Forests and Climate Change: Analysis of local experiences of climate change impacts in Nepal's community forestry

Bhagwan Dutta Yadav (bhagwanduttayadav@gmail.com)
Support For Development, New Zealand https://orcid.org/0000-0002-9573-1580
Krishna Kumar Shrestha
University of New South Wales
Bishnu Prasad Acharya
Government of Nepal Ministry of Forests and Environment
Dan Bahadur Shrestha
Government of Nepal
Lal Babu Yadav
Government of Nepal Ministry of Forests and Soil Conservation: Government of Nepal Ministry of Forests and Environment

---

Research Article

Keywords: Climate change impact, community forestry, local experiences, forest management, public policy

Posted Date: March 16th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1423351/v1

Abstract

Community management of forests are considered to be vital for responding to Climate Change (CC) impacts. However, the questions of how do local communities perceive climate changes and how or whether their activities contributing to addressing climate change impacts are still widely debated. This paper aims to examine Nepal's community forestry stakeholders' experience of Climate Change (CC) impacts. A semi structured questionnaire survey of 310 local households was carried out on 31 Community Forestry User Groups (CFUGs) in Siraha, Saptari and Udaypur in inner Terai and Terai regions, Nepal. We stratified households into rich, medium, poor, and poorest based on their socioeconomic status. The analysis results showed that 59% of local respondents had seen an increase in temperature, heat waves (82.9%) and cold waves (51.6%). Conversely, rainfall intensity (65.8%), fog intensity (47.42%), fuzzy sky (50%) and humidity (36%) had decreased. Socioeconomic conditions, forest and climatic change variables were used as explanatory variables against the dependent variables of CC impacts, rainfall and changed temperatures over the last 40 years. Multinomial logistic regression analysis shows that broadleaf forest type, sky haze and rainfall were positively significantly and temperature, fogs, cold waves, biodiversity and amenity variables were negatively significantly correlated with CC and CFOMP that, in turn, increases the likelihood of affecting the livelihoods of local respondents. Results demonstrated that people's beliefs and perceptions of CC and the adaptations and mitigating responses are vital for devising effecting policies and practices. We propose a set of models that help linking locals experiences with policy, thereby improving both climate change and forest management policies.

Statement

If this article will be published, it will present new knowledge and analysis contributing to the existing literature regarding local experience of change in weather, temperature, rain and climate, and whether and how these changes are linked with forest management particularly in Nepal. There is paucity of knowledge and analysis that demonstrate how and why local experiences of forest management are critical to understand climate change impacts.

1. Introduction

Many changes have been observed in the global climate over the past century. The nature and causes of this climate change (CC) have been perceived in increased temperatures and air pollution, and decreased rainfall intensity (Roy et al., 2020: Zhang et al., 2020). Agriculture productivity has decreased because of the influence of CC and CC's influences on forests and it is argued that forest species composition is because of human induced activities (Hatfield et al., 2008). The threat of CC in the developing world, such as Nepal, has emerged from deforestation, incongruous forest management, immigration from hill, mountain and Himalayan regions to the Inner Terai and Terai (Nash et al., 2019; Paudel et al., 2018). Consequently, natural climatic disasters reflect climate hazards, particularly events in weather cycles like landslides, hurricanes, droughts and wildfires, flooding, and high winds. These can trigger prolonged droughts, unprecedented changes in temperature, heat/cold waves, rainfall, fogs, humidity increase, flooding, siltation, riverine floods and windstorms. Soils are exposed by extreme rainfall, which creates sedimentation and siltation that raise the river bed downstream and cause floods in the rainy season but reduce groundwater recharge. These impacts, over time, have a cumulative effect on the livelihoods of local people, including economic, social, ecological and environmental aspects. These problems are most visible at the local level and are experienced directly by local communities. Yet, a critical and grounded analysis of local experience of climate change is rarely undertaken.

Research Problems

Climate change impacts are highly visible in Nepal as many local communities experience it every day. Nepal's problem of climate is due mainly to physical, social and economic geography: the high Himalayas (16%) to the north, the middle hills (68%), and the lowland Terai (17%) to the south. Altitude ranges from 73 to 8,848 metres above mean sea level and includes diverse geo-climatic zones. South Asia, including Nepal, covers diversified climatic regions and experiences an array of CC impacts (Dobias, 2018). Human activities, such as land use change, deforestation and improper management of forest resources, amplify the effect of CC that causes havoc in food production and the livelihoods of local communities. The most vulnerable areas to climate change are the Inner Terai, the Terai and hills where forest species composition, flowering season, cropping pattern and productivity are changing. This is because of prolonged droughts, changes in temperature, heat/cold waves, rainfall, fogs, humidity, forest fires, flooding, cyclones, siltation, riverine floods, windstorms and water scarcity. In the long run, the changes impact the availability of quality water and local amenities, forest ecosystems, cause biodiversity loss, reduce food security, deplete energy resources, and degrade rivers.

In this paper, we examine local experiences of climate change, taking case study analysis of Nepal's community forestry stakeholders. In doing so, we aim to fill a knowledge gap with evidence from a detailed assessment of stakeholders' perspectives of CC from the relatively recent CFOMP under Nepal's CF programme. We design and develop a conceptual model of willingness to implement pro-CC friendly behaviour in Nepal. We investigate three key questions: (1) what is the stakeholder engagement process in designing and implementing CFOMP that makes CC friendly with existing government policy? (2) What is the understanding of key forestry stakeholders of CFOMP and how do they perceive CC mitigation and adaption over the last 40 years? (3) What is lacking in CFOMP and what are the factors that make CFOMP local stakeholders friendly? We highlight the role of stakeholders in managing CF, in general, which is relevant and beneficial to Nepal to identify the specific reasons behind the inactivity of regular users and disadvantaged users in the implementation of CFOMP and the Nepalese government's policy to adopt a process of awareness to CC. To achieve the above objectives and answer the research questions, the following hypotheses are proposed.

1.1 Hypotheses

a. When different power actors A[1] and B[2] have power exercises in designing and implementing CFOMP, there is an increased likelihood of mitigating and adapting to CC.

b. When both A and B actively and equally support one another on the basis of mutual dependency, cooperation and synergy, collective goals in decisions, and articulation of the rules, more benefits from CF are delivered to the regular and disadvantaged stakeholders to increase the likelihood of CC resourcefulness.

