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Article *in* Journal of Mountain Science · June 2020

DOI: 10.1007/s11629-019-5616-3

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J. Mt. Sci. (2020) 17(6): 1462-1474
https://doi.org/10.1007/s11629-019-5616-3

Rural coping and adaptation strategies for climate change by Himalayan communities in Nepal

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Citation: Dhungana N, Silwal N, Upadhaya S, et al. (2020) Rural coping and adaptation strategies for climate change by Himalayan communities in Nepal. Journal of Mountain Science 17(6). https://doi.org/10.1007/s11629-019-5616-3

Abstract: Climate change has major impacts on the livelihoods of forest-dependent communities. The unpredictable weather conditions in rural Nepal have been attributed to a changing climate. This study explored the climate change adaptation and coping strategies that rural communities adopt for the conservation of natural resources and livelihoods in the mid-hills of Nepal. This paper explored major climatic hazards, assessed different coping and adaptation measures, and barrier faced to climate change adaptation based on perceptions by forest-dependent communities. We conducted focus group discussions, questionnaire surveys, and semi-structured interviews with local communities and stakeholders. The results showed that rural communities had experienced significant impacts of climate change and variability. In response, they are practicing diverse coping and adaptation strategies, including the construction of bioengineering structures and planting different species that grow quickly and establish promptly.

Received: 02-Jun-2019
1st Revision: 05-Nov-2019
2nd Revision: 01-Jan-2020
Accepted: 31-Mar-2020

Keywords: Climate Change; Community Forest Users Group; Index of Usefulness of Practices for Adaptation (IUPA); Adaptation Measures

Introduction

Increases in greenhouse gas (GHG) emissions have been attributed to rising temperatures resulting in increased variability of precipitation and extreme climatic events such as droughts, floods, shifting of seasons and irregular precipitation globally (IPCC, Intergovernmental Panel on Climate Change 2014; Manyeruke and Mhandara 2013). The most vulnerable populations are already experiencing the effects of global warming. The world's poorest countries feel the effects of climate change the most, despite their negligible contribution to global warming. This includes Nepal (Gauli and Upadhaya 2014; Timilsina-Parajuli et al. 2013), which is responsible for roughly only 0.05% of annual greenhouse gas emissions globally (Khadka and Pathak 2016). In three decades (1975-2005), the mean annual temperature in Nepal has increased by 0.06°C while the mean rainfall has decreased by 3.7 mm (-3.2%) per month, per decade (Ministry of Environment 2010). Due to the increase in temperature and decrease in precipitation, various climate-induced events (extended dry periods, erratic and intense rainfalls leading to flash floods, flooding, and landslide, increased incidences of forest fires, glacial retreats, and glacial lake outburst flood (GLOF) are frequently occurring in Nepal (Shrestha et al. 2007). Floods, landslides, drought and other climate-induced hazards cause the greatest risk especially in fragile systems when disturbances cause damages to road construction, communication systems, drinking water supply, agricultural production, land use and soil conservation (Khadka et al. 2018). These changes and events have had significant impacts on water availability and agricultural productivity (Khanal et al. 2019; Marahatta et al. 2009). This poses threats to rural forest-dependent communities, which require a regular supply of water to support their livelihoods.

Forests have the potential to absorb about one-tenth of global carbon emissions projected for the first half of this century into their biomass, soils, and products and store them (in principle) in perpetuity (FAO 2012). However, climate change presents potential risks to forest resources and future challenges for forest managers (Keenan 2015). Adaptation of forest management to climate change requires an understanding of the effects of climate change on forests and forest-dependent communities.

Community forestry in Nepal is an exemplary institution for participatory resource management. It involves collaboration and coordination among all stakeholders (Bridgewater and Upadhaya 2013) to reduce the impacts of climate change and increase the resilience of rural communities by implementing local adaptation plans (Khadka et al. 2018). Community forestry is an institutional innovation that empowers local communities to manage forest resources for their benefit in coordination with the national government, although they do not own the forest under the Forest Act and Regulations in Nepal (Stapp et al. 2015). Under the 1993 Forest Act of Nepal, every Community Forestry User Group (CFUG) is granted full authority to manage and utilize forest resources. The study by Timilsina-Parajuli et al. (2013) found that the awareness of rural communities and stakeholders about climate change, its impacts and their views on climate change were only related to their geographical boundaries. The extent of climate change impacts is however not confined to such boundaries. The crucial role played by forests in sequestering CO_2 from the atmosphere and the livelihood benefits that accrue to local communities enable community forests to meet the dual objectives of clean development mechanism (CDM), i.e., emissions reduction and sustainable development. There is the potential for more exploration on this linkage that provides local, as well as global, benefits (Sharma et al. 2004).

