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GEOGRAPHY | RESEARCH ARTICLE

Climate change adaptation by subsistence and smallholder farmers: Insights from three agro-ecological regions of Nepal

Sikha Karki[1]*, Paul Burton[2] and Brendan Mackey[3]

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*Corresponding author: Sikha Karki, Cities Research Institute & School of Environment and Science, Griffith University, Gold Coast Campus, Queensland, Australia
Email: sikha.karki@griffithuni.edu.au; sikhakarki@gmail.com

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Abstract: The unprecedented challenges posed by climate change necessitate agricultural adaptation by farmers, especially in the regions of Asia, where rain-fed agriculture is the principal source of food production. Studying adaptation not only assists in knowing how farmers are dealing with the repercussions of climate change, but also provides the baseline for the planned interventions which are essential in this era of human-instigated climate change. We used case study data to examine whether and how subsistence-oriented smallholder farmers in three agro-ecological zones of Nepal (Terai, Hill, and Mountain) are developing and implementing adaptation strategies. The findings from small farm household interviews (n = 384), key informant interviews (n = 33), and focus group discussions (n = 3) suggest that farmers are dealing with the challenges facing their traditional agricultural practices. The main adaptation strategies include changing crop types and varieties, adding fertilizers, the use of new technologies, soil and water management, diversification of income sources, and migration. Both climatic and non-climatic factors were found to influence these subsistence smallholder farmers' adaptation practices. However, climatic factors that are beyond individual control threatened the livelihood of rural farmers who predominantly rely on natural resources for their livelihood and income. The findings highlight the interplay of multiple agents: local farmers, community-based organizations, and the local and

ABOUT THE AUTHORS

Sikha Karki holds a master's degree in Biodiversity and Environment Management from the University of Bergen, Norway and Tribhuvan University, Nepal. Currently, she is doing her PhD at Griffith University, Australia. Her research focuses on the impacts of climate change and food security on farm households in Nepal.

Paul Burton is Professor of Urban Management and Planning and Director of the Cities Research Institute at Griffith University. He was previously Head of the School for Policy Studies at the University of Bristol, UK.

Brendan Mackey has a PhD in ecology and is Director of the Griffith Climate Change Response Program. He has authored over 200 academic publications in the general field of environmental science and policy, including on climate change adaptation problems.

PUBLIC INTEREST STATEMENT

Climate change is a global challenge that has impacted all sectors of the economy, including agriculture. Farmers, especially subsistence and smallholder farmers in low-income countries, are particularly vulnerable as they rely heavily on nature and often possess weak adaptation capacity. A higher proportion of these vulnerable groups is still not able to cope with this pressing issue, which has threatened their livelihood. It is imperative to understand how farmers are adapting to climate change and to identify the constraints impeding them from adapting successfully. Studying adaptation enables the improvement of existing management strategies as well as providing the baseline for further planned interventions to combat the impacts of climate change. This study thus examines how farmers in Nepal are adapting their agricultural practices to the effects of climate change.

central government organizations in the role they play in assisting farmers adapt to the impacts of climate change; this interplay emphasizes the need for collaboration for effective adaptation. The findings from this study can inform policymakers about ongoing adaptation measures as well as the needs of farmers. This information can assist in bridging the gap between farm households and policymakers and help develop suitable policies and effective adaptation strategies within this local Nepalese context.

Subjects: Agriculture & Environmental Sciences; Environmental Issues; Environmental Change & Pollution

Keywords: Climate change; adaptation strategies; rural farmers; agricultural practices; constraints; developing countries; Nepal

1. Introduction

Climate change adaptation has received much attention over recent decades with the recognition of climate change impacts all over the world. Adaptation entails adjusting social, economic, and ecological systems following real or anticipated climate effects or impacts (Smit, Burton, Klein, & Wandel, 2000). In agriculture, adaptation is typically a two-step process requiring farmers first to first recognize alterations in climate (Adger et al., 2009) and then to respond via a range of adaptation responses (Brown, Kothari, van Oudenhoven, Mijatović, & Eyzaguirre, 2011; Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009; Maddison, 2007). Adaptation can be responsive or reactive (ex-post), or concurrent or proactive (ex-ante) according to the time undertaken. It could be autonomous or planned, based on the specified objective (Smit et al., 2000). Adaptation measures affect the severity with which climate change impacts will negatively affect agriculture and agricultural communities (Brooks, Adger, & Kelly, 2005; Lobell et al., 2008). Thus, successful adaptation measures should be in place at the farm level to guarantee food security and safe-guard rural sustenance from climate change impacts (Abid, Scheffran, Schneider, & Ashfaq, 2015). Multiple players, comprising farmers, local communities, private organizations, agricultural sectors, and research and policy organizations are a prerequisite for enabling successful adaptation (Bryan et al., 2013). Adaptation further requires planned coordination and collaboration between national and subnational levels of government as well as other relevant stakeholders in developing and implementing a range of supportive policies (Mimura et al., 2014).

Farmers have been responding to climate variability for many years, yet new risks are emerging, driven by the changing climate which is continually altering baseline conditions (Adger, Huq, Brown, Conway, & Hulme, 2003; Bryant et al., 2000; Parry, Canziani, Palutikof, Van Der Linden, & Hanson, 2007). The south Asian countries of Nepal, India, Pakistan, Afghanistan, Bangladesh, Bhutan, the Maldives, and Sri Lanka, despite having relatively low per capita greenhouse gas emission profiles, are among the countries most affected by global climate change (World Bank, 2013). This is especially the case with Nepal, which only contributes 0.025% of the world's total greenhouse gas emissions (Ministry of Environment, 2010), but falls among the countries most vulnerable to climate change.

Based on the Global Climate Risk Index 2016, Nepal ranked 17th in the list of countries most affected by weather-related loss events (e.g, floods, storms, heat waves) from 1995 to 2014, and was the 7th most affected country in 2014 (Kreft, Eckstein, Dorsch, & Fischer, 2015). Furthermore, the Hindu Kush Himalaya (HKH) region where the entire territory of Nepal is located is already facing disruptive changes. By the end of the 21st century, the HKH region is predicted to experience a larger change in the surface mean temperature compared to the global average. A rise of 1.5°C in global temperature would be equivalent to an increase of at least 2.1 °C in this region. (Wester, Mishra, Mukherji, & Shrestha, 2019). This unprecedented warming is likely to bring a myriad of socio-economic and biophysical impacts, which will affect the well-being and livelihood of the

countries in the HKH, including Nepal. Nepal is profoundly impacted by climate change and associated challenges, which include floods, landslides, erratic precipitation, increasing temperatures, glacier shrinkage, hailstorms, fog, and winds. A report by the Ministry of Environment (2010) states that more than 1.9 million people are highly vulnerable to climate change, and a further ten million are increasingly at risk. Sectors such as agriculture, forestry, health, tourism, water and energy, and urban and infrastructure are also highly sensitive to climate change. Nearly 65 % of the total population of Nepal is involved in agriculture (Central Bureau of Statistics, 2011b). The agricultural sector, which includes agriculture, forestry, and fishery, contributes 27.6% of the country's GDP (Government of Nepal, 2018a). Agriculture principally comprises traditional low input farming practices, and only 40% of agricultural land is irrigated; therefore, most farmers rely on natural rainfall (Gentle & Maraseni, 2012; MOAC, WFP & FAO, 2009), making agriculture extremely sensitive to changes to the climate (Easterling et al., 2007; IPCC, 2007). Only 15.1% of smallholder farms (< 0.5 ha) are irrigated. Much of the irrigated land is used by those that can afford the infrastructure and who live in well-serviced areas, and thus have a higher adaptive capacity (Central Bureau of Statistics, 2011a).