1.3 Previous Studies

Climate researchers believe that the role of forest management in adapting to and mitigating the impact of CC has become an international as well as a Nepalese matter. CC is caused by both natural and anthropogenic factors in Nepal. However, there has been very limited study in the Inner and Terai regions. Anthropogenic factors drive changes that include the biophysical environment and ecosystems, biodiversity, and natural resources. The most common causes of the degradation of forests and land cover are over grazing, forest fires, erosion, floods, and loss of, or threats to, biodiversity. The consequences are increased landslides, floods, the disruption of river and wetland ecology, and the depletion of ground water resources that result in evidence of negative effects in the environment; these effects influence CC (Bauer, 2013). Ghimire (2017) and Yadav et al. (2019) studied forest cover in two areas in Duns and two areas in Bhawar and found that 92, 72, 48, and 79% of the total area in 1954, reduced to 89, 43, 36, and 64% in 1979, respectively. In the Terai and inner Terai, changed forest was only 11.73% of forest cover in 2015 (USAID, 2016). The lack of literature shows that the Terai is a “white spot” because of the lack of adequate research. Tiwari et al. (2010) found decreased water sources and groundwater, and increased siltation and sedimentation in the downstream Terai region. Devkota et al. (2013) assessed the flood vulnerability of the West Rapti River basin using the perceptions of people who had been affected by floods for years. Yadav et al. (2021b) examined the forest management plan for the economic impacts of CF particularly in the Terai region of Nepal. Omerkhila et al. (2020) explained that the hilly and plain zone is a harsh climatic region vulnerable to the high frequency of pest and disease outbreaks as the main risk. In addition more uneven rainfall and higher temperatures because of CC also had an impact. Giri et al. (2021) examined the inhabitants of informal (illegal) settlements whose inhabitants migrated from the hills to Nawalpur in the plains because of lower adaptive capacities as informal settlers.

Climate-smart approaches in forestry are enthusiastically linked to the sustainable distribution of forest products and ecosystem services (Temperli et al., 2022). The management of CF has played an important role in the mitigation of and adaptation to CC (Pandey et al., 2016). Puri et al. (2020) found that the current benefit level fits is insufficient to stimulate forest user groups to enhance forest management in the mid hills in Nepal. Cedamon et al. (2017) argued that local CFOMPs have given little focus to the technical management of forests in mid hills of Nepal. The production-oriented forest management plan under the Scientific Forest Management (SFM) programme of the Collaborative Forest Management (CFM) regime in Terai is required to assess the situation because CFOMPs have been limiting forest production (Bhattarai et al., 2018). Modak and Poudyal (2018) found that the promotion of greenery, control of encroachment, protection of forests and biodiversity conservation were aroused by SFM in CF. Pokharel (2013) showed that the ecological, geographical and biophysical conditions of the Chure region had rapidly degraded over 32 years. Bhandari (2013) found that the temperature of the Kapilbastu district had an increasing trend and rainfall was now unpredictable with increasing droughts and a two to three week delayed monsoon with fewer rainy days that resulted in a loss of species, declining yields, and outbreaks of pests and diseases. Panta (2017) revealed that the health and vitality of forest ecosystems were adversely affected by climatic and land use changes. Yadav et al. (2021a) analysed the socioecological impacts based on CFOMPs.

The above studies did not consider the CFOMP and whether they offer an option in forest management to adapt to and/or mitigate the impact of CC. Hence, the main aim of this study is to investigate the pragmatic knowledge of local respondents who have resided in the region for over 40 years, particularly the Inner Terai and Terai, including Churia. The study was carried out in the Siraha, Saptari and Udaypur districts, which are the regions and people who designed and have implemented a CFOMP for about 40 years. The design and implementation of the CFOMP have been prejudiced by powerful local stakeholders and professional experts who played a dynamic role in compliance with the initiatives for adapting to and mitigating CC, particularly in favour of disadvantaged households that had no lucrative interest in the CFOMP for the Inner Terai and Terai regions. The study's main aim was to analyse Nepal's community forestry stakeholder's experience of climate change, thereby to fill the knowledge gap through detail from stakeholders on the CC impacts.

[1] A denotes reinforcive power to reform existing structures and institutions for their specific interests (bureaucrats, technocrats, politicians and policy makers).

[2] B denotes end users and disadvantaged stakeholders including the weaker women of the society.

2. Literature Review

A forest management plan is a complementary form of political and ecological influences based on scientific and silvicultural operational principles. The plans have assumed a great responsibility for adapting to and modifying for confrontations with CC. Nepal is "one of the countries in the world that is most vulnerable to CC, being ranked as the fourth most climate vulnerable country in the world by the World Bank in 2011" (MoHA & DPNet-Nepal, 2015, p. 9). This study tries to answer the question: "What are the more effective strategies for managing the CFOMP for CC to influence the likelihood and/or severity of individual extreme events?" As we understand it, improved forest management is the process of planning and implementing the use of forests to meet specific environmental, economic, social objectives. It deals with the administrative, economic, legal, social, technical and scientific aspects of managing forests. Smart forest and tree management are the main sources of improved farm productivity, increased food security, and increased milk production by providing fodder and income (Pandey et al., 2013). Moreover, well managed forest resources also reduce human-wildlife conflict, reduce drought periods, potentially reduce risks, increase farm income and increase the risks to lives and livelihoods. Enhanced forest and tree management can play a significant role in climate and environmental change adaptation and provide alerts at a critical value (Duvey 2020; Shyamsundar et al., 2021; Tognetti et al., 2021). CC increases risk to life: changes in temperature, carbon dioxide and precipitation levels can increase the length of tree growing seasons and affect the livelihoods of the forest-reliant poor by affecting forest ecosystem services and the biodiversity on which they depend (Hajjar et al., 2021). CC increases flooding (Khan et al., 2021), intensifies cyclones (Bacmeister et al., 2018; Jangir et al., 2021) and increases soil erosion (Borrelli et al., 2020). It also threatens existing forests and tree-based goods and services. Floods, tropical storms, degraded landscapes, and landslides in forests can lead to loss of human life, livestock, and dwellings (Das and Vincent, 2009; Samir, 2013). Locatelli et al. (2012) found that forests can reduce social vulnerability to climate hazards, provide good local communities facing climate threats, regulate water, soil and microclimate for more resilient production of trees in agricultural fields, regulate forested watersheds, protect soils by reducing climate impacts and regulate temperatures.