Climate change adaptation is mostly location-specific, and its effectiveness depends on local institutions and socioeconomic setting (Morton 2007). Formulating climate change adaptation plans has recently emerged as a popular development agenda to deal with the vulnerabilities and adverse impacts of climate change in human and natural systems (Khadka et al. 2018). The National Adaptation Program of Action (NAPA) provides ample space to implement climate change adaptation projects and activities for different stakeholders, including government, non-government and international non-governmental agencies. Accordingly, these agencies have supported community forest users in translating the global concept into local actions by contextualizing and applying different adaptation strategies. Climate adaptation plans should help to address socially relevant problems through joint knowledge integration and mutual learning (Nkoana et al. 2018). They produce robust knowledge including both scientifically valuable and relevant information for societal progress (Schmidt and Pröpper 2017; Schuck-Zöller et al. 2017). The assessment and evaluation of adaptation strategies have become more inclusive over time and need to link future climate change with current climate risks and other policy concerns (Füssel 2007). In the development field, evaluating the effectiveness of adaptation strategies is a high priority for donors who are eager to know the success of their investments (Schipper et al. 2010).

The evaluation of the usefulness of an adaptation practice responds to a judgment that will be dependent on the spatial, temporal, and social context in which adaptation occurs or is desired (Debels et al. 2009). The Index of Usefulness of Practices for Adaptation (IUPA) tool can be used for general evaluation of the adaptation practices, comparison among practices, support during the project formulation process, assistance for the fundraising process as well as a communication tool. It is recommended for use in the evaluation of adaptation practices during activities/program design, implementation and post-implementation phases (Debels et al. 2009). Therefore, assessing, evaluating, and prioritizing adaptation options and outcomes are urgently needed to increase the adaptive capacity and resilience of rural forest-dependent communities who are more vulnerable to climate change stresses. To improve the ability of communities and households to adapt to ongoing and probable climate change in the future, we need an improved understanding of the risks they face and the adaptation measures that they are adapting (Dhungana et al. 2017; Godar Chhetri 2012). Climate change fosters an increase in frequency and or severity to forest fire, drought, the introduction of invasive species, insects and pathogen outbreaks, windstorms, landslides (Debels et al. 2009) and shifts forest ecosystem distribution across much of Nepal (Dahal et al. 2010). Community livelihood depends upon the natural resources which are affected directly by climate change. Those impacted respond in traditional as well as innovative ways using new technologies (Ishaya and Abaje 2008). To cope robustly with the effect of climate change at the local and CFUG levels, it is crucial to understand climatic variability on both biological and socioeconomic systems (Thornton et al. 2014). Understanding these patterns will assist in implementing effective measures to cope and adapt to the impacts of climate change (Dhungana et al. 2017). To cope with various kinds of climatic hazards that are likely to occur due to climate change, communities should be made aware of different adaptation strategies so that the forest-dependent communities will not be impacted in the short-term and also contribute carbon sink in the atmosphere through reducing carbon footprint and forest management. The major objective of this study is to assess different coping and adaptation measures adopted by the communities. This study also aims to identify the barriers to climate change adaptation faced by forest-dependent communities in rural Nepal.

1 Materials and Methods

1.1 Study area

Three CFUGs located in the Lamjung district of Nepal were selected for this study (Table 1, Figure 1). The study area has altitudinal diversity (385 to 8162 m above sea level). The population of the district in 2011 was 167,724 with good diversity of caste and ethnicity etc. (CBS 2011). The selected three CFUGs are located in the prioritized sub-watershed, a part of the Marshyangdi River Basin, and is vulnerable to different climatic and weather related disaster i.e. flood, landslides and drought. The three slected CFUGs are practicing different climate change adaptation measures.

1.2 Data collection methods

A detailed stakeholder consultation was conducted to finalize the study area. District Soil Conservation Office (DSCO), District Development Committee (DDC), District Forest Office (DFO), CARE International in Nepal, Rural Community

Table 1 Details of the study area in the Lamjung district of Nepal

Description	Community Forest Users Groups		
	Kirepani	Jagreni	Kalika
Address	Besishahar- 5, Lamjung	Besishahar- 4 & 5 Lamjung	Besishahar- 1 & 2 Lamjung
Area	47.34 ha	83.87 ha	63.27 ha
Date of registration	1995 A.D.	2002 A.D.	1996 A.D.
Households	192	273	151
Total population	1008 (483 female, 525 male)	1473 (688 female, 785 male)	833 (406 female, 427 male)
Indigenous people	Gurung and Dalit	Dalit and Janajati	Gurung and Dalit
Education status	55% educated	70% educated	60% educated

