari* (basket grain storage) and *kothari* (storage room)? Who is responsible to fulfil the quota of grains food in the territory of *barghar* (village head and traditional leader) in 100 *kothari* (room) and nine *bakhari* (grain storage) who does control *dahiya* (chlorophyll eating insect and blight) and *gandhi*?
> Kesauka – We fulfil, we control.]

The *guruwa* offers *bandhup* to the deities that is prepared by the *guruwa*. The *bandhup* is composed of 1) rice flower 2) flower of *duba* (*Cynodan dactylon*) 3) cow butter 4) beehive 5) pinewood and 6) rice mixed with the blood of Guruwa (*Baan*). *Bandhup* is prepared once a year in on *dhikrahwa (*8th day of Nava Durga worship during the first moon of October). *Guruwa* make sure *bandhup* is enough for a year; if not, then ingredients are added on that special day to increase the amount of *bandhup*.

Khirbhan, holy biomedicine is prepared by the *guruwa*, poured in the canal that enters the village for making the crop green, protecting it from insects, and ensuring good irrigation. *Khirbhan*[48] is a mixture of new rice, cow's milk, and *kush* (*Desmostachya bipinnata*) prepared by *Kanya* girls (whose menstruation has not yet started). This is holy and put in the *kush* ring and poured in the starting point of the canal in the village. There is a *mantar* to prepare and remove Gandhi bug (*Leptocorisa* spp.) insects, as described by Sarbahari (2016, p. 34),

> *Sonke Kolhu, Rupan ke Jath, Jehim Peru aruwa karuwa tel,*
> *E tel ka karbo?*
> *Isru Mahadeva Gaura Parvatik baram biha karbi,*
> *Mor sajal tel nai saj jaibe,*
> *Isru Mahadeva Gaura Parvatik Asthan nai saj Jaibya.*
> [Meaning: Golden oil extractor, beautiful grinder, in which [there are] extracts [of] edible oil,
> What do you do to this oil?
> Marry to the God Isru Mahadeva and Gaura Parvati,
> The oil purified with the *mantar*,
> The place of the God Isru Mahadeva and Gaura Parvati is not purified.]

The *kesauka* performs fire dance by jumping over the burning fire with spiritual control of fire by the *guruwa,* who offers *Jagganathiya* to control the fire with his *mantar* (Dahit, 2005; Sarbahari, 2016). A *mandra* (small musical drum) can be played throughout the *hareri,* and dances can be performed in the village.

Previously *gandhi* bugs (*Leptocorisa* spp.) were removed in a separate event by deer horns played as flutes, but now this symbolic removal is performed during the *hareri*. During the *gandhi* removal process, a deer horn is fluted, straw smoke is burned and the *guruwa* catches a pair of *gandhi* insects and puts them in his mouth and finally eats them without biting. This acidifies '*koth*', the teeth of the *gandhi* bugs, so they cannot suck rice milk. Birbal shared, "It's a hard job, insect legs are rough,

[48] There is a variation in materials to make *khirbhan*. Most of the *guruwa* informed me that cow milk is necessary, but Dahit (2005) has not included it; instead, he mentioned mustard, *mankhun* (dried cereals), and *khudi* (broken piece of cereals).

but I ate with my saliva. After that, I have not tried from the next time. I did it with desbandhya guruwa", Purna Bahadur Chaudhary.

Reflection—how *hareri* helps in agriculture

Hareri signifies the importance of the rice transplantation season so that music, dance, and recreation activities are banned in the village before the *hareri*. When people fully concentrate on farming, youth take appropriate rest at night, having no chance to go singing and dancing. This ritual opens the music and dance season.

It is a celebration of the first harvest of maize and conveys wishes for green and healthy crops. The summer/rainy season is the season with the greatest scarcity of vegetables and other food. Praying for good crops especially rice is a vital practice, as it is the most important food in the community. People are allowed to eat green maize for food security only in scarce times.

The pouring of milk at the head of the canal and the use of only cow milk to deities signifies the importance of the cow and its milk. How milk helps the rice crop may be the subject of further research. Vegetable farmers in the study villages sometimes use milk and water solution to control aphids. Similarly, Tharu farmers have an old tradition of spraying yoghurt to control *dahiya (*may be a combination of blight and leaf roller). A bunch of thorny *bayar* (*Ziziphus* spp.) pulled over the crop exposes insects to sunlight, and they dropdown on the water. The pegging of *khayar* (*Acacia catechu)* branches in four corners of the rice field to control *khaira* disease is still practiced in the Tharu villages.

2. *Darbandhi*

Darbandhi is not directly related to agriculture, but it has a significance to protect people through sealing the four corners of a village. It is usually performed through *Fagun* to *Chait* (March–April). There is a traditional belief that the village becomes safe after the event.