Malik et al. (2016) estimated that the different disturbance parameters and forest structural attributes such as canopy cover and disturbance index on the basis of the density of cut stumps were negatively significantly correlated to anthropogenic disturbance, tree species richness was positively significantly related to anthropogenic disturbance in western Himalaya, India. Pokhriyal et al. (2020) by GIS hierarchy analysis identified the significant drivers of forest vulnerability in Himalaya, India. They found that, of the total forested area, most (61%) was very highly vulnerable followed by 36% being highly vulnerable because of degradation and exploitation through anthropogenic activities. Guptal et al. (2020) found that the effect agricultural production was negative, in combination with high population density in middle-altitude communities. Pandey et al. (2016) found higher adaptive ability of urban households and low adaptation capacity of rural households because of poor farm productivity.

2.1 Adaptation strategies

Forests can contribute to CC adaptation by providing biodiversity conservation, ecological balance and environmental services; they protect watersheds and provide a buffer against landslides, erosion, flooding and other natural disasters. Forest management plans should be implemented with the intended adaptation activities that avoid negative impacts on ecosystems and the wider landscape (FAO, 2010). CFUGs are clearly being incorporated into activities in the CFOMP. The CFOMP has a core action plan on CC and recognises groups' contribution to strengthening local livelihoods and diversifying income sources (Mishra et al., 2019). Authorised forest professionals, including the Divisional Forest Officer (DFO), national and state government authorities monitor and evaluate the plan's activities.

2.2 Mitigation strategy for CC

Biophysical interactions between mixed tree species with an active silvicultural management plan play a vital role in the mitigation strategy for CC. Open discussions with local stakeholders, forestry professionals, and political leaders at national, state, and local level are required to develop and implement the CFOMP with a clear aim of CC mitigation (Yousefpour et al., 2020). Cross-sector coordination, stakeholders' integration, democratic decision-making and enhancing forestry professionals' capacity assist the mitigation strategies with financial resources (Ahmed et al., 2019).

3. Conceptual Framework

Using an appropriate forest management plan helps reduce the cost of CFOMP and contributes to the local and national economy by generating income, employment, revenue, and stimulating infrastructure development at local, state, and national levels, which are aims of CF. The inter-dependence of ecological, economic, and social sustainability, including CC impacts and the mitigation and adaptation activities, must be recognised in the SFM and in contributing to the national Gross Domestic Product (GDP) (Dwyer et al., 2018). Efficient, effective monitoring is required to implement the CFOMP based on silvicultural principles by skilled forest specialists so that CF users are treated equitably. The implementation of an appropriate CFOMP that can produce proper mitigation and adaptation to CC is required (Jandl et al., 2019; Kumar et al., 2020; World Bank, 2020). A CFOMP developed to safeguard stream margins and water bodies will achieve healthy Inner Terai, Terai and hill regions and reduce the impacts of CC (Richman et al., 2016). Forest managers should provide appropriate advice and give the public access to forests on SFM principles to mitigate CC vulnerability (Karki et al., 2020). All industry employees need to be qualified in skills relevant to the tasks they perform or be under training to acquire such skills. Economic forest management is primarily concerned with establishing and harvesting tree crops for commercial purposes without ignoring the mitigation of and adaptation to CC. The industry operates in a market environment and managers need the freedom to change management practices to meet CC susceptibility and community preferences while maximising CC returns. Forest managers are free to maximise the economic returns from both natural and planted forests provided their operations meet statutory requirements and comply with the principles that include CC (World Bank, 2020). The costs and benefits of environmental effects should be incorporated into forest industry annual statements. Both local stakeholders and forest managers must agree to these principles and meet from time to time to monitor their implementation and address issues that may arise including CC impacts (Mansuy et al., 2020). The World Bank (2020) reported that there is substantial potential to redirect farm support toward CC mitigation. Additional interested parties are welcome to become signatories to the principles with the full support of the signatories.

This outline provides a means to develop a conceptual framework specific to the functioning of CFUGs under the influence of the powerful stakeholders. That conceptual framework will help deal with specific problems that apply to Nepalese CF and other institutions. The key elements in CFUGs are the powerful stakeholders form the basis of the conceptual model as shown in Table 1. The assumptions of the conceptual power model of CFUGs (Fig. 1) are as follows.

Table 1

The conceptual framework model of stakeholder power dynamics in Community Forestry User Groups

Adopted from Avelino (2021) and Yadav et al. (2021).

Form of Power	Type of stakeholder power dynamics (A&B[3])		
	(1) A &B power over each over	**(2) B has power over A**	**(3) A and B have no power over each other**
Power over	A depends on B but B also depends on A = > A and B have power over each other	A depends on B but B does not depend on A = > B has power over A	A and B do not depend on each other = > A and B have no power over each other
	Mutual dependence	**One-sided dependence**	**Independence**
More/less power	A exercises more/less power than B, but A and B have similar, collective goals	A exercises more/less power than B, while A and B have mutually exclusive goals	A exercises more/less power than B, A and B have independent co-existent goals
	Cooperation	**Competition**	**Co-existence**
Different power	A’s and B’s different power exercises enable and support one another	A’s and B’s different power exercises restrict, resist or disrupt one another	A’s and B’s different power exercises do not (significantly) affect one another
	Synergy	**Antagonism**	**Indifference**

In a power structure, a stakeholder's power often originates with the quantitative implications of having more or less power. It is assumed that the power can be distinguished according to resources such as natural resources, wealth and power structure of the regimes including interactions among structures, processes, rules, and traditions that determine how authority is exercised, how responsibilities are distributed, how decisions are made, and how various actors are involved (Hoffman, 2013). There are two types of power relations: (1) A has power over B to achieve similar collective goals/interests where mutual dependency, cooperation and different power exercises enable and support one another for synergy; (2) A has more power over B to achieve A's vested desires (having an unquestionable right to the possession on CFOMP or a privilege) where one sided dependency and completion are antagonistic and impacts are towards exclusive gaols. We have the argument that there is a third type of power relationship that tends to be overlooked: (3) A and B exercise different types of power relationships to and over. This shows that **A and B have no power over each other** including the understanding of independency, co-existence and differences that have existed. On this basis we proposed the types of power relationships and dynamics to analyse the CFOMP to see whether it is CC in the prevailing conditions or the environment in an outdoor setting around or near Nepalese communities in the Terai.

In summary, the social structure in south Asia, including Nepal, plays a crucial role in people gaining power. The existing structures and institutions for their specific interests (bureaucrats, technocrats, politicians and policy makers) can influence decisions; access public resources capture influential institutions and overlook the adaptation and mitigation strategies of CC if there is commercial interest in both public and CFUG organisations. Hence, as the principle of CF, the appropriate one is type (1); A has power over B to achieve similar collective goals/interests where mutual dependency, cooperation and different power exercises enable and support one another for synergy. The next section explains CF's impacts that helped develop the conceptual framework of the study.