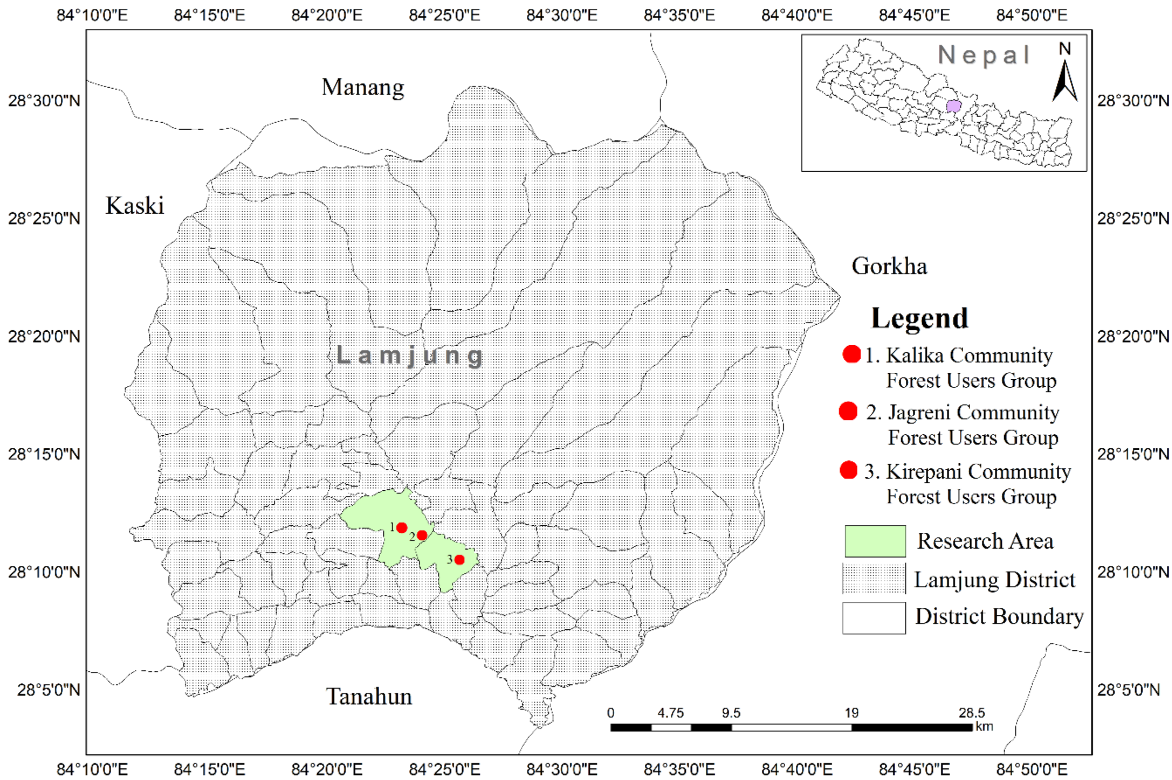

Figure 1 Location of three CFUGs (Kalika Community Forest Users Group, Jagreni Community Forest Users Group, Kirepani Community Forest Users Group) in the Lamjung district of Nepal.

Development Centre (RCDC), other development organizations and other key persons were consulted for sharing feedback and suggestions on selection criteria (variables) adopted from Debels et al. (2009). Similarly, primary data collection was employed to identify major hazards in the community forest (e.g., floods, landslides, droughts, etc.). Identification of major adaptation measures implemented by CFUGs and preference ranking were conducted in consultation with key stakeholders.

Ten percent of total households (616) were selected for the survey (Appendix 1). We identified four well-being ranking groups (Well-off, Medium, Poor, and Very-poor) for the study purpose, as mentioned in Table 2. The demographic information of respondents participated in household survey are mentioned in appendix 1.

Total sampling units were distributed in each economic class, gender, and across settlements. As this is an empirical case study, respondents were interviewed about their perception of climatic change, its impact, implemented adaptation measures and their usefulness. Focus group discussions (FGDs) and expert consultation from the different organizations were conducted to gather information on past and present climatic patterns as well as strategies adopted to combat the negative impacts of climate change. Twelve key informant interviews were conducted with village

Table 2 Criteria, indicators, and status of well-being ranking analysis (HHs =households)

Major Criteria Applied	The well-being status of the community forest user groups			
	Well-Off (18.75% of total HHs)	Medium (34.38% of total HHs)	Poor (28.13% of total HHs)	Very-poor (18.75% of total HHs)
Human health status	Healthy and fit, Capable to ding any work, food production throughout the year and gains profit from it too	Healthy, food production sufficient for about six months on average	Suffered from diseases, food production sufficient for about three months on average	Suffered from several diseases, no food production, depend on others for food
Social status	Hold higher managerial post, administrative and professional	Hold intermediate managerial post, administrative and professional	Semi/unskilled workers or being on very junior managerial post	Wage workers who do not belong to any post
Financial status	Sufficient money, contribute to different development activities, lend loans and rents to the poor people	Those who can fulfill their own needs do not borrow loans from others	A major source of income is wages, hardly manages to fulfill their own needs	No source of income, very difficult to fulfill their needs, depend on others for food and shelter
Political status	Very active and in the leading post	Intermediate	Inactive	Not interested in politics
Educational status	University or higher graduate	High school graduate	Elementary level	No education

leaders and individuals who have lived in the area for a long period of time (Appendix 2). They were interviewed in major matters about change in rainfall, flood pattern, water stress trends, and their adaptation to those impacts and so on. Present and past scenarios of the community, climatic experiences, vulnerabilities, and shocks due to changes were collected.

We conducted field observations for validation of primary information collected from respondents. During the field observations, we also observed local areas impacted by climate change, adaptation measures and interviewed locals. During field observations, we also cross-validated the perceptions and responses of locals about climate change impacts. At least one local person accompanied the research team from the CFUG during the entire data collection period.