Five branches of *sakhwa* (*Shorea robusta*), green bottle gourd, are opened and filled with a solution of neem (*Azadirachta indica*), cloves, sugarcane, and nutmeg (*jaifal*). The first branch of *sakhuwa* is placed in the south corner of the village. The place is plastered with cow dung and water, lamp, *jal* (water), *daru* (local liquor) is offered to deities. A white and a red piece of cloth are tied in *munj* (*Saccharum spontaneum*). Then, northeast corner, northwest corner, in the well, southeast corner and returned to the first start-up place, i.e., southeast corner. *Pancho Dev, Pancho Thakur, Pancho Bhuihar* are requested to protect the village. Then *kisan/gardhurya* (head of the household) returns to the village and eats together. There is no *bali* (slaughtering of animals) in the ceremony.

There could be a scientific basis to of hanging a round bottle gourd with bio-pesticides to control insects, such as mosquitoes, to prevent disease in the village. It serves as a natural pheromone trap for insects. Sweet (sugarcane, molasses) attracts insects, and neem and cloves work as bio-pesticides. The use reflects the Indigenous knowledge of the Tharu to prevent mosquitoes and hence malaria in the Tarai.

3. *Dhuriya*

It is performed in *Baisakh* (April–May). The main purpose of this worship is saving livestock and peoples in the village. The ritual is performed in the *thanhwa/ marwa/ brhamathan* (village shrine place). The main deity who is worshipped is Jagganathya. *Kesauki* is performed during worship, to which all deities are invited, where the *guruwa* intones a *mantar* and the *kesauka* shakes his body and then makes requests, such as saving/protecting livestock and people of the village. It also indicates the dry tillage *dhuriya* for the preparation for summer maize cultivation.

Desbandhya guruwa buries an egg during the worship by offering water, milk, *chhaki* (liquor), tiger's *satokh* (soul), and most importantly his blood from the heart/abdomen. The whole process is called *thateina* (convincing to sit calm) to Baghesri (Jagganathya).

4. *Gaiya berhna*: a rainmaking tradition in the Tharu

Gaiya berhna is a rainmaking tradition in the Tharu community performed if there is a delay in monsoon onset and an increased possibility of drought in the monsoon season.

In the ritual of reversal, women wear men's dress and men wear women's dresses. Ploughing is not allowed for women in the contemporary Tharu culture, but in this ceremony women plough. The plough is turned upside down. The *juwa* (yoke) is also made upside down. Women go to another village and bring someone's plough and bullock to their village. Next day, they start to plough in one place and villagers from another village (whose plough and bullock have been taken) come in opposite-sex dresses. Special songs called *sajana* are started as a means of conversation; and the opposite party needs to win by singing *sajana* songs to get back their things. The ceremony may go on for several days, so men in women's dress come to serve water and food to women who are tilling the land. In the end, a special event to pray to god Mahadeva is performed by both villages who participated in this process. This tradition is vanishing and was last performed 10 years ago when nearby village (Josipur) took a plough from Bikri village. This whole process is called '*gaiya berhna'*. Criticisms and vulgar words, such as sexual profanity and criticising personal characteristics, are also spoken during the event.

To me, it gives two types of indication. First, men and women understand the works and associated difficulties of each other's tasks performed in daily life. So they respect each other's work. Second, they have experience wearing a dress of opposite sexes and speak vulgar words so that they do not speak them in everyday contexts in public places. Furthermore, the ceremony also plays a role in creating social harmony and an atmosphere of fun in harsh drought conditions.

5. Being the frog *magha lotna*: another rainmaking tradition in the Tharu

This is another rainmaking tradition performed in the Tharu community in the western Tarai of Nepal when there is drought and no start of the monsoon. In this ritual, boys below 10–12 years take off their clothing and catch a common non-poisonous frog in one hand and then act like a frog by sleeping and moving on the ground. They call this ritual '*le megha de pani'*, which means to take the frog and give the rain. It is performed in the front yard of each household, so the owner of the household pours water over them. At the end, all pray to the god Indra. Frogs are considered an indicator of rain and ask for rain by producing sounds. Though science said the sound is for the breeding purposes, but villagers believe they ask for rain by crying. Similarly, the god Indra is considered the god of rain.