3.1 CF impacts

The last four decades have witnessed a shift in the paradigm to Natural Resource Management (NRM) and conservation from a costly state-controlled approach of central government towards local communities with the assumption that local communities will play a vital, more active role in conservation of NRM. The main purpose of this reform was purportedly to shift the responsibility from central government to local communities regarding increasing participation in forest resource management and conservation including the mitigation of and adaptation to CC. Nepal has predictably depended on community forests for basic needs: firewood, timber, fodder and a balanced environment through mitigation of and adaptation to CC impacts (Galloway, 2010; Malla et al., 2005). Those impacts are achieved for the end-users through a CFOMP (FAO, 2000; Lippke et al., 2011). However, this rhetoric shaped a different level of power structure and relationships between user organizations and central and state government forest specialists who are responsible for preparing and controlling the CFOMP implemented by CFUGs.

We have analysed the main impacts of CF, the socioecological (Yadav et al, 2021a) and economic impacts (Yadav et al., 2021b). In this paper we examine and explain only the impacts of CFOMP in relation to CC.

Figure 1 shows the actor categories influencing CF's impacts including mitigation of and adaptation to CC and the environmental benefits if CFOMP is appropriately designed and implemented.

Figure 1 here

3.2 Integrated CC impacts, adaptation and mitigation impacts

Forest and CC policies and frameworks linked with CFOMP formulated recently lack specific steps for dealing with the mitigation of and adaptation to CC. The policies fail to identify the institutions and procedures for implementation and, in most cases; legislation has not been shaped to implement the policies. Paudel et al. (2019) found that there was integration of the concepts and issues of CC in policies but they were lacking in forest management activities. The implementation of adaptation to and mitigation of activities of CC initiatives in policies, frameworks and CFOMPs seem poor. Poudyal et al. (2019) found that implementation of the policies seemed poor because of a lack of a legal framework and activities in the CFOMP. Further participation of local stakeholders, including forestry professionals who have an important role in jointly determining and implementing adaptation activities that are feasible, effective, and avoiding maladaptive impacts of CC, is required.

3.3 CF resource attributes (forest stand density and size)

Tropical forests mostly occur in the inner Terai, Terai and Siwalik regions; the main tree species are *Shorea robusta*, *Terminalia tomentosa*, and *Adina cordifolia*. *Acacia catechu, Dalbergia sissoo* and *Bombax ceiba* are common in riverine forests. The high commercial value tree species are *Shorea robusta, Dalbergia latifolia, Dalbergia sissoo* and *Acacia catechu* in the Siraha, Saptari and Udaypur districts. Tropical sal (*Shorea robusta*) and associated species in the inner Terai and Terai are epicentres of biodiversity and important modulators encouraging the rate of adaptation to CC. Recent research on deforestation rates and ecological change in tropical forests has been reviewed as have the important aspects of the forests' role in meeting CC mitigation goals (Lewis, 2005; Moomaw et al., 2020). High diversity of tropical tree species with complex density encourages the rate of modification in moderation and adaptation to CC. Tropical forest management now needs to be adapted to maintain important forest stands, species, density and ecosystems that will smooth the transition through CC (Bruno et al., 2012). Mean stem volume (ob) in Nepal is 178 m^3 per ha. The main tree species, in terms of total stem volume, is sal with 28.2% of total volume (DFRS 1999). In the most recent study, the mean stem volume (ob) in Nepal was 164.76 m^3 per ha; the proportion of sal was 19.28.% of total volume (MFSC, 2015). This shows that the average growing stock per hectare and sal's proportion was reducing. This is a sign of forest composition changing in favour of species other than *Shorea robusta*.

[3] A denotes Reinforcive power reformed the existing structure and institution for their specific interests (bureaucrats, technocrats, politicians and policy makers) where B explicates (end users including weaker women of the society).

4. Methods And Materials

We use random sampling to select districts and study sites. The special attributes of this sampling method are that the likelihood of the sample units behaving like every other one and that each sample unit has specialist knowledge of the research issue or the capacity and willingness to participate in the study.

4.1 Sampling method

Sample selection assumes every household and the two similar regions (Terai and Mahabharata range) of Nepal have an equal probability of being selected. The primary data were collected using a pre-tested questionnaire; we carried out interviews with key informants before carrying out interviews with household members. We then verified the responses. The final questionnaire was developed for collection of relevant data from individual households. It was divided into three sections: general information regarding CF and households; socioeconomic variables of households; and forest attributes with climatic change variables. To get representative study sites and to meet the study's purpose, we stratified households into rich, medium, poor, and poorest based on their socioeconomic status. The Siraha, Saptari and Udaypur districts were selected in the inner Terai range including Churia Hills, and the Terai. They are ethnically and climatically diverse and CF programmes have been implemented for over 40 years. Semi structural questionnaires for each district site were designed to address context-specific research questions for the three survey sites. All three surveys derived knowledge based on people's observations and perceptions of a changing climate and the circumstances of adaptation to and mitigation of the responses. The selected districts are typical of all regions where a CF programme has been implemented so the findings can be applied widely to other Inner Terai, Terai, hill and mountain districts of Nepal. Data were collected three ways: (a) a household survey of 310 households including the rich, medium, poor, and poorest households; (b) a survey of the CFUG Executive Committees (ECs) of 31 CFUGs; and (c) secondary sources.

4.2. Empirical model to measure Community Forest Operational Management Plans

The conceptual model provides the basis of the empirical model to measure CC inventiveness, particularly the perceptions of the respondents based on CFOMP. Well managed tropical forests plays important roles in global CC. Trees are vital for adaptation to and mitigation of CC; an inappropriately managed forest leads to deforestation and creates climatic risk (Fischer et al., 2017).

The most severe CC impacts in the inner Terai, the Terai and hills are changes in species composition, flowering season, cropping pattern and productivity, prolonged droughts, temperature, heat/cold waves, rainfall, fogs, humidity, forest fires, flooding, cyclones, siltation, riverine floods and windstorms, water quality and local amenities, forest ecosystems, biodiversity loss, food security, depletion of energy resources, and degradation of rivers (Tazeze et al., 2012). Based on the literature review, the following is an empirical model in which variables are proposed for testing.