Smallholder farmers depend mainly on their farms for food and income generation and rely on the family's own labour (Cornish, 1998). Smallholders constitute more than 50% of Nepalese farmers, cultivating less than 0.5 ha per household (Central Bureau of Statistics, 2011b). Subsistence farming is farming and associated activities in which farmers consume most of the output from a farm and sell only a small portion of it (Barnett, 2011). As these communities rely on natural resources for their livelihood, they are more vulnerable to climate change impacts than those not dependent on natural resources (Mcdowell, Ford, Lehner, Berrang-Ford, & Sherpa, 2013) and have limited capacity to adapt (Aggarwal & Singh, 2010). The HKH region of which Nepal is a part is home to many of these economically, socially, and politically marginalized people (Gioli et al., 2019). Location, livelihood strategies, income sources and crops, and access to food and facilities, all contribute notably to the vulnerability of the rural, hilly and mountainous households of the HKH regions (Aryal, Brunton, & Raubenheimer, 2014; Mcdowell et al., 2013; Pandey, Cockfield, & Maraseni, 2016). Besides, the poverty rate in these hilly and mountainous HKH regions is one-third compared to one-fourth for the national average (Gioli et al., 2019). In the context of Nepal, around 25% of the population lives below the national poverty line. Given that Nepal is already burdened with several pressures including irrigation problems, poor transport infrastructure, low productivity, and inadequate food storage facilities, the further risks arising from climate change mean that adaptation is of utmost importance (Government of Nepal, 2016). Many adaptation strategies have been put forward in response to numerous adverse effects in Nepal (Regmi, Paudyal, & Bordoni, 2009). At the local level, farming households have adopted strategies such as soil and water management, adjustments to the timing of farm operations and crop and varietal adjustment (Dahal et al., 2018; Giri, Tiepolo, & Hada, 2015; Khanal, Wilson, Hoang, & Lee, 2017; Maharjan, Maharjan, Tiwari, & Sen, 2017). At the national level, some of the strategies put in place include capacity building; greater policy integration; community-based adaptation supported by the World Food Programme, Ministry of Science, Technology, and Environment, Ministry of Federal Affairs and Local Development through projects such as Adapting to Climate-Induced Threats to Food Production and Food Security in the Karnali region of Nepal, community-based adaptation via project Anukulan: driving small farmer investment in climate-smart technologies implemented by iDE UK. The Department of Soil Conservation and Watershed Management has implemented project Building Climate Resilience of Watersheds in Mountain Eco-Regions with the aim of capacity building; knowledge communication; field implementation; community-based adaptation, climate-smart villages have been implemented by the CGIAR Research Program on Climate Change, Agriculture and Food Security led by the International Center for Tropical Agriculture and Earth First (Patra & Terton, 2017). Several policy initiatives have been commenced by the Government of Nepal including the National Adaptation Plan of Action (NAPA) 2010, the Climate Change Policy (2011), the National Framework for Local Adaptation Plans for Action (LAPA), 2011 and the National Adaptation Plan (NAP) formulation process. However, for adaptation to be successful, it is essential to have a comprehensive assessment of climate change risks in

specific locations (Gamble et al., 2010) and this holds especially true for smallholder and subsistence farmers using their local climate understanding of the local climate when making decisions (Wilken, 1990).

Assessing how people understand and deal with climatic events provides insight into local knowledge-based activities which can be amplified and replicated by those undertaking planned adaptations elsewhere (Forsyth, 2013; Reid & Schipper, 2014). The systematic study, documentation, and validation of local-level responses are all needed to provide feedback for adaptation planning at higher levels of governance (Wester et al., 2019). Autonomous adaptation in the HKH regions reflects local knowledge systems; however, there is limited information on the adaptation needs and the existing interventions of mountain people (Mishra et al., 2019).

From a review of existing peer-reviewed articles dealing with adaptation by farmers in Nepal; published before June 2019, only two of the publications Khanal, Wilson, Hoang, and Lee (2018b), Khanal, Wilson, Hoang, and Lee (2019) had studied adaptation in the three agroecological zones of Nepal, focussing on the technical efficiency of farmer's adaptation measures and the impact of community-based organisations. More detailed comparative analysis of adaptation strategies and action being taken by smallholder farmers in the three agroecological zones of Nepal is therefore warranted to increase our understanding of which adaptation strategies are being implemented, how these vary among agro-ecological zone and the extent to which adaptation is autonomous or dependent upon the support of government and private organisations.

This study aims, therefore, to assess how subsistence-oriented smallholder farmers are adapting to climate change and to explore adaptive strategies proposed by various agents, including national or district governments, private and local level organizations. In addition, this study, therefore, bridges this gap by investigating adaptation by subsistence smallholder farmers in three agro-ecological regions of Nepal. Moreover, it attempts to improve our understanding of the actions these farmers have been taking to confront the harsh climatic events they have experienced, together with the constraints impeding adaptation to climate change.

2. Materials and methods

2.1. Case study context

Nepal is a landlocked country occupying 0.3% of the total area of Asia and 0.03% of the world. Surrounded by China to its north and India to the east, west, and south, it extends 885 km from east to west and 193 km from north to south (Government of Nepal, 2018b). Based on the National Population Census 2011, Nepal had a total population of about 26.5 million, with an annual population growth rate of about 1.35%. Nepal is diverse in terms of landscape, topography, altitude, and temperature. The Terai, Hills, and Mountains areas form the three agro-ecological zones in Nepal, covering its agricultural land (World Bank, 2011). The total land area of Nepal is 147,181 km^2 of which 51,817 km^2 is covered by the Mountain region, 61,345 km^2 by the Hill region and 34,019 km^2 by the Terai region. Of its total population, about 83% are rural dwellers (Central Bureau of Statistics, 2016). In September 2015 Nepal was restructured into seven provinces formed by groups of existing districts (Government of Nepal, 2018b). The former District Development Committee (DDC) is now called the District Coordination Committee (DCC). To fulfill the new constitution in 2015, 744 local body systems have been adopted by the government of Nepal as of 10 March 2017, representing 460 rural municipalities, 276 municipalities, 11 sub-metropolitan cities, and six metropolitan cities.