We collected the meteorological data relating to rainfall, minimum and maximum temperatures for the last 28 years (1987-2015) from the Department of Hydrology and Meteorology (DHM) for the stations, 802 (Khudi), 807 (Kunchha), and 823 (Gharedhunga).

2 Data analysis

The listed adaptation measures were prioritized using the criteria (variables) based on stakeholders' preferences. The criteria were shared with various experts and community forest users, key informant assigns a relative weight, and it was framed by the Index of Usefulness of Practices for Adaptation tool developed by Debels et al. (2009). This Index allows the users to assign weight and score to a set of user-defined evaluation criteria. Individual criteria scores are aggregated into a final index value. Both final values and the individual parameter scores provide information for improved decision making in the context of climate change.

IUPA tool developed by Debels et al. (2009) was used for the evaluation of the general usefulness of practices for prioritization of adaptation strategies to climate change and variability based on the criteria adopted.

An integrated index value for the IUPA is obtained by,

i) Multiplying individual variable scores with the assigned variable weight; and

ii) Consequently, summing the weighted individual parameter scores (weighted sum).

$$\mathrm{IUPA} = \frac{\sum_{i=1}^{n} Ci \times Pi}{\sum_{i=1}^{n} Pi} \ldots\ldots \quad (1)$$

where, n is the total number of criteria (variables); C_i is the score (value between 0 and 10) assigned to criterion i; P_i is the weight of the i^{th} criterion in the total index score (value between 0 and 10, an indicator of its relative importance in the global evaluation of the practice's usefulness).

3 Results

The household survey, FGDs followed field verification shows that Khirepani CFUG had eroded more land along the slopes as compared to Jagreni CFUG and Kalika CFUG. The latter two have dry, harsh agricultural land and forest mainly affected by fire. Communities from these three CFUGs are more vulnerable to drought, flood, and landslides which lead to decreasing agricultural production, drying of water resources and decline of biodiversity (Table 3).

3.1 Temperature and rainfall trends

The trend analysis of the annual rainfall record of 1987-2015 at three stations showed that Khudi and Gharedhunga have decreasing rainfall with a rate of 25.8 mm/year and 16.42 mm/year respectively. On the other hand, Kuncha Station showed that the annual rainfall is increasing at a rate of 2.82 mm/year (Dhungana et al. 2018). On average, this concludes that the study area has a negative precipitation trend. The seasonal rainfall analysis shows that the highest decrease in rainfall occurred during monsoon season at the rate of 17.60 mm/year from the Khudi Meteorological Station. Due to the late start of monsoon, people were compelled to leave the agricultural land barren and the drying of water resources caused a decrease in crop production, etc. Additionally, the community stated that now monsoon rain falls with higher intensity and amounts causing erosion of fertile land and crops.

The climatic data analysis showed that the overall trend of annual maximum, minimum and average temperatures from 1987 to 2015 has increased by 0.056°C, 0.01°C and 0.03°C, respectively. Similarly, it was also observed that the trend of increase in temperature was high in the pre-monsoon season and low in the winter season. This indicates that summer is getting longer and hotter. Generally, communities perceived that the winter temperature is increasing rapidly and the duration of winter is decreasing. They observed that water resources were drying, which directly supports the results as analyzed from the climatic data.

The communities related various local indicators with climate change. Among these changes in drought, frequency ranked first, the increase in temperature ranked second, and occurrence of forest fire ranked third. This indicated an increased frequency of drought, rising temperature (Dhungana et al. 2018), and fire risk while water sources are drying. The study by Dhungana et al. (2018) mentioned that locals correctly perceived change in temperature, the unpredictable occurrence of rainfall and increased incidence of change in crop phenology, an increase in drought. Drought has a higher impact on the people affecting their lives and livelihoods. We have presented detailed climatic data analysis (Dhungana et al. 2018)

Table 3 Major forest types, conditions of the area and major hazards and impacts of climate change observed during the field visit. CFUG =Community Forest Users Group

Location	Forest Type	Condition of the Observed Area	Condition of the Forest	Major Hazards	Major Impact of Climate Change
Kirepani CFUG	Mixed Sal Forest	Eroded land in the sloppy area	Forest is degrading with the disappearing of wild animals and birds.	Drought, flood, landslides.	- Decrease in agricultural production. - Threats in the wild animals, birds. - Drying of water resources.
Jagreni CFUG	Mixed Sal Forest	Dry, harsh agricultural land	Tree species like Katus are decreasing due to droughts, Pinus species are planted in the area, diseases, and pests are degrading the forests.	Drought, flood, landslides	- Decrease in agricultural production. - Invasive species are degrading the forest. - River bank cutting. - Pests and diseases in the crops. - Water induced disasters like flood and landslides.
Kalika CFUG	Mixed Sal Forest	Forest mainly affected by the fire.	Invasion by Invasive species as well as diseases and pests.	Drought, flood, landslides, forest fire.	- Threats in the wild animals, birds, and forest biodiversity. - Gradual disappearance of important fauna from the forest. - Water induced disasters like flood and landslides. - Drying of water sources

3.2 Major climate hazards and coping measures in community forest user groups

The study found that 91.94% of the respondents experienced drought as major climatic hazards followed by floods (83.87%), landslide (70.97%), and forest fire (67.74%). Agricultural lands, forests, and the communities are the major sector that has been impacted by climatic hazards. The major impacts observed in the study area were water sources drying resulting in a shortage of water, floods damaging lives and livelihoods of the communities and the forest, riverbank cutting, decrease in agricultural production, and the overall impact these threats pose to biodiversity. However, the short term adaptation measure adopted by the community is presented in Table 4.