(i) CC impacts (Y_i) = f (changes in cropping patterns and productivity, changes prolong drought, change in temperature, heat wave, cold waves, rainfall intensity, fogs intensity, humidity, forest fires, flooding, cyclones, siltation, riverine floods and windstorms, water quality and local amenities, other relevant explanatory variables to avoid omitted variables problem). 1

We use multinomial logistic regression to examine the relationships. The model Multinom is a generalized linear model to estimate the probabilities form categories of a qualitative dependent variable Y, using a set of explanatory variables X. The generic relationships between the dependent variables, CC impacts, and the explanatory variables can be mathematically illustrated as:

$$\text{(ii)} \qquad Y_i^z = \beta^z{}_0 + \beta_{ij}^z X_{ij}^z + e^z \qquad 2$$

where: Y_i^z represents the z response variables (socioeconomic, climatic variables, and the forest common management attributes forest area, important forest stand, species, density, growing stock in *i* commons forest user group; Xj represents the j^{th} explanatory variable for the *i*th local forestry organisation; the error term is ; and $\beta_0{}^{\mathrm{z}}$ and $\beta_{\mathrm{j}}{}^{\mathrm{z}}$are, respectively, a constant term of the model and the coefficient of the variables.

5. Results And Discussion

The results highlight respondents' perceptions of CC in three districts. The results are explained in two stages: descriptive results and regression results for initiatives on CC. The next section describes the perceptions of the CC initiatives.

5.1 Descriptive analysis

Respondents who had resided for over 40 years in the surveyed districts reported their experiences and insights including their knowledge of CC. They are also linked with the CFOMP and CC is often identified as one main reason explaining why they have their own perceived understandings as in the Figs. 2, 3.1 and 3.2

5.1.1 Temperature

Temperature is a vital component of CC because it can lead to a chain reaction of other changes around the world. Climatologists and scholars advocate that temperature plays a significant role across the globe in declining air quality and erratic weather patterns as different manifestations of CC (Herbst, 2019). Paudel et al. (2020) found that farmers have identified CC indicators in various forms, e.g., an increase in temperature in Nepal (99.2% of those surveyed). Figure 2 shows 182 stakeholders of the 310 surveyed, 59%, expressed the view that the maximum temperature was increasing and minimum temperature was decreasing over last 20 years in inner Terai and Terai. The increased temperature has been significantly prolonged and affects human and living beings' health, reduces crop production, decreases species diversity, and increases flowering, sprouting of the plants and, in the long run, negatively affects respondents' livelihoods.

Only few respondents thought temperature was constant or had no idea (3 each). Hence, we ignored those responses in the analysis. The numbers who said increase and decrease are statistically different by a t-test assuming unequal variances (see Table 2 which shows that the t statistic value for increase is statistically positively different from the decrease). This shows that temperature could be a suitable variable for econometric analysis.

Table 2: t-Test: Two-Sample Assuming Unequal Variances										
Temperature			*Increase*	*Decrease*						
		t-Test: two-sample assuming unequal variances for ratio of Temperature								
	Increase	*Decrease*	*Constant*	*Critical two-tail values*		*DF*	*Numbers of Observation*			
Increase	*4.26**			*1.96*			*310*	*310*		
Decrease	*4.43**	*-3.21**		*1.96*	*1.96*	*456*	*310*	*310*	*310*	*310*
** Statistically significant, critical two-tail value at the 5% significance level is 1.96.*										

5.1.2 Rainfall

Natural rainfall is very important for growing and harvesting agricultural produce. Because of CC problems, the Terai has been facing environmental challenges, particularly pressure on natural resources like rainfall intensity (CBS, 2019). Rainfall intensity is very high for a short period. The daily summer rainfall distribution is highly uneven; 10% of annual rainfall precipitation can fall in a day and 50% of annual precipitation can fall in 10 days during the monsoon (Pokharel & Hallet, 2015). Two hundred and four respondents (66%) agreed with decreased rainfall in the last 20 years (Fig. 2). Every year, human, domestic and wild animals' lives have been lost in last 20 years. For example, because of heavy rainfall and flooding in the monsoon in 2020 (BBC Nepali news, 29 August 2020), over 300 humans died, 100 were missing and 99 were seriously injured in the inner and Terai regions.

Table 3		*t-Test: two-sample assuming unequal variances for ratio of rainfall*							
	Decrease	*Increase*	*Critical two-tail values*		*DF*	*Number of Observations*			
Decrease	*3.35**		*1.96*			*310*	*310*		
Increase		*-17.9368**	*1.96*	*1.96*	*433*	*310*	*310*	*310*	*310*
Note: Because of the limited length of the manuscript, we did not incorporate the analysis of all the variables'- test assuming unequal variables.									

Only 25 and 2 responded with constant and no idea, respectively. Hence, we ignored those responses. The increase and decrease responses are statistically different; a t-test assuming unequal variances shows that the t statistic value is greater than the critical two tail value for the increase and decrease, which indicates that increase, is statistically positively different from decrease (see Table 3). This shows that temperature could be a suitable variable for econometric analysis. The two variables increase and decrease means are 0.251 and 1.316 and the variances are 0.188 and 0.902, respectively.

Figure 2 **here**

5.1.3 Humidity

Humidity changes also indicate CCs. Humidity is significant in that relative humidity is shifted upwards by hundreds of metres during the winter dry season when tropical forests typically bank most on humidity from cloud contact (Shrestha et al., 2019). Simultaneously, an increase in warmth implies increased evapotranspiration (Stoy et al., 2019). One hundred and thirteen respondents (36%) said humidity had increased. That proportion is significantly higher than the proportion of respondents who humidity had decreased, was constant or had no idea.

5.1.4 Fog

No studies seem to have analysed the impact of fog on CF management. Several studies have been conducted on winter fogs in the Indo Gangetic Plain (IGP) of India, Bangladesh and Pakistan. However, in Nepal's Terai region, there has been limited study of winter fogs, including the days and months linked with CFOMP. We had 147 (47.42%) of respondents (Fig. 2) believed dense foggy days and months have increased, particularly in winter. Foggy periods in the Terai region are considered important for local stakeholders because of their effects on people's health, transport, farms, and forest management activities in the livelihoods of locals. This finding is similar to that of Shrestha et al. (2018) who studied the occurrence of fog in the Terai region by analysing visibility data from 1980 to 2015 at four airports in the region and found an increasing pattern of fog impacts on crop production and food security.

5.1.5 Fuzzy Sky

Of the respondents, 155 individuals (50%) indicated that fuzzy sky occurrence has significantly increased in last 20 years. Only 63 (20%) expressed the belief fuzzy sky was constant over that time. All respondents had the impression that a fuzzy sky had a direct, significant influence on agricultural production and the natural regeneration of forest.