2.2. Sampling design

The study used a multilevel sampling technique to select case study sites and households for the interviews (Bryman, 2012; Yin, 2003). First, Province Three was chosen randomly out of Nepal's seven provinces as a case study province (Figure 1). Second, the three District Coordination Committees (DCC) of Sindhupalchowk, Dhading, and Chitwan were selected purposively out of 77 District

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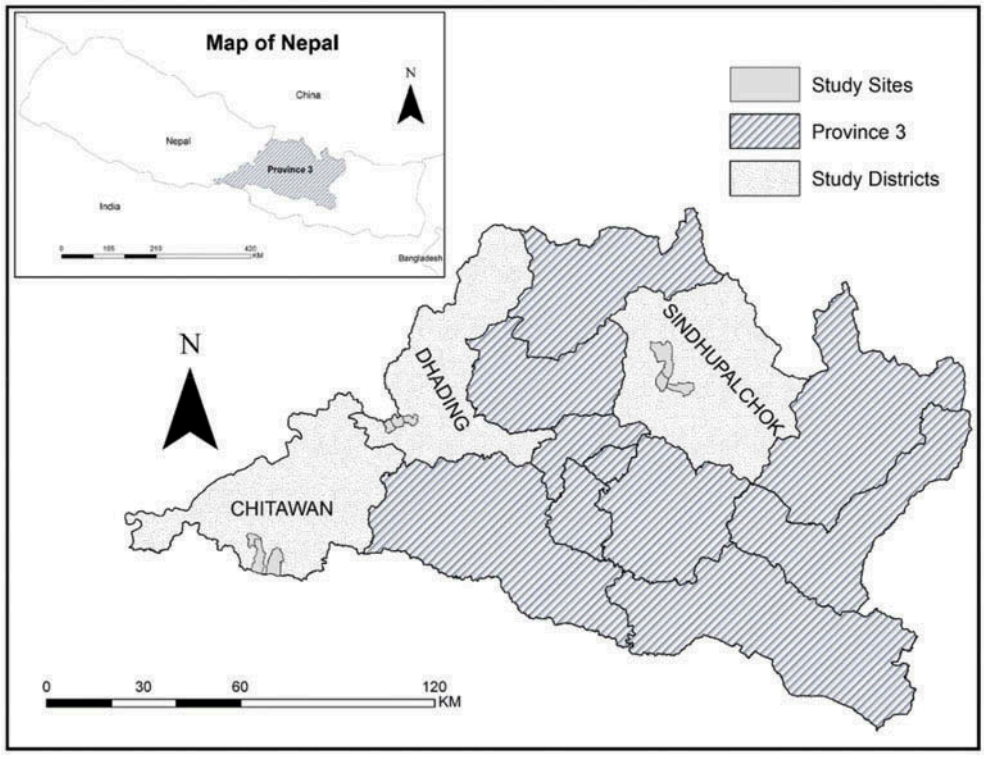

Figure 1. Map of Nepal showing the study sites within the study districts.

Coordination Committees (DCC), one each from the three agro-ecological zones (AEZs) of Himalaya, Hill, and Terai respectively. AEZs are geographical regions with similar climatic conditions that reflect elevation gradients and topographic effects on temperature, rainfall, and seasonality that regulate their potential to support rain-fed agriculture (Sebastian, 2014). The average rainfall and temperature conditions characterising each AEZ are given in Table 1. The purposive selection of districts, one from each agro-ecological zone, was guided mainly by our aim to reflect agro-ecological diversity across each zone. Three municipalities within each DCC were then selected randomly, and finally, three wards from each municipality were chosen. Finally, at the local level, a total of 384 households (Krejcie & Morgan, 1970), 128 households from each DCC (selected from the three wards based on stratified random sampling) were selected for the interview. The selection bias which may have occurred due to a purposive selection of province and DCC was minimised in the sampling by following the advice of Skowronek and Duerr (2009) to consider the representativeness and diversity of the sample and to use a sufficiently large data set. The sample representativeness was achieved by using random and stratified random sampling to select subgroups (municipality and wards) and research participants. A stratified sample specifically promotes representativeness by directing investigators to decide on the proportion of interviews in and within each place, allowing for an appropriate number of interviews from, in this case, each ward. The sampling within each ward is random, but the stratification forces the sample into a more representative balance (Tyrer & Heyman, 2016). In addition, this study embraced a diverse technique of data collection, including key informant interviews (n = 33) and three focus group discussions which enabled triangulation. The relatively large sample size was obtained by using household interviews (n = 384).

2.2.1. Case study district coordination committee

Three District Coordination Committees (DCCs) were selected from Province Three. Province Three is one of the seven provinces of Nepal, with a population of 55,29,452. It consists of 13 districts, three metropolitan cities, one sub-metropolitan city, 74 rural municipalities, and 41 urban

Table 1. Characteristics of the three Districts (Chitwan, Dhading, and Sindhupalchwk) used in this study including key climatic parameters

Features	District		
	Chitwan	**Dhading**	**Sindhupalchowk**
Representing AEZs	Terai	Hill	Mountain
Area (km^2)	2,238	1,926	2,542
Population	579,984	336,067	287,798
NAPA Ranking	High	High	Moderate
Administrative units:	(1)	None	None
• Metropolitan city	1	0	0
• Municipalities	6	13	12
Average annual rainfall (mm)	1,784	1,684	2,035
Average monsoon rainfall (mm)	1,461	1,366	1,688
Average winter rainfall (mm)	45	48	52
Annual maximum temperature (°C)	29.5	22.8	17.4
Monsoon maximum temperature (°C)	32.5	26.2	21
Winter maximum temperature (°C)	23	17	11.9
Annual minimum temperature (°C)	17.4	11.8	7
Monsoon minimum temperature (°C)	23.8	17.7	13.0
Winter minimum temperature	9.2	4.7	0.

*Temperature and rainfall data are extracted from Department of hydrology and meteorology DHM (2017)

municipalities. Its population comprises an almost equal proportion of males (49.69%) and females (50.31%) (Nepal in Data, 2018).

Chitwan DCC (Terai) lies in the central development region in Province Three (Table 1). It is in the southwestern part of the Narayani zone and occupies an area of 2,238.39 km^2. With a population of 579,984 and an annual population growth of 2.06% (Government of Nepal, 2012), Chitwan lies in a high vulnerability zone based on the NAPA ranking for climate change vulnerability (Ministry of Environment, 2010). *Dhading DCC (Hill)* lies in the central development region in Province Three and Bagmati zone (Table 1). The district covers an area of 1,926 km^2, and in 2011, Dhading's population was 336,067 (Government of Nepal, 2012). Based on the NAPA ranking for climate change vulnerability, it also lies in a high vulnerability zone (Ministry of Environment, 2010). *Sindhupalchowk DCC (Mountain)* lies in the central development region in Province Three and Bagmati zone covering an area of 2,542 km^2 (Table 1). As of the 2011 census, Sindhupalchowk had a population of 287,798 (Government of Nepal, 2012). Based on the NAPA ranking for climate change vulnerability, this district lies in a moderate vulnerability zone (Ministry of Environment, 2010). Despite being close and easily accessible to the capital of Kathmandu, the district is poorly developed (DCC Sindhupalchowk, 2018). Note that here the terms Terai, Hill, and Mountain are used interchangeably with Chitwan, Dhading, and Sindhupalchowk respectively.

2.3. Interviewee selection and interview formats

2.3.1. Face to face interviews with individuals from subsistence-oriented smallholder farm households

The head of the household involved in agriculture was selected for the interview based on the selection procedure described in section 2.1.1. The household head (age 30 years and above) was selected irrespective of sex. However, if the household head was not available, then the next most senior member of the household was invited to be interviewed. Participation was voluntary, and respondents were free to withdraw from the study at any time if they chose to do so. The interviews were conducted from July 2018 to Jan 2019 at a location convenient to the participants, and before each interview, participants completed the approved ethical consent process, with the researcher explaining the purpose of this and its significance to the participants. Participants were also provided with an information sheet outlining the details about the study. Interviews were conducted in the native Nepali language to ensure the respondents had an adequate understanding of the questions. Note that the first author who conducted all the interviews is a Nepalese citizen with verbal and written fluency in both Nepali and English language. Additionally, locals were employed in each study site to assist the researcher to identify smallholders and to serve as guides into rural areas. The identity of participants is not disclosed, maintaining the anonymity and confidentiality of respondents. Based on the questionnaire, participants were asked to describe their experience of change in climate and its impact on their agricultural practices over the last 30 years. The questions asked were identical across the three regions. The adaptation-related questions were left open-ended. Moreover, they were asked to describe any coping or adaptation measures they followed to overcome these impacts. Each interview lasted between 30–45 minutes, and answers were recorded on the questionnaire sheet by the interviewer and transcribed as soon as possible thereafter. The research was conducted under Griffith University Ethics number 2017/427. The reader is referred to as the supplementary table for a general description of the survey questionnaire employed in this study.