3.3 Preference of adaptation measure for drought

As stated by the communities, impacts of drought were more visible than other hazards in the study area due to its altitudinal location (hilly region). As a result, it was found that locals are more adaptable to drought than other hazards. Table 5 shows the adaptation strategies that the local people had adapted in this area. Plantation of trees was found to be the most effective adaptation measures for drought. 'Plantation of trees' strategy scored high IUPA score than other strategies.

As stated by communities, 'plantation of trees' is the best strategy for water sources conservation in the area. Tree cover also prevents evaporation from rivers, reservoirs, and soil — saving water for drinking and agriculture as well as increasing shade and cooling the surrounding area. After planting trees, the level of dryness of the land is reduced whereas, the availability of water for forest and agriculture has increased.

Climate change directly impacts the water cycle. Longer dry season and change in rainfall pattern will affect water recharge as well as water sources like springs, rivers, and rivulet which start to dry up. The selected CFUGs are currently rich in water sources for drinking as well as for other household activities, but the overall trend is decreasing. Thus, they give higher priority to conserve these sources. Strategies like conservation of the catchment area and restricting the local people from collecting forest products are carried out. Currently, communities are using the waters from the source available in Kalika CFUG and Jagreni CFUG. Likewise, local people had also constructed the "Plastic Pokhari," which became the source of water for agriculture in need as well

Table 4 Major coping strategies adopted by communities within three different Community Forest Users Groups (CFUGs)

Major Hazards	Major short term adaptation measures		
	Kirepani CFUG	Jagreni CFUG	Kalika CFUG
Droughts (91.94%)	-Plantation and protection of trees. -Plantation of drought-resistant species. -Irrigation from the Khahare Khola.	-Irrigation from the stream. -Plantation of drought-resistant species.	-Plantation of drought-resistant species. -Irrigation from the stream. -Protection of Forest.
Flood (83.87%)	-Plantation of trees. -Construction of Gabion wall. -Plantation of *Salix Tetrasperma* (Bains) in Riverbank areas.	-Diversion of the flood by the planks and timbers. -Brushwood check-dam construction. -Removing the obstructing materials like stones, wooden planks, etc. from the rivers	-Diversion of the flood by the planks and timbers in the other direction. -Construction of small drainage channels to drain the flood in a desirable direction.
Landslide (70.97%)	-Plantation of grasses in barren areas. -Gabion wall construction. -Use of bioengineering techniques.	-Avoiding the grass cutting and grazing livestock's in the landslide-prone areas. -Prohibition of tillage practices until the landslide is treated properly.	-Plantation of deep-rooted plants and grasses in the barren and sloppy areas. -Construction of the Gabion wall in the prone areas.
Forest fire (67.74%)	-Use of green branches of trees, mud, etc. to beat the fire.	-Use of water, green branches of trees, mud, etc. to remove the fire. -Construction of fire line.	-Construction of fire line. -Use of green branches of trees, mud, etc. to beat the fire. -Awareness-raising

Table 5 Preference of adaptation strategies for different major hazards calculated by IUPA index.

Major Hazards	Adaptation Strategies	Sum of Assigned Weight	Sum of Weighted Score	IUPA Score	Usefulness Rank
Drought	Plantation of trees	116.50	1021.50	8.77	I
	Water sources conservation	103.50	796.75	7.70	II
	Construction of the conservation ponds	97.50	727.25	7.46	III
	Protection of forest	90.50	665.63	7.35	IV
	Construction of irrigation channel	90.50	598.50	6.61	V
	Planting drought-resistant crops	87.75	541.88	6.18	VI
	Maintaining clean environment	80.00	479.75	6.00	VII
Flood	Construction of engineering structures (Gabion wall, check-dam)	116.00	913.00	7.87	I
	Bamboo plantation	106.50	780.75	7.33	II
	Bio-engineering	107.50	730.75	6.80	III
	Plantation of trees	101.50	643.25	6.34	IV
	Protection of forest	93.00	482.00	5.18	V
Landslide	Bamboo plantation	105.00	912.50	8.70	I
	Bio engineering	109.00	823.00	7.55	II
	Construction of engineering structures	107.00	748.50	7.00	III
	Protection of forest	104.00	671.00	6.45	IV
Forest fire	Construction of fire line	114.00	944.50	8.29	I
	Public awareness	110.00	900.25	8.18	II
	Use of green branches, mud, water, etc.	91.50	559.50	6.11	III
	Control grazing	85.00	487.13	5.73	IV
	Use of fire tools	91.50	475.75	5.20	V

Note: IUPA=Index of Usefulness of Practices for Adaptation.

as the source for fish farming.