Figures 3.1 **and 3.2 here**

5.1.6 Cold waves and heatwaves

Over the last two decades, the Terai region has experienced climate extremities such as cold waves, heat waves, and erratic precipitation. One hundred and sixty respondents (51.6%) said there was an increasing trend and 89 (28.7%) said a decreasing trend in cold waves. For heat waves, 267 (86%) of respondents said they were increasing over the last 20 years and 22 (7%) said they were decreasing (Fig. 2). These events cause severe, prolonged dryness affecting demographic features such as mortality of disadvantaged, vulnerable people including children and the elderly (Gurung, 2014; Pradhan et al., 2019).

5.1.6 Summary

A two-tail t-test assuming unequal variances was conducted to analyse whether these paired groups were statistically different. The socioecological and forest attributes with the CC issue-related variables were statistically significant by various descriptive and t-test analyses. The results indicate that the variables in Table 4 were suitable for econometric analysis.

The explanatory variables for the regression are in Table 1. The dependent variable is CC impacts 40 years after the transfer of forests to CFUGs. Three regressions were carried out for CC impacts. The CC impacts were observed by the local household heads who participated in an interview. The potential explanatory factors determining the CC impact (the dependent variable), as recommended by the descriptive analysis for further analysis in a regression model, were examined in a multinomial logistic regression model. The explanatory variables were examined in different functional forms (i.e., logarithm and raw) as well as in their interactions. A multi-collinearity test was conducted to see whether there was any collinearity problem with the explanatory variables. The explanatory variables are defined in Table 4.

Table 4
Definitions of the dependent and independent (explanatory) variables

Dependent Variable	*Description*
CC outcomes	*CC was observed by the households' heads over 40 years in their experience after handing over the CF to local communities; if in experience of interviewees yes 1, otherwise 0*
Changed intensity in rainfall	*Changes in rainfall were observed by households' heads over 40 years which could assume four discrete values 1, 2, 3 or 4 that denote increase, decrease, constant and no idea, respectively.*
Change in temperature	*Changes in temperature were observed by households' heads over last 20 years which could assume four discrete values 1, 2, 3 or 4 that denote increase, decrease, constant and no idea, respectively.*
Independent Variable	Description of variable
(a) Socioeconomics variables	
Age HHH	*Age of household head who participated in an interview*
HHNo	*Number of households in CFUGs*
Own land	*If household has own land includes Khet, Bari 1, otherwise 0*
Ed level	*Education level: illiterate, primary, middle high school, intermediate, bachelor degree and above*
Cow	*Number of cows per household*
Buffalo	*Number of buffaloes per household*
Goat	*Number of goats per by household*
Gender	*If household head male 1, otherwise 0.*
(b)Forest attributes with climatic change variables	
CFArea	*CF area in hectares*
BroadlF	*Broadleaf forest composition, % with broadleaf species*
CONFER	*Conifer forest type composition, % with coniferous species*
CropPro	*Crop production per unit area: increase 1, decrease 2, constant 3, no idea 4.*
Humidity	*Grams of water vapour per cubic metre of air (g/m^3); if increase 1, decrease 2, constant 3, no idea 4*
Foggy	*Density of fog: if increase 1, decrease 2, constant 3, no idea 4.*
Sky fuzzy	*Magnitude per square arc second: if increase 1, decrease 2, constant 3, no idea 4.*
Cold wave	*Cooling of the air: if increase 1, decrease 2, constant 3, no idea 4.*
Heat wave	*Intensity of heat wave: if increase 1, decrease 2, constant 3, no idea 4.*

5.2 Regression analysis

The chi-square results show that likelihood ratio statistics are highly significant (p > 00001) suggesting that the model has a strong explanatory power.

5.2.1 Multicollinearity and autocorrelation

Multicollinearity among predictors may hamper the analysis of species-environment relationships in multiple regression settings. Because of collinearity, ecologically more causal variables may be excluded from the models if other inter correlated variables better explain the variation in the response variable in statistical terms (Heikkinen et al., 2004; Luoto & Hjort, 2006; Mac Nally, 2000; Xie et al., 2019). The variables are significant in the stabilised (restricted) model as presented in Table 5.

Table 5: The results of multinomial logistic regression of CC and a range of variables

	StdError	z-value	Pr(>|z|)	
(Intercept):	-0.12398	0.57330	-0.2160	0.02895 *
PHHArea:	0.00107	0.03195	3.3549	0.00079 ***
Humidityb:b	-0.84340	0.00343	-2.5224	0.01165 *
Humidityc:a	-0.00179	0.00004	-4.2216	2.42615 ***
Coldwavb:b	0.72297	0.03326	2.1731	0.02977 *
Coldwavd:d	0.00466	0.00199	2.3415	0.01920 *
Tempera	-0.02874	0.04486	-0.641	0.00033 ***
LnBroadlF	0.28819	0.13318	2.164	0.03135 *
Foggyinc	-0.12473	0.07292	-1.710	0.08834.
SkyHazc	0.14468	0.07760	1.864	0.06333.
Gender	0.94180	0.38764	2.430	0.01512 *
SkyHaza	0.17563	0.08807	1.994	0.04713 *
Coldwava	-0.15840	0.08262	-1.917	0.05625.
Rainfallc	0.37889	0.10293	3.681	0.00028 ***
BioDCond	-0.23263	0.09273	-2.509	0.01271 *
Amenitya	0.33638	0.10103	3.329	0.000989***
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘’ 1				

Notes: the number of Fisher Scoring iterations was 2; Ln is natural logarithm; denotes increase; b decrease; c constant; d, no idea. Log-Likelihood: -194.73, McFadden R^2: 0.1836, Chisq = 87.588 (p = 0000003); Pseudo R^2 0.2888

Temperature increase (TempIncs) is statistically negatively significant at the 1% level. Respondents' perceptions are aligned regarding increased temperature in the last two decades. They also perceive that winter temperature has been decreasing during that time. Temperature affects forest management and, in turn, influences human health, heat related illness and, significantly, the carbon, biodiversity and other ecosystem service costs that are considered to some extent in designing the CFOMP. This result supports Lin et al. (2019), Nash et al. (2019) and Nicholas et al. (2018) who report that locals mention a strong influence of temperature increases over 20 years on crop yields and off farm activities.

Log of broadleaf forest type (LnBroadlF) is statistically positively significant at the 1% level. This indicates that greater the broadleaf forest proportion and proper management and implementation of the scientific CFOMP, the less is CC's impact on the environment and the more favourable for maintaining the livelihood of locals. Nuberg et al. (2019) argued that this creates a responsibility to turn the public debate from resistance to acceptance of scientific forest management involvement by locals in the design, implementation and monitoring of CFOMP.