2.3.2. Focus group discussions

The existing patriarchal social norms and traditions (Panta & Thapa, 2018) and restricted cultural roles of Nepalese women necessitate the recognition of gender perspectives on climate change and related issues. Thus, three focus group discussions were conducted as part of this study. Focus group discussions are an interactional discussion focusing on specific issues with a group of people, aimed at identifying a range of perspectives on a research topic and gaining an understanding of the issues from the participant's perspectives (Hennink, 2014). "Aama samuha", or "mothers'group" in a literal translation to English, is a voluntary group initiated by women in Nepal. Though women's or mothers' group by name, the working dimensions of these groups are not limited to dealing with women's issue but in fact they are involved in development works, community welfare, income generation, family planning issues, resolving domestic violence and/or supporting the victims establishing saving and credit schemes, and raising funds for social causes. Focus group discussions were conducted with three of these groups selected randomly; one from the mountain region district, one from the hilly region district and one from the Terai region. In each group, there were six to nine female participants (age 30 years and above). The general theme of questions of the focus group discussion is presented in the supplementary table.

2.3.3. Key informant interviews

Key informant interviews (Lavrakas, 2008) were also conducted at the national, district, and municipality levels through the purposive sampling of experts knowledgeable of the issues related to the research. Accordingly, private organizations (both national and international) and government departments whose work involved climate change, agriculture and food security were visited, and the relevant officials consulted. A total of 33 key informants were interviewed including officials from government departments (n = 12), non-governmental organizations (n = 9); international non-governmental organizations (n = 9) and teachers (n = 3). Detail of the themes of questions asked in the key informant interview is presented in the supplementary table.

2.4. Data analysis

The results of the surveys were analyzed using a variety of methods (Greene, Caracelli, & Graham, 1989). Qualitative data was managed following Ritchie, Lewis, Nicholls, and Ormston (2013) and involved the identification of initial concepts or themes; labeling or tagging the data; sorting the data by theme or concept, and then summarising or synthesizing the data. NVivo software (QSR, 2017) was used for the content analysis of the key informant interview and focus group discussions. The interviews were transcribed and imported into NVivo (Bazeley, 2007), and the transcribed interviews were analyzed to identify and code themes and categorize these into subthemes in line with the study objectives. Based on the responses, adaptive measures revealed through the NVivo analysis were categorized into broad themes following the adaptation studies in Nepal by Khanal et al. (2017) and Gentle, Thwaites, Race, Alexander, and Maraseni (2018). For the quotes, the alphanumeric code HH refers to the number assigned to each of the households interviewed; KI refers to the key informants and FGD-T, FGD-H and FGD-M refers to the focus group discussions each from the Terai, Hill, and Mountain regions. The quotes presented are the translated versions, and the authors have tried to retain the context.

3. Results

Table 2 shows the various adaption measures are being used by the farming communities to mitigate the adverse impacts of climate change. The agricultural adaptations to climate change were entwined with the need to also adjust to non-climatic impacts complicating the isolation of these two factors. The following sections provide summary statistics and indicative quotes relating to each of these categories.

3.1. Crop and varietal adjustments

The most common and widely adopted measure among the farming communities was crop and varietal adjustment. Altogether, 87% of the farming communities were found to have adjusted the crop type and varieties including switching to hybrid varieties, mixed cropping, diversifying crops, crop rotation, and use of local varieties. All the respondents from Chitwan reported having changed crops and varieties or adopted one or more of the measures mentioned before, followed by a majority of those in Sindhupalchowk (86%) and Dhading (76%).

Table 2. Main categories of adaptation being employed by subsistence smallholder farmers

Theme	Total % (n = 384)	Chitwan (%) (n = 128)	Dhading (%) (n = 128)	Sindhupalchowk (n = 128)
Crop and Varietal adjustments	87	100	76	86
Fertilizer management	79	88	84	65
Farm operations time management	58	78	55	40
Adoption of technologies	45	66	50	20
Soil and Water management	40	42	39	38
Diversification of income sources and agricultural practices	23	21	38	10
Migration	22	31	6	30
Access to financial resources and risk reduction measures	20	0	39	22

Key informants frequently talked about the plantation of hybrid, drought-tolerant, and climate-resilient varieties by farmers in all three regions. A key informant (KI3) said,

> The changes made by households to respond to climate uncertainties are crop rotation, crop diversification, intercropping, change in crop varieties, and adoption of climate-resistant crops/varieties.

> Another key informant (KI23) narrated, "The responses are localized. Alternative crops are planted. Short duration rice varieties are planted."

As some of the key informants revealed, their organizations have been providing households with seeds and the Nepal Agricultural Research Council (NARC) is involved in research on and the development of cold-tolerant, drought-tolerant species, and research. A key informant (KI30) stated, "Our organization provides Agro input support: paddy and potatoes seeds and livestock support."

3.2. Fertilizer management

Fertilizer management includes the use of farmyard manure as well as the use of chemical fertilizers. In total, 79% reported using fertilizers and/or manure for increased yield. A higher percentage (56%) of farm households reported applying farmyard manure, followed by those in Dhading (47%) and then by those in Chitwan (25%) while more respondents from Chitwan stated increased use of chemical fertilizers (65%). The increased use of fertilizers was also described in group discussions and key informant interviews as well to combat declining productivity. At the same time, declining productivity was attributed to climate change. According to the discussion, farmers used cattle manure as a fertilizer, but recent years had witnessed an increased use of chemical fertilizers from agricultural goods suppliers or the nearest market, mainly in low land followed by hills. Respondents from the focus group discussion in the hilly region added (FGD-H), "We make use of compost, urea." Also, a key informant (KI 18) stated, "Farmers are using more urea and pesticides."

3.3. Farm operations time management

More than half of the respondents (58%) reported changing the date and time of planting and harvesting mainly to respond to an uncertain onset and cessation of rainfall. Most respondents in Chitwan described changing the agricultural calendar, i.e., depending on the timing of rainfall for crop plantation (mainly paddy), followed by those in Dhading and then in Sindhupalchowk. A farmer (HH-185) lamented, "We are forced to plant late, due to the untimely rainfall." According to some key informants, due to the rain-fed agriculture, farmers are adjusting their sowing and harvesting time depending upon the climate (rainfall) pattern. One key informant (KI 14) emphasized, "Mainly for paddy, households have changed plantation time, planting according to the rainfall timing." while another key informant (KI 21) said, "Households have adapted the calendar according to the weather."