6. *Harot lena*

The main purpose of the *harot* is worshipping the plough and bullock to ensure a good crop and production. It is performed on Monday through *Basiak* to *Asar* (April–June) (Dahit, 2005). Guruwa Jhaggu Prasad Dahit of Bikri informed me, It is performed in *Asar* (June–July) after the sowing rice seedling and maize sowing. A *banthi* (bamboo basket) is plastered with cow dung and a statue of horse made with *sendur* (red cosmetic powder) by the house *guruwa*. Rice is kept in a *banthi* (basket), *nandha (ploughing* rope), *paina* (stick), *phar* (share), and an odd-number of pairs of fishes (3, 5 or 7 pairs) taken to the field. All goods taken to the field are kept on a cow dung-plastered spot. Then, a lamp is burnt, water and liquor are offered to the deities for good production, and protection of the bullocks from sicknesses, so farming can be done in a timely and productive way. Eating and drinking of all the food stuffs (fish, liquor) take place on the spot, since it is not allowed to bring food back home. Fishes *pakwa* (barbecue) are cooked in fire. This ritual has largely been forgotten and is not normally performed nowadays.

There are several other household rituals related to agriculture. The *auli lena* is for offering new produce (rice and wheat) to deities, and the *auli utarna* is a celebration of the last day of the rice harvest. Similarly, in the first day of rice transplantation, the Desauri Tharu (a Tharu sub-group) celebrates *barka kalwa* (the big lunch) in the field and worships the *bagha* deity to protect from cutting legs of the bullocks and to protect the tiller from abdominal diseases such as diarrhoea. *Hardahwa* is celebrated at the household level, as well as village level, after completion of rice transplanting.

Appendix 11. Comparison of grain storage in *dehari* with other storage structures

Name, age, and village	***Dehari***	**Aluminium bin**	**Other storage structures**
Sundari, 60 years, Bikri	No problem of insects (rice weevil, rice moth) even paddy (unhulled rice) stored for 5 years. No problem with storing hulled rice for one or more years.	She was using two bins since 2014. Short-term storage (three months) is good for both rice and hulled rice. Bin outside the house absorb moisture and damage stored grains. Long-term storage (even one year) damages hulled rice in the bin because it absorbs heat and moistens the rice.	Bamboo *bakhari* – Sarju-52 rice was stored for 6 months (November–April); there was a problem of weevil. It was even more problematic in hybrid rice.
Kumari, 46 years, Bikri	*Dehari, kuthli* is much better than the aluminium bins in terms of storage.	Received in 2014 from Save the Children and *Dalit Sewa Sangh* to protect the seed from flooding. Stored rice for one year and had blackish rice on the bottom; thereafter stopped storing seed and now rice bran is stored there.	
Siri, 43 years, Bikri	Storing rice for five years doesn't have any problem. Termites can enter from legs if it is wood or mud. So, it is better to put plastic below the *pendi* (base) or use bricks.	She has been using an aluminium bin for 4 years provided by an NGO. She keeps on changing rice, milled rice in 3-4 months so has not experienced any problem. It is a new experience for her. Good for short-term storage.	Bamboo *bakhari* used in a joint family for 6–12 months. It was temporary storage before the sale, or mill.
Elu, 50 years, Bikri	No problem at all to store rice, wheat, and other crops for 3 years.	No experience	No experience.

	Rice moth, weevil problem have been seen, but do not cause complete loss. More loss in chickpea, pea, and wheat than rice.		
Raku and Fudya, 46 and 47 years respectively, Bikri	No problem in *dehari* and *kuthli* if legs are protected from termites.	I stored rice in 2010 and the outer and bottom layers of rice became black and a rice ball is formed. Milled rice is not damaged because of regular use from it. Wheat and pulses storage for one year without a problem.	No experience
Tali Tharu, 65 years	Emotional attachments with *dehari* since not just built it, but also stored paddy and hulled rice for short and long-term. She thought there would be no other structures better than the *dehari*.	The problem of rice ball formation and black mould, ultimately rotten.	*Bakhari* is good for a few months of storage, needs to be plastered on all sides and up with cow dung. In the bottom, rice straw should be plastered.
Kura, 70 years, Surkhet	No space to keep *dehari* and *kuthli* in the house in the city. However, in the village he still uses *kuthli*. He has good experience of using *dehari* and *kuthli*.	No experience of using	He stored rice in the cement bag by tying the mouth. It is better than storing in *bakhari* because of less infestation of rice moth. He puts wood/plastic on the bottom before piling the bags to protect from moisture.
Basiya Tharu, 45	Unhulled rice can be stored for 4–5 years	Mould formation and rice ball formation. It is not	Plastic drums are also using because they float

years, Thapuwa	without a problem and even hulled rice can be stored for 4–5 years. Cooking old rice increases the volume of rice upon cooking.	good for storage, but due to the flooding problem people are adopting a plastic tank and an aluminium bin for storage of grains.	in flooding and no problem of falling down, as experienced by *dehari* in the flooding.

Note: names of the participants are changed for the privacy.