Fog increase (Foggy inc) is statistically negatively significant at the 10% level. This shows that fog density and foggy days in the season are correlated; as fog intensity increases, visibility decreases. This also reveals that the production of sensitive crops and soft tissue species' regeneration is influenced by increasing fog. This result is like other findings on CC; Panuio et al. (2019) found where there is a high level of fuzziness..

Sky haze increase (Sky Hazea) is statistically positively significant at the 10% level. This indicates that in the inner Terai and Terai, sky haze increase increases environmental pollution. Haze also influences agricultural and human livelihoods that are susceptible to the impact of CC and weather patterns. Locals in the regions are being forced to incrementally adapt and reframe their perception of their neighbourhood because of both severe events and gradual CCs such as warming temperatures and changing weather patterns. This result is like found by Poudel et al. (2020) that the Terai and Siwalik Plains show negative annual trends in cold indices and mixed changes in other extreme indices include shy haze.

Cold wave (ColdWavea) is statistically negatively significant at the 10% level. This indicates that inner Terai and Terai have a negative annual trend in cold indices. This result is similar to Khanal and Wilson (2019) who argued that cold spell risk perception had a negative effect on forest management as well as on people's livelihoods. Harsh cold particularly impacts on the life of the elderly.

Rainfall (Raindec) is statistically positively significant at the 1% level. The results therefore appear relatively insensitive to the specifics of monsoon rainfall. Rainfall has a significant beneficial relationship with the change in forest management. The intensity of rainfall increase in a short period created landslides in the hills and Siwalik whereas it created flooding in Inner Terai and Terai that destroyed people's life and livelihoods. For example, many people's homes were flooded and 141 people died (21 in Inner Terai and Terai) (Nepalese Kantipur TV, 24 News 24 July 2020). Almost all respondents indicated decreasing rainfall over the last 20 years. This result is similar to Aryal et al.'s (2020) and Sharma et al.'s (2020) results. They argued that decreasing rainfall had a significant negative relationship with the changes in forest management.

Biodiversity conservation (BioDCond) is statistically negatively significant at the 5% level. This shows that biodiversity conservation is negatively correlated with the present scenario of CFOMP and limits the likelihood of biodiversity conservation, particularly in the understanding of the respondents. Community-based forest management is guided by certain tangible objectives that may reduce species diversity; there are no clear parameters for conserved biodiversity. Respondents perceived biodiversity conservation as degraded in the GLC because of both anthropogenic pressure and climate variability. This finding supports Roka (2019) who argued that biodiversity has a reducing trend because of the influence of CC.

Amenity (amenityb) The amenity factor is statistically positively significant at the 1% level. There has been greater determination in forest management to influence amenities. Amenities such as water sources, wildlife, wilderness, small predators, carnivores in and around blocks of forest, and recreation depend on forest age.

This result supports Thapa et al. (2018) who argued that amenities and their factors depend on forest age, protection, a linear Terai arc landscape and forest management.

6. Conclusions

This study examined local experiences of climate change impacts in Nepal’s community forestry. We analysed the perceptions of local respondents using a descriptive approach, which showed, 59% of respondents had observed an increase in temperature, heat waves (82.9%) and cold waves (51.6%). Conversely, rainfall intensity (65.8%), fog intensity (47.42%), fuzzy sky (50%) and humidity (36%) were seen to have decreased. Regression analysis showed that broadleaf forest type, sky haze and rainfall were statistically positively significantly correlated with CC and CFOMP that, in turn, affected the livelihoods of locals. Temperature, fogs, cold waves, biodiversity and amenity variables were negatively correlated with CC and CFOMP. We also examined CFOMP compliance with changes in climate variables – crop productivity, prolonged droughts, flooding, siltation, riverine floods and windstorms, water quality and local amenities. Our analysis support the conceptual framework model for the type of stakeholder power dynamics (A&B) 1 in CFUGs and we have presented a conceptual framework using a forest management plan that could help reduce CFOMP’s implementation cost and silviculture-based forest management.

Our study also support the hypothesis that when different power actors A (bureaucrats, technocrats, politicians and policy makers) and B (end users and disadvantaged including weaker women of the society) exercise power in designing and implementing CFOMP, there is an increased likelihood of mitigating and adapting to CC. Therefore this study support the hypothesis that when both A and B enable and support one another, more benefits from CF are delivered to disadvantaged stakeholders.

We argue that appropriate scientific CFOMP should be operated that would minimise unnecessary political and bureaucratic interventions. I highlight the conceptual framework; stakeholders’ power dynamics A&B (1) in which local stakeholders consider that CFOMP is socially acceptable, economically lucrative, and environmentally responsive since it includes CC resilience so is highly appropriate for the management of the Terai sal and ecotone (a zone of transition between two different ecosystems) centred pine forest resources. These findings can help policy makers, forest professionals and managers to make informed decisions about CFOMP to enhance Nepal’s climate change programs, particularly the inner Terai and Terai. The findings offer implications to bridge between locals, forest managers and policymakers and help develop suitable policies and effective CFOMP strategies in Nepal.

We cover the perceptions of local people about CC related variables that directly link with the CFOMPs of Nepal’s inner Terai and Terai Sal and ecotone-based mixed Sal and pine forest. Pure Sal forest species and hill Sal and pine associated forest species in tropical region, and other types of forest, have also initiated CFOMPs so further study is recommended in those areas to analyse whether those forests are managed in consideration of CC. We recommend local stakeholders’ active participation in the planning, monitoring and good governance of CFOMP since that is a key contributing factor to promote environmental economic benefits. This study is based on data from three districts only. Some respondents’ perceptions of CC could be different in the other 20 districts in the Terai. In addition, macroclimatic factors can change in the same region within a greater biome that has climatic differences in the surrounding area. Therefore, this study needs to be repeated in many districts and from time to time to update our understanding of the effect of CC impacts. Second, because of time and resource constraints, we sampled only 10 households in each CFUG. A more comprehensive study that sampled all households in a number of CFUGs would provide a more complete picture of respondents' perceptions of CC impacts. We argue that an appropriate framework of environmental risk must be imagined to consider policies that address social, economic, ecological, and biodiversity conservation challenges in conjunction with CC initiatives. New policies and legislation must include active and equitable way of managing communities' forests so that community forestry user groups recognise their efforts are making a difference in coping with climate change. Government and other agencies must recognise the challenges and efforts of local communities in addressing climate change impacts on the ground.