3.4. Adoption of technologies

Adoption of technologies, including the use of agri-chemicals (insecticides, pesticides), improved technologies, and plastic tunnels and greenhouses, were mentioned by nearly half of the respondents (45%). More respondents from Chitwan and Dhading (Table 2) reported having used improved technologies, and the increasing use of agri-chemicals was highly cited by the farming communities. An interviewee (HH 268) stated, "We have started growing vegetables in a plastic greenhouse." Women's groups articulated increased pest infestation and consequently increased investment in pesticides. In Terai they (FGD-T) described,

> These days, because of pest infestation, we must make use of pesticides/fertilizers. Without pesticides, there is no production, and even with pesticides, the production is not so good compared to what it used to be before. Previously we didn't have to spend more on farming, but now we have to spend too much on pesticides or seeds; still, it's not that profitable.

The officials for the interview emphasized the escalated use of a plastic tunnel, which is a small greenhouse-like setup mainly used for growing vegetables. A key informant (KI 1) said,

> People are not directly adapting to climate change, or they don't intentionally mean to adapt to climate change; however, they are making uses of greenhouses, implementing pest management programs.

Some (e.g., KI 17) noted less use of smart technology by farmers themselves, "Farmers have adopted low cost locally available measures. Very few climate-smart technologies have been adopted." The officials mentioned the promotion and provision of climate-smart technologies in the targeted area of the district by the respective organizations, including greenhouse gases, flood warning systems, computer applications, and climate field schools for testing and validation of climate adaptation technologies.

3.5. Soil and water management

The responses relating to agroforestry, rainwater harvesting, pond construction, and increased irrigation were included in soil and water management. Only 40% of the respondents reported having adopted these measures. The number of respondents was slightly higher in Chitwan compared to Dhading and Sindhupalchowk. A respondent (HH-110) stated,

> We are using drip irrigation and plastic tunnel for farming supported by the organization. I don't exactly remember the name-it must be from Samari Uthan.

Based on the key informant interviews, organizations like Oxfam Nepal, CARE Nepal and CSRC have been providing and promoting drip irrigation spray water use, among others. A key informant (KI 21) highlighted,

> People have started adopting soil and water conservation measures like agroforestry, water harvesting, and drip irrigation.

According to the key informants from Terai and the hilly regions, investment in irrigation is growing rapidly while some are practicing soil and water management measures such as mulching, zero tillage farming, and the adoption of agroforestry mainly in the hills. A key informant (KI 23) stressed,

> The responses are not only automatic but through the interventions as well. Agroforestry is adopted in the hilly region.

3.6. Diversification of income sources and agriculture practices

Twenty-three percent of the respondents noted diversifying sources of income and agriculture practices. These include responses like doing side jobs, labour works, shared agriculture, and shifting to vegetable farming or cash crops. A higher percentage of respondents from Dhading reported diversifying income sources and agriculture practices followed by those in Chitwan and then Sindhupalchowk. More respondents from Dhading (20%) reported shifting to vegetable farming, followed by those in Chitwan (17%). A farmer (HH-154) stated,

> We didn't know about vegetable farming before, so previously we used to focus on cereal crops only, but now we have shifted to vegetable farming as cereal crops are no more productive.

Another respondent (HH-291) said,

> Yes, we are growing tea and black cardamom which is provided to us by organizations.

Another interviewee (HH 242) emphasized, "Now a day we have started rearing a few goats (small animals) and selling them."

Lack of interest of youth in agriculture, less productive and less profitable cereal crops and unpredictable weather were mentioned as the reasons for the diversification of agricultural practices and source of income. A farmer (HH 146) said:

> Young generation is least interested in farming and have shifted to other jobs. Even we are slowly shifting to vegetable farming and planning to sell it.

This result accords with the experiences shared by the women's group in Dhading and with the key informant's views. The women's group in the hilly region (FGD-H) described:

> We are involved in agriculture. Even in farming, we used to plant cereal crops, but now we plant cereal crops in monsoon mainly paddy and vegetable in other seasons. We are more involved in vegetable farming nowadays. Previously, our elders and even we used to be involved in the cereal crops farming.

A key informant (KI 18) mentioned: "Households are mainly shifting from traditional plantation into cash crops." Another key informant (KI 19) quoted, "Some farmers are searching for an alternative within the country or abroad."

3.7. Migration

Internal and/or external migration was reported by 22% of the interviewees. More respondents from Chitwan and Sindhupalchowk noted migration, mainly by young people, as an adaptive measure. Along with the climatic factors and natural disasters (floods, earthquakes, and landslides); this migration was reported to be driven by a combination of various factors including lack of interest among some youth in agriculture due to its perceived lack of productivity, poor income opportunities, and poor access to fertile land and food. This migration is especially prevalent among young men, as evident in the results, was also reflected in the comparatively higher number of females participating in the interviews as household heads, a position that is traditionally held by males.

Based on the women's group discussion, the main reason why youth migrated was to find work and earn more money. A women's group in the hilly region (FGD-H) said,

> Nowadays, youth are migrating abroad. Usually, one from each household seems to have migrated abroad. However, some are involved in vegetable farming commercially.

However, respondents also reported that migration also occurred to move to safe areas to escape floods or involved temporary migration to cities during harsh weather or disasters. Women in the group from the mountain region also noted migration was influenced by economic background, as the affluent ones move to the city or abroad whereas those with limited income lived on in the villages, often struggling to cope with the changes. The women's group from the Terai and Mountain region noted:

> Because of the flood events, the downstream dwellers are forced to shift to safer areas. Some were forced to leave their house. (FGD-T)

> Affluent ones move to Kathmandu (like they did in an earthquake or did during extreme winter). But those with lesser income have lived here struggling with the changes (FGD-M)

The key informants also stressed the growing practice of migration within the country and abroad.

> Labor migration/remittances are the major sources of income nowadays. The migrating pattern is like people with low earning migrating to India; medium is earning in golf areas, and people with good economic background go to countries like Australia. (KI 20)

> Short-term transfer (or temporary migration) to the low lands or secure food area during the insecure seasons (winter, pre-monsoon, is based on the time and conditions) and back to the same place after the season are practiced by households (KI 24)

3.8. Access to financial resources and risk reduction measures

Twenty percent of the respondents reported taking loans, especially as an adaptive measure in agriculture. However, in informal discussions with interviewees and the farming communities, many said they were involved in cooperatives, saving, and credit schemes within women's groups. One respondent (HH-227) stated, "We have received support from agricultural cooperatives."

More respondents (Table 2) from Dhading and predominantly from Cheppang communities reported taking loans followed by those in Sindhupalchowk; targeted more towards meeting their subsistence needs. This was common among the farmers who reported having poorer land, less income, and limited livelihood options and those who practiced sharecropping. Sharecropping is the system of allowing a person or the sharecropper to till or use the land by a landowner in return for a share of the harvest from the land. Both the landowners and tenants get incentives as risk is shared between them (Shakya, 2009). Some farmers involved in sharecropping reported taking loans from the landowners. Even the women within the women's group run-saving and credit schemes and provide loans to the destitute members within the group.