Drought is one of the most pressing environmental stresses affecting forest quality and agricultural productivity. Protection of forest was also one of the best options to respond to drought conditions. If the forest is well stocked, water availability in the area also increases, increasing groundwater. The community initiatives for protection and management of the forest, which had shown positive results, were grazing control, daily patrolling in the forest by forest guards (daily Laure Palo) and implementation of prescribed actions per the operation plan. Furthermore, drought-resistant crops like leguminous species such as field mustard, wheat, and maize in the suitable seasons (late March or early April) are planted in some parts of the study area.

3.4 Preference of adaptation measure for flood

The mid and high hills of Nepal have a high drainage density, which carry high loads of sand and boulders during flash floods as a result of erratic rain during the rainy season. The problem of the landslide, slope failures and floods were observed because of the unstable landscape. In the study area, there are more than four seasonal rivers that flow through forests, settlements and agricultural fields. Locals living in the community were more affected by floods in the past than now but the establishment of the community forest and application of the different adaptation activities gradually reduces the frequency of floods occurrence. IUPA scoring showed that construction of engineering structures such as gabion-wall/check-dam etc. is the most effective adaptation measures adopted by communities, followed by bamboo plantation, bio-engineering, and plantation of trees and protection of forest (Table 5).

Riverbanks and adjoining agricultural areas were most affected by the floods. The community stated that due to the initial higher strength of the engineering structures such as check-dam and spurs to reduce the velocity of rivers, they had adopted it despite the costs. Bamboos were planted in the rehabilitated area after the construction of the engineering structure. Even though plantation of bamboo in an area where the intensity of flood was high resulted in a failure of the bamboo establishment even though it survived for few years of the plantation but gradually, after four to five years of bamboo establishment, it has been highly effective in reducing the velocity of floods.

Plantation of bamboo, fruit species like

Choerospondias axillaris (Lapsi), *Ananas comosus* (Pineapple), *Thysanolaena maxima* (Amliso), etc. is a common practice by poor and marginalized people. These plantations of mixed species, along with engineering structures, have directly reduced flood velocity while also being an effective measure for income generation. Among the different measures, use of living materials such as above mentioned plants and or part of plants with gabion check-dam and with spurs was seen in most of the area during field observation.

3.5 Preference of adaptation measure for landslides

There were six landslides within the past fifteen years of different intensities and impacts near the Rakse Khola in Jagreni CFUG in which the community was severely affected and even resulted in the loss of life. Adaptation measures were more effective to reduce the number of landslides. The bamboo plantation was preferred as the most effective adaptation measure by the community (Table 5).

The Bio-engineering measure practiced, along with plantation of bamboos, fruits species like *Choerospondias axillaris* (Lapsi), *Ananas comosus* (Pineapple), and *Thysanolaena maxima* (Amliso), etc. and in combination with spurs, check-dam, gabion wall, etc. inside and outside community forest was cost-effective in the long-term. These structures were expensive and required skilled human resources for construction. But they stabilized the slopes, significantly reducing the amount of soil erosion. While it is time-consuming and difficult to establish in heavy landslide-vulnerable areas where the soil layer is minimum, only limited species are adapted to this kind of soil. The protection of forests for control of landslides is a permanent and effective option.

3.6 Preference of adaptation measure for forest fire

Fires of different scale were observed frequently in the study area. After the handover of forest governance to the CFUGs, the frequency of occurrence decreased through effective management and mobilization of forest guards (Ban Heralu). The most effective adaptation measure for forest fires were the construction of fire lines followed by public awareness (Table 5). The calculated IUPA score showed construction of the fire line was preferred as most preferred adaptations measures (Table 5).

The objective of constructing a fire line is to remove or reduce the flammable materials that allow the fire to spread up and break spreading. All three CFUGs have formed sub-groups as mechanisms to construct the fire line. In most of the cases, forest fires are due to the carelessness of people, like throwing the remaining parts of cigarettes in the forest or carelessness of fire during picnic spots inside forest areas. Awareness activities can be an effective adaptation measures for controlling a forest fire.

Community people use green branches of trees and mud to stop the fire as an immediate response. If available, water from the nearby water sources was also used. Grazing was controlled in the areas prone to forest fires. After the handover to CFUGs, forest fires were more effectively controlled. Also, more grasses were planted in the open and barren area. Different fire tools were provided by the District Forest Office, Lamjung to the Kalika CFUG people. The fire tools were best applied to control and stop the fire. The poor implementation of the suggested actions by the community forest operational plan, adoption of the new tools and techniques such as firefighting equipment's, limited know-how for the remedial measure are often seen in the community forest. Generally, January to June is the sensitive fire period in Nepal, so adoption of preparedness measure, clearing of fuel, construction of fire breakers, the arrangement of firefighting tools and equipment, capacity building and formation of trained firefighting groups needs to be done by the community.