> We all are a member of the women's group and this women's development saving and credit cooperative as well. Through the cooperative, we are involved in several programs targeted for the uplifting of women. We save money every month and then utilize in income-generating activities like vegetable farming or provide a loan to the needy members. FGD-H

> We from the women's group collect money, and we support the needy ones: flood victims FGD-T

3.8.1. Role of organizations/institutions in adaptation

A little less than half (46%) of respondents said that they had received support from governmental organizations or non-governmental organizations to cope with the changes in the community (Table 3). This support had been provided to both formal and informal community-based groups such as the forestry group, women's group, agriculture group, and cooperatives. Farm households note that the support provided mainly involved the provision of inputs (eg seed support) and training. As one farmer stated:

> We are supported by the government for vegetable farming but no support from Non-governmental organizations (NGOs) and International non-governmental organizations (INGOs) (HH 208)

> Yes, we have been supported by governmental and non-governmental organizations. We have received support for drip irrigation and tunnel farming from Samari Uthan. HH 110

Women in the women's group acknowledged the help of these organizations via these groups in their personal and professional development. However, some of the respondents noted that some of the assistance was not equitably available and not helpful for some. As they explained,

> Seeds were provided from IPM Nepal and Sano Kishan. Moreover, support was provided for irrigation as well. Training has been provided both from the governmental organizations such as the District Agriculture Development Office (DADO) and Women Development organization. Women development provided training (4–7days) on agriculture and livelihood targeted for women and children. Focus, Nepal, and Prayas Nepal have also implemented programs. We were backward in every aspect and now we have gained confidence. We are more aware of current affairs and things going around. Our livelihood has improved. Awards are provided for good works. We are able to talk and speak confidently. (FGD-H)

Table 3. List of adaptation interventions provided to the farmers by the various organizations as reported by the key informants (n = 33)

Major role/focus	Description	Organizations
Soil and Water management	Rainwater harvesting, supporting infrastructure, promotion of drip irrigation, spray water use, pasture mulching	District Agriculture Development Office (DADO), Oxfam DRR/NCCA, Community Self Reliance Center (CSRC), CARE Nepal
Pest management	Pesticides provision, integrated pest management	DADO, Community Self Reliance Center (CSRC)
Fertilizer management	Compost management and improved shed	PRAYAS Nepal
Technology	Climate-smart agriculture technologies/greenhouses program/climate field schools	DADO, District coordination committee (DCC), Forward Nepal, Save the Children (Sabal program)
Agricultural production, crops and cropping system	Development of both health and cold tolerant, drought-tolerant species, organic farming, tunnel farming, agriculture production, strengthening, and agri-based micro-enterprise development	DADO, Resource Identification and Management Society Nepal (RIMS-Nepal), Community Self Reliance Center (CSRC), Municipality (ward office)
Capacity building	Training, strengthening the local community, farmer business school	District coordination committee (DCC), Local Initiatives for Biodiversity, Research, and Development (LI-BIRD), CARE Nepal, MANK (Mahila atma nirbhar kendra) Nepal, Heifer International, Rural Reconstruction Nepal (RRN)
Sensitization	Awareness	Oxfam DRR/NCCA/District coordination committee (DCC), Forward Nepal, Heifer International, Municipality (ward office), Save the Children (Sabal program)
Support livelihood	Livelihood supporting physical and natural assets creation/cash for food and cash for assets	Resource Identification and Management Society Nepal (RIMS-Nepal), MANK Nepal
Disaster risk reduction	Disaster risk management, early warning	Department of hydrology and meteorology (DHM), CARE Nepal, Forward Nepal, Rural Reconstruction Nepal (RRN), Save the Children (Sabal program)
Policies/regulations	Coordinate in policy formulation, policy analysis	Oxfam DRR/NCCA, Food First Information & Action Network (FIAN Nepal), Local Initiatives for Biodiversity, Research, and Development (LI-BIRD)
Information dissemination	Provide information about the weather phenomenon/risk minimization information/flood warnings information/flood alert through SMS/weekly advisory to the farmers/	Animal Health Research Division (AHRD), Nepal agricultural research council (NARC), Department of hydrology and meteorology (DHM)
Researches	Conducting research	Animal Health Research Division (AHRD), Nepal agricultural research council (NARC)

*Note: Climate change is incorporated as a cross-cutting issue in organizations' agendas and programs. Additionally, adaptation interventions supported by these organizations included in this table are the major adaptation interventions mentioned at the time of interview

> Mainly, two organizations CARE and CSRC have targeted their programs in our area. They have provided us with seeds and training for some. No governmental organizations have helped us. (FGD-M)

The benefits of being in the group were recognized along with the complaint of being deprived of the benefits as they are not in any groups. As one interviewee (HH 122) said, "I am not in the farmer's group; otherwise, I would be receiving benefits, so I have to buy seeds and other input from agro-vet."

3.8.2. Constraints in adaptation to climate change

Various themes relating to the constraints to adaptation emerged and are summarized in Table 4 below.

When asked about factors obstructing them in responding to the adverse impacts of climate change, overall, a high percentage of the respondents (82%) described not receiving enough support from the government. More respondents from Chitwan reported receiving less support from the government. Around 78% of the farming communities described adaptive measures being costly or lacking the financial means to respond. Financial constraints were highly reported by respondents in Sindhupalchowk (Table 4). Lack of technology was felt also to be a constraint on their ability to adapt by 76% of the respondents. Seventy percent of the respondents described a lack of sensitization or awareness among the communities regarding climate change, its impacts, and the adaptation options to respond to climate change. This was followed by 61% of respondents who stated a lack of weather information/forecast or information about climate change was a significant constraint. The respondents were not especially familiar with the term climate change or "Jal Bayu Pariwartan" in Nepali. Only 38% of all respondents expressed any understanding of climate change. Not being able to access support organizations was cited as a constraint to adaptation by 59% of the households. Fewer respondents from Sindhupalchowk (40%) reported access to support organizations as constraints compared to other study areas. In

Table 4. Main categories of constraints in adaptation to climate change faced by subsistence smallholder farmers and the percentage of farming households surveyed (n = 384) who are facing each constraint theme

Theme	Response (%)	Chitwan (%)	Dhading (%)	Sindhupalchowk (%)
1. Insufficient support from the government	82	91	72	83
2. Financial constraints	78	73	79	81
3. Lack of Technology	76	81	77	68
4. Lack of awareness/ communication and information dissemination on climate change, its impacts, and adaptation	70	66	70	77
5. Lack of weather information/ forecast or information about climate change	61	65	56	61
6. Access to support organizations	59	77	60	40

addition to these major constraints, others mentioned by respondents included not receiving proper support from organizations, lack of market access, irregularities by brokers, and lack of irrigation facilities. A farmer (HH185) lamented,

> There is no proper policy and even the current policy lacks implementation. We suffer from the lack of subsidy and untimely provision of agricultural equipment. Even if we try vegetable farming, the mediators between the farmers and consumers take the benefit, and we don't have control over it.

The women's groups also identified as important constraints receiving insufficient support from the government and the non-governmental organizations, a lack of information about climate change and lack of information on and access to the support organizations. Key informants reported a range of constraints as the reasons for households not being able to respond to climate abnormalities including a lack of knowledge, technology financial constraints, poor infrastructure, and diverse agro-ecological conditions, less prioritizing adaptation to climate change, weak plan and policies. A key informant (KI 14) stated, "Lack of awareness about climate change, though they are experiencing it, other constraints are access to the helping agencies, market access." Other (KI 24) explained,

> The major constraints to climate change adaptation are weak finance, weak policy and planning on climate change adaptation, unavailability of timely and reliable climate information and warnings, public unawareness on climate change issue and adaptation measures (lack of knowledge), no proportional and common channel to communicate with relevant institution on climate change for general public, unpreparedness to adapt for the untimely occurring climate extremes, only limited few short-term climate change adaption project for some regions.

4. Discussion

The farming communities included in this study were found to be adjusting to uncertainties in their agriculture systems arising from climate change. These activities relating to adaptation were predominantly driven by their skills, local knowledge, and judgment, which varied according to their agroecological region, vulnerability, available technology and resources, and institutional support. Adjusting crops and the varieties of crops, the use of fertilizers, the management of time regarding farm operation, better soil and water management, and migration were most commonly practiced in all three regions. Other studies have also found these adaptations to be employed in Nepal (Dahal et al., 2018; Giri et al., 2015; Khanal et al., 2017; Maharjan et al., 2017) and elsewhere in the countries of the HKH region and indeed the world (Alam, Alam, & Mushtaq, 2017; Ali & Erenstein, 2017; Gezie, 2019; Tripathi & Mishra, 2017; Yamba, Appiah, & Siaw, 2019).

Specific adaptation strategies were more favoured more in some of the regions and other strategies by other regions. The highland zones grew a variety of local crops, and farmyard manure was used far more than technology and pesticides compared to in the other two regions. The communities in Terai, the lowlanders, had more alternatives which could be due to better market access, transportation, and the greater availability of agricultural technology. These findings concur with other studies conducted in Nepal's three agro-ecological zones (Giri et al., 2015; Tiwari, Rayamajhi, Pokharel, & Balla, 2014). Agroforestry was more common in the hills of Nepal. However, respondents from all the three study sites reported using tree plantations on farms that served as windbreaks and shelterbelts; hedgerows for the growing of maize; and as a source of timber, fuelwood, and fodder. In contrast to our study, however, (Tembo & Tadesse, 2018) found that off-farm activities and a change in plantation dates were more commonly carried out by highlanders.

The adjustments in the planting of crops in response to changing conditions, mainly in terms of shifting rainfall patterns, and farmers' increasing inclination towards vegetable farming and/or cash crops in this study, suggests that farmers are already responding to the influence of climate change on their rain-fed agriculture. Shrestha and Nepal (2016) found that farmers in Nepal were

shifting from cereal crops to vegetables as a response to low production resulting from increased temperature and erratic rainfall. Altering the plantation and harvesting time and shifting to vegetable farming and cash crops by farmers to deal with the climate variability concurs with other studies in Pakistan, India, and Ethiopia (Abid et al., 2015; Banerjee, 2015; Belay, Recha, Woldeamanuel, & Morton, 2017; Bhatta, Van Oort, Stork, & Baral, 2015). A recent assessment report from HKH regions by Wester et al. (2019) reported that the transition from subsistence agriculture to a commercial, cash-crop based economy is pervasive in the HKH region. This kind of livelihood, including a shift to a cash-crop based economy or services and industry, is driven by a variety of factors which include economic, logistical, institutional, and environmental factors. It is important to note that despite this shift, a very high number of the population still relies on agriculture for their livelihood.

Agriculture is negatively affected by a combination of both climatic and non-climatic factors. Consequently, agricultural adaptations to climate change were intertwined with the need to also adjust to non-climatic factors. Alterations of crop varieties and types, therefore, have a dual purpose. The first being to increase production, which was highly cited, and the second being to find crops better suited to the new climatic conditions. As found in other studies in Nepal, Ghana, Australia, Ethiopia and Nigeria (Antwi-Agyei, Stringer, & Dougill, 2014; Bryan et al., 2013; Deressa, 2007; Fosu-Mensah, Vlek, & Maccarthy, 2012; Manandhar, Vogt, Perret, & Kazama, 2011; Smit & Wandel, 2006), farmers are having to respond in parallel to climatic as well as non-climatic (social, economic, political) stresses.

Farmers indicated in our surveys that the lack of interest among some young people in farming was due to it being relatively unproductive and unprofitable and has resulted in them either migrating or seeking other economic opportunities. While this affects farmers' capacity to adapt and maintain food production, the additional family income from this economic diversification can improve their overall food security and household wellbeing. From this perspective, migration can be understood as an adaptation measure that is gaining popularity among rural households. The increasing migration of men, mainly youth, internationally as a foreign labour force or to pursue education was highly evident among those in Terai.

While migration, predominantly by men, has increased remittances back to communities in rural areas, this has left women, however, with an increased burden of agricultural and household labour. This has resulted in some leaving the land fallow or dependent on purchasing goods from markets to meet basic needs. This feminization of agriculture evident in Nepal has resulted in the use of less intensive farming practices and abandonment of agricultural land by women, further lowering production and decreasing food security (Tamang, Paudel, & Shrestha, 2014). However, Gray (2009) highlighted that smallholders are often considerably more resilient to demographic changes like migration and thus spatial adaptation could help them invest in agriculture via increased remittances (Gray, 2009). Given these uncertainties, a further detailed study of the impact of migration on smallholder agriculture is required.

Migration was also reported as occurring to escape and avoid climate-related and other natural hazards. Migration is widely recognized as a likely adaptation strategy to cope with environmental change (De Moor, 2011) and is more prevalent in the HKH region (Wester et al., 2019). Drought-induced reduction in agricultural production has been found by other Nepalese studies to be one of the factors influencing migration (Sujakhu et al., 2016). However, some rural areas are also experiencing an inflow of people. Households from the higher regions are more inclined to move within the country or move to the city and low lands in times of harsh weather (winter) and natural disasters such as earthquakes.

Adaptation measures in this study were mostly autonomous (Parry et al., 2007), ad hoc, localized, and short-term (Smit & Pilifosova, 2001). Khanal, Wilson, Hoang, and Lee (2018a) reported the effectiveness of a farmer's adaptation in increasing agricultural yield in Nepal but also emphasized the need to gauge other socio-economic and environmental impacts arising from

those adaptation measures. Adaptation strategies can sometimes bring unintended outcomes (Rodriguez-Solorzano, 2014) or result in maladaptation if not appropriately planned (Gentle et al., 2018). This holds true for households where the capacity for successful adaptation is controlled by multiple factors such as the level of poverty (Mcdowell & Hess, 2012) and other conditions affecting people's vulnerability. In Bangladesh, failed autonomous crop adaptations to combat flood events were found to have a significant social and economic impact and are likely to magnify food insecurity and eventually threaten human security (Younus & Harvey, 2014).

The localized adaptation measures found to be used by farmers in this study could prove to be ineffective or generate adverse impacts in the long run if not implemented carefully. The soaring use of pesticides, for example, as reported by farmers in Chitwan and Dhading in this study, raises serious concerns regarding the potential for undesired subsequent health and environmental impacts (Aktar, Sengupta, & Chowdhury, 2009; Neupane, Jørs, & Brandt, 2014). The effect of pesticides on soil quality is already evident in the Indrawati Basin, Nepal (Pradhan, Sijapati, & Bajracharya, 2015). Moreover, inadequate knowledge of farmers regarding the use, handling, types, and selection of pesticides was reported in the Chitwan district of Nepal (Rijal et al., 2018). The change in the sowing time of the cereal crops popularly noted in all three regions could affect the growing season as well (Macchi, Gurung, & Hoermann, 2015). Considering, the pace with which climate is changing and creating impacts, vulnerable communities may not be able to cope on their own, and their autonomous responses may prove inadequate, thus necessitating planned adaptation through support from outside organizations (Leary et al., 2007).