3.7 Major barriers for climate change adaptation measures by the local communities

Adaptation aims to manage climate risk to an acceptable level while taking advantage of any positive opportunities that may arise. Some of the communities in Lamjung, including the CFUGs in the study area, have been preparing and implementing a climate change adaptation plan to deal with the negative impacts of climate change.

Likewise, other studies have also highlighted the preparation of climate change adaptation plans that are emerging in the development agenda to enhance the adaptive capacity of human and natural systems (Khadka et al. 2018). The focus group discussions and key informant interviews revealed that these adaptation plans became a milestone for capturing community perception on climate change, its impact, hazards, and vulnerability. The coping and adaptation option as mention in Table 5 implemented by the forest dependent community showed community participation which might contribute to adaptation capacity (Ogden and Innes 2009). In the opinion of CFUGs in the study area, the major barrier in working for climate change adaptation and mitigation is insufficient funds, as agreed by 95 percent of the total respondents. Lack of knowledge, unavailability of technology, lack of time, lack of mandatory policy (Regmi and Bhandari 2013; Dhungana et al. 2017), in the case of community forestry like limited priority for climate change intervention by operational plan and allocation of forest income for implementation of climate change adaptation measures were other obstacles as stated by CFUGs (Figure 2). Enhancing the capacity of the CFUGs on how to increase their adaptive capacity and engage CFUGs practitioners and policymakers are an urgent need (Kolström et al. 2011). Furthermore, monitoring and evaluation is needed to identify how coping and adaptation strategies are contributing for forests and forest dependent communities for adaptation change (Innes et al. 2009).

4 Discussion

In the changed context due to climate change i.e. changes in rainfall patterns and temperature, community have adapted different coping and adaptation mechanisms as mention in Table 5 to adopt the from drought, floods, landslide and forest fire. Mainly community performs cropping adaptations and vegetation managements as adaptation strategies for different climate induced hazards such as landslides, floods, and droughts. Factors like tree covers, changes in rainfall pattern and water cycle influenced adaptation strategies to climate change. Shrestha et al. (2017) argued that climatic, social, and economic factors influenced the choice of adaptation strategies in future. So, the appropriate short- and medium-term adaptation technology need to be adopted to facilitate the long term adaptation of forest dependent community.

Local perceptions and anecdotal evidence coincide with the meteorological record of increasing temperature and decreasing rainfall in the study area. Similar results of the increasing temperature and decreasing rainfall trend were reported by Khadka & Pathak (2016). Because of these meteorological patterns, communities are facing water scarcity in most of the study area. As an adaptation strategy the community prefers

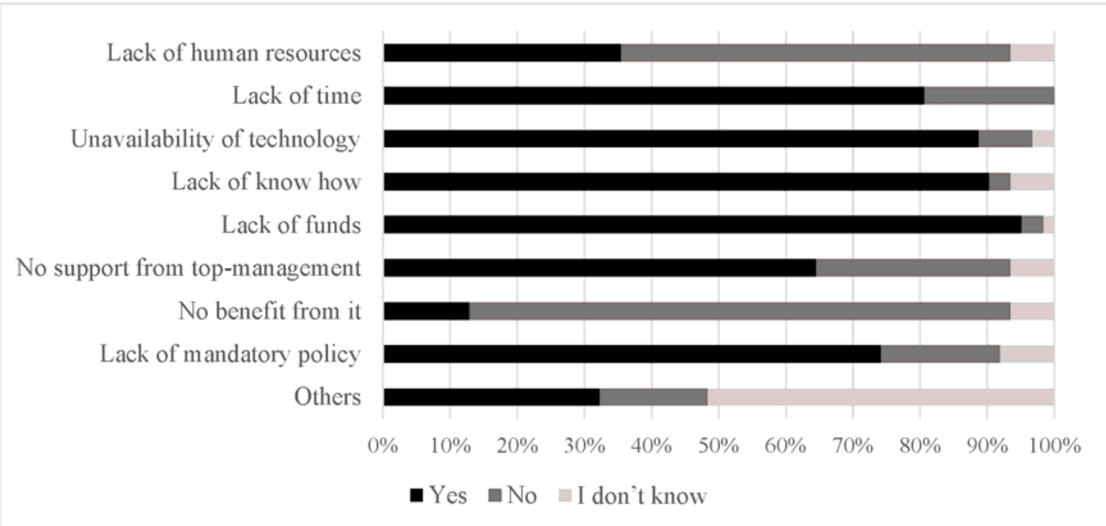

Figure 2 Obstacles felt by the Community Forest Users Groups to work in climate change mitigation and adaptation sector.

drought-resistant species in addition to improving irrigation system. However, they face decrease in agriculture productivity due to drought. We suggest a combination of locally adapted adaptation practices such as agro-forestry practices, water management systems, renovation of the existing water catchment pond including construction of new ones with improved technology such as seasonal weather forecasts, warning systems etc. improve their forest health and agricultural productivity. Similarly, farmers prefer plantation of mixed species with engineering structures as an effective adaptation strategies for flood reduction and landslides. The study suggested that the use of live plants and other natural materials have demonstrated good results to reduce the floods problems in different parts of the world (Dhital et al. 2013). Protection of forests not only reduces the rate of evaporation but also reduces the rainfall intensity and helps to reduce the runoff velocity which ultimately reduces flood occurrence (Poudel 2012). After the handover to CFUGs, flood impact was controlled, and the forest had played a significant role in flood control. Forest management including afforestation and protection of existing forests reduces the rate of evaporation, decreases the intensity of rainfall and reduces the runoff velocity resulting in the reduction of flood possibility. The different coping strategies such as construction of engineering structures, bamboo plantation and bio-engineering measures (Paudel and Kafle 2012) might be a potential coping measure.