Several factors were held to be responsible for impeding farmers' adaptation. A high percentage of farming communities stated they had received inadequate governmental support. This could be related to the lack of support staff, and offices in the rural areas, as most of them, are concentrated at the district headquarters. Moreover, the slower pace of reconstruction and poor disaster recovery following the disastrous 2015 earthquake left many rural communities skeptical about government services in Dhading and Sindhupalchowk.

Government support via loans, subsidies, or technology can be effective in assisting farmers in combatting climate change in South Africa (Wilk, Hjerpe, Yang, & Fan, 2015). Manandhar et al. (2011) described the confidence of Nepalese farmers in coping with the dry period of farming if they received governmental support in managing irrigation systems and lack of government support as a barrier to adaptation has been observed elsewhere (Biggs, Tompkins, Allen, Moon, & Allen, 2013; Panda & Singh, 2016; Salau, Onuk, & Ibrahim, 2012). Much adaptation work being conducted and initiated by the government and reported by the key informants is inhibited by a gap between the information generation/services and its dissemination/provision. The hills and mountains terrain in the HKH regions lack adequate infrastructure related to communication, transportation, irrigation, energy, and urban utilities (Mishra et al., 2019). Furthermore, rural communities with a lack of infrastructure and coping with the everyday battles to make ends meet are likely to prioritize support for improved infrastructure and help meet basic needs over solving climate change issues per se. Thus, investment in these infrastructures could aid adaptation to climate change.

Lack of financial resources has been found in other studies in India (one of the HKH regions), Pakistan, the Mekong Basin and Australia (Abid et al., 2015; Abid, Schilling, Scheffran, & Zulfiqar, 2016; Bastakoti, Gupta, Babel, & Van Dijk, 2014; Brown, Bridle, & Crimp, 2016; Chalise, Maraseni, & Maroulis, 2015; Pandey et al., 2018) to be a major hurdle for adaptation. The adaptation options deployed by farmers in an economically sound position included the use of technology, diversification of livelihood opportunities, and changing crop varieties and farming practices. The struggle to earn a sufficient livelihood rendered the low-income farmers with limited adaptation options, making them in turn even more vulnerable. The use of inexpensive practices such as changing the time of planting and crop diversification by many and the use of technology by only some farmers further suggests that their financial status affects their choice of adaptation responses (Tambo & Abdoulaye, 2013). The poor, marginalized farmers have insufficient funds compelling

them to rely on loans, seek employment, and sell livestock, as other adaptation measures were too costly and unaffordable.

The lack of technology cited here as a barrier concurs with other climate change adaptation literature from studies in Ethiopia, India and South Africa (Kassie et al., 2013; Loria & Bhardwaj, 2016; Wilk, Andersson, & Warburton, 2013). Awareness and lack of climatic information among rural farmers arise from a gap in the way information are produced and circulated, and a failure in delivering it to rural households. This information shortfall could also be related to the lower level of education among participating farmers. Other studies in Nepal and the HKH region have also identified a lack of information and access to information (Pandey et al., 2018) and technology, and institutional frameworks as major factors limiting adaptation (Regmi & Bhandari, 2013). When considered alongside the other factors identified by farmers in this study as causing constraints on adaptation such as included inadequate support from organizations, lack of market, irregularities by brokers, it is clear the successful adaptation to climate change among the farming communities requires dealing with the interplay of an array of factors.

The lack of market access, reported mostly by highlanders, could be related to the lack of proper transportation facilities and road networks. However, a higher percentage of respondents from Sindhupalchowk, followed by those from Dhading, reported getting access to support from NGOs and INGOs in the wake of the 2015 earthquake despite the location and topography. Many organizations are now even more focussed on disaster risk reduction after the heinous 2015 earthquake. Dhading and Sindhupalchowk heavily affected and post-earthquake many of their programs aimed at disaster reduction and resilience in these districts. Much of the agricultural adaptation in Sindhupalchowk related to changes in crop type, the growth of new varieties of vegetables or fruits, perhaps highlights the influence of these organizations in adaptation programs. Adaptation is easier and more effective if there is some level of appropriate external support for rural households.

Our case study shows that NGOs and INGOs organizations play a role in adaptation by advocating policies, through governance, research, disaster risk reduction, material support training as well as support indirectly liaising with farmers, a result supported by other studies both in Nepal and elsewhere (Biermann, 2009; Biggs et al., 2013). The acknowledgment of the role of governmental organization and other organizations in reinforcing the confidence, leadership, provision of training and simultaneously implementing development programs by the women's group in Dhading suggests future mobilization of these networks would be beneficial for planned interventions and improved adaptation responses and outcomes.

The potential of formal and informal community-based networks and groups in effective awareness-raising and adaptation responses is evident from the farmer's interview and the group discussions. These community-based networks and groups have been providing a forum for their members to share ideas and discuss problems and solutions. Moreover, they have provided community members with farm inputs, loans, and other kinds of support for agriculture. Greater membership in farmers groups (Shikuku et al., 2017) and networking (Esham & Garforth, 2013) is likely to boost adaptation, including through enhancing alteration of crop types and varieties and farm operation timing (Khanal et al., 2017).

5. Conclusion

Climate variability and its consequent disturbances constitute a significant factor in the plethora of challenges faced by the rural farming communities of Nepal. The adverse impacts of climate change can bring significant hazards and risks to these farming communities, who depend on rain-fed agriculture for their survival. This study revealed that the farmers in all three case study regions were adapting their practices and that the kinds of adaptation responses varied between agro-climatic regions in terms of priority and feasibility. However, despite their efforts to adapt, many farming communities remain vulnerable. Poor farmers with limited land, resources, knowledge, and

meagre opportunities for diversifying their livelihood options are the most vulnerable. Furthermore, the intensifying climate change impacts reported by various studies could increase the vulnerability of others as well if the effective and appropriate adaptation does not take place. The planned and collaborative efforts of organizations and farmers were found to be more effective than the autonomous and localized adaptations initiated by individual farmers. Adaptation results from the interplay of both climatic and non-climatic factors and any proposed adaptation measures should have the potential to improve people's livelihoods as well as manage climate-related risk. In this way, adaptation can be seen as a priority that brings benefits to all. This study has highlighted the value of policies and programs that strengthen social networks and community-based organizations involved in the design and implementation of adaptation plans. The results can help inform policy and decision-makers in designing and implementing strategies and programmes that better reflect the needs of subsistence and smallholder farmers. Subsidized farming inputs such as climate-resilient seeds, fertilizers, equipment, and the application of new technologies, and diversified agricultural systems should also be promoted to retain the interest and ability of young people to continue working in their own country and to make a living from agriculture.

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Author details
Sikha Karki[1]
E-mail: sikha.karki@griffithuni.edu.au
E-mail: sikhakarki@gmail.com
ORCID ID: http://orcid.org/0000-0002-9739-5584
Paul Burton[2]
E-mail: p.burton@griffith.edu.au
ORCID ID: http://orcid.org/0000-0002-6092-0779
Brendan Mackey[3]
E-mail: b.mackey@griffith.edu.au
ORCID ID: http://orcid.org/0000-0003-1996-4064
[1] Cities Research Institute & School of Environment and Science, Griffith University, Gold Coast Campus, Queensland, Australia.
[2] Cities Research Institute, Griffith University, Gold Coast Campus, Queensland, Australia.
[3] Griffith Climate Change Response Program, Griffith University, Gold Coast Campus, Queensland, Australia.

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