Including the study area, most of the mountainous region of Nepal is susceptible to the risks of landslide due to various biophysical and other factors such as unplanned construction of infrastructure, immature and fragile geology of the hills, high-intensity rainfall, and deforestation (Dhital et al. 2013). Our results suggested that farmers prefer plantation of bamboo as an effective adaptation strategy for minimizing landslides. Bamboo can grow in any kind of soil, grows fast to bind the soil and generates fodder and is small timber for poor people which can be an alternate source of income for local people (Paudel and Kafle 2012). The bioengineering techniques like gabion wall, check dam, spurs, etc. used in our study area are extensively used in Nepal (Dhital et al. 2013). Even though these structures consume more time to construct and is difficult to establish in the heavy landslide area but once established, provide multiple benefits. Thus, the practice and development of agro-forestry may be a potential solution to address the problem of landslide (Neupane et al. 2002) and includes many other co-benefits. The occurrence of fire in the study area was due to dry land which directly affects the agricultural as well as forest land. The frequent occurrence of forest fire has extrapolated loss of soil property and productivity, soil erosion and loss of forest resources (Parajuli et al. 2015) leading decrease in agricultural productivity. Decrease in agricultural productivity severely affects the ability of vulnerable populations to cope with climate change. These most vulnerable populations, the world's poorest communities, feel the effects of climate change the most, despite their negligible contribution to global warming. Due to these climate induced hazards, their agricultural productivity goes down which forced them to be more vulnerable to the climate change. Our results shows farmers prefer cropping adaptation and vegetation management as major adaptation strategies for climate change impacts such as droughts, landslides, floods and fire. Such different adaptation practices to reduce climate related risk, but still not aligned with the forest operational management plans (Ogden et al. 2008). However, they lack the knowledge and resources to perform these adaptation strategies. This necessitates intervention on increasing the capabilities of poor farmers. Eriksen and O'Brien (2007) suggest providing knowledge about water harvesting, keeping reserves, tilling practices, in-situ conservation practices, groundwater recharge system, diversification of alternative feed and fodder sources, agro-silviculture and livestock types which will increase farmers' capacity, skills and knowledge to prevent burning, landslides, droughts, and floods.

Local people and community representatives should be supported to conduct a sustainability assessment exercise to assess the resilience of climate adaptation action plans against maladaptive practices that might increase the vulnerability of the intended beneficiaries in the long-term (Nkoana et al. 2018). Decision makers are often baffled by the risk and adaptation priorities of local communities shaped by socioeconomic, political and cultural issues (Sellberg et al. 2018). We suggest that identifying the coping and adaptation measures adopted by forest dependent communities may have higher chance of achieving adaptation (Ogden and Innes 2009) objectives and foster resilience communities.

5 Conclusion

Climate change and its impact on natural resource management and thus on the social system are complex. Forest-dependent local communities in the study area had adopted more adaptation measures to drought than to floods, landslides, and fire. The plantation of trees was most preferred for adaptation measures for drought. Likewise, engineering structures like gabion wall, check-dam, etc. was highly preferred for adaptation for floods. Furthermore, the bamboo plantation was highly prioritized by the local community for adapting to landslides. Construction of fire lines were best adapted as well as highly prioritized by the local people for adapting to forest fire. Communities agreed that community forests had contributed directly and indirectly to stabilizing soil, reducing natural hazards, controlling soil-erosion, increasing forest vegetation cover, and carbon sequestration. Application of bio-engineering measure, construction of conservation ponds and irrigation, planting drought resistant crops seems highly effective adaptation measures for maintaining the livelihoods of forest dependent communities. People have been using different adaptation practices to climate change impacts in various ways regardless whether it has contributed for climate change adaptation or not. But still, they are not properly linked with community forest operation plans. It is very crucial to incorporate climate change knowledge its impact and potential activities in community forest operation plans. The policy document of the government should include the provision of climate change adaptation planning. Different government and non-governmental stakeholders need to understanding how rural communities are coping with its impacts to develop effective action plans at various scales from local to national.

Acknowledgments

We would like to thank all the local communities, Government/Non-government organizations of Nepal and personnel who provided their valuable time and shared their experiences during the study and Claire McMahon for English editing. We also like to thank two independent reviewers for their constructive suggestions and feedbacks. e also acknowledge the Ministry of Education, Youth and Sports of CR within the National Sustainability Program I (NPU I)

Electronic supplementary material: Supplementary materials (Appendixes 1-2) are available in the online version of this article at https://doi.org/10.1007/s11629-019-5616-3

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