7. Study Limitations And Weaknesses

This study is based on data from only three districts. Some respondents' perceptions of CC could be different in the other 20 districts in the Terai. In addition, macroclimatic factors can change in the same region within a greater biome that has climatic differences in the surrounding area. Therefore, this study needs to be repeated in many districts and from time to time to update our understanding of the effect of CC impacts. Second, because of time and resource constraints, we sampled only 10 households in each CFUG. A more comprehensive study that sampled all households in a number of CFUGs would provide a more complete picture of respondents' perceptions of CC impacts.

Acronyms

CFOMP	Community Forestry Operational Management Plan
CF	Community Forestry
CFUGs	Community Forestry User Groups
CC	Climate Change
SFP	Scientific Forest Management
CFM	Collaborative Forest Management
DFO	Divisional Forest Officer
NRM	Natural Resource Management
OB	Over Bark
ECs	Executive Committees
IGP	Indo Gangetic Plain
BBC	British Broadcasting Corporation

Declarations

Acknowledgements

The authors thank the CF User Groups, EC members and general stakeholders who gave their valuable time to participate in our survey. The support of Support For Development, New Zealand, is also gratefully acknowledged for funding data collection.

Interest: There are no conflicts of interest.

References

1. Ahmed AU, Appadurai AN, Neelormi S (2019) Status of Climate Change Adaptation in South Asia Region. In Alam M., Lee J., Sawhney P. (Eds), Status of climate change adaptation in Asia and the Pacific (pp 125–152). Publisher name?
2. Antle JM, Ray S (2020) Economic development, sustainable development, and agriculture.*Sustainable Agricultural Development*,9–42
3. Aryal JP, Rahut DB, Sapkota TB, Khurana R, Khatri-Chhetri A (2020) Climate change mitigation options among farmers in South Asia. Environ Dev Sustain 22(4):3267–3289. https://doi.org/10.1007/s10668-019-00345-0
4. Avelino F (2021) Theories of power and social change. Power contestations and their implications for research on social change and innovation. J Political Power 1–24. doi: 10.1080/2158379X.2021.1875307
5. Bacmeister JT, Reed KA, Hannay C, Lawrence P, Bates S, Truesdale JE, Rosenbloom N, Levy M (2018) Projected changes in tropical cyclone activity under future warming scenarios using a high-resolution climate model. Clim Change 146:547–560. 10.1007/s10584-016-1750-x
6. Bauer K (2013) Are preventive and coping measures enough to avoid loss and damage from flooding in Udayapur district, Nepal? Int J Global Warming 5(4):433–451
7. Benz JP, Chen S, Dang S, Dieter M, Labelle ER, Liu G, Hou L, Mosandl RM, Pretzsch H, Pukall K, Richter K, Ridder R, Sun S, Song X, Wang Y, Xian H, Yan L, Yuan J, Zhang S, Fischer A (2020) Multifunctionality of forests: A White Paper on challenges and opportunities in China and Germany. *Forests 11*, 266
8. Bhandari G (2013) Assessment of climate change impacts and adaptation measures in the Kapilbastu District of Nepal. Appl Ecol Environ Sci 1(5):75–83. DOI:10.12691/aees-1-5-2
9. Bhattarai BP, Poudyal BH, Acharya P, Maraseni T (2018) Policy and governance issues in timber harvesting: a case study of collaborative forest in Nepal. In Prof. Dr Abhoy Kumar Das, Coordinator, TGG-N Project Dr Bishwa Nath Oli, Secretary, Government of Nepal Prof. Dr. Carsten Smith-Hall, Project Head, TGG-N Project Prof. Dr. Santosh Rayamajhi, Coordinator, SCIFOR Project Dr. Suresh Ghimire, Central Department of Botany, TU Dr. Shiva Prasad Dhakal, Faculty of Agriculture, AFUWild Harvests, Governance, and Livelihoods in Asia Proceedings from the International Conference, Kathmandu 30 November to 2 December 2017
10. Borrelli P, Robinson DA, Panagos P, Lugato E, Yang JE, Alewell C, Wuepper D, Montanarella L, Ballabio C (2020) Land use and climate change impacts on global soil erosion by water (2015–2070). *Proceedings of the National Academy of Sciences* 21994–22001 DOI – 10.1073/pnas.2001403117

11. Bruno L, Markku K, Maria B, Carol PC, Murdiyarso D (2012) Facing an uncertain future: How forests and people can adapt to Climate Change. CIFOR, pp.97, 2008, 978-979-1412-75-9. FCFirad-00699333
12. Cedamon E, Nuberg I, Paudel G, Basyal M, Shrestha K, Paudel N (2017) Rapid silvicultural appraisal to characterize stand and determine silviculture priorities of community forests in Nepal. Small Scale Forestry 16:195–218. https://doi.org/10.1007/s11842-016-9351-0
13. Chalise D, Kumar L, Kristiansen P (2019) Land degradation by soil erosion in Nepal: A review. Soil Syst 3:12. doi:10.3390/soilsystems3010012
14. Devkota RP, Maraseni TN, Cockfield G, Devkota LP (2013a) Flood vulnerability through the eyes of vulnerable people in midwestern Terai of Nepal. Earth Sci Clim Change 4(1):1–7
15. Devkota RP, Maraseni TN, Cockfield G, Devkota LP (2013b) Indigenous knowledge for CC induced flood adaptation in Nepal.The International Journal of Climate Change: Impacts and Responses(1),33–46http://on-climate.com/
16. Dobias R (2018) Climate change in South Asia. Asian Development Bank
17. Duvey D (2020) Comparison of socio economic development of Tarai and Nepal. Res Nepal J Dev Stud 3(1):67–76. https://doi.org/10.3126/rnjds.v3i1.29653
18. Dwyer E, Indranil P, Salvador A, Nilay S (2019) Smart energy systems for sustainable smart cities: Current developments, trends, and future directions. Appl Energy 237:581–597. doi.org/10.1016/j.apenergy.2019.01.024
19. FAO (2000) Development of national level criteria and indicators of sustainable forest management of dry forest of Asia, Bhopal India. Food and Agriculture Organisation of United Nations, Regional Office for Asia and Pacific Region, Bangkok, Thailand
20. FAO (2010) Forests and climate change in the Asia and Pacific Region. Forest and Climate Change Working paper number 7. Food and Agriculture Organisation of the United Nations
21. Fischer G, Tramberend S, van Velthuizen H, Wunder S, Kaphengst T, McFarland K, Bruckner M, Giljum S (2017) Extending land footprints towards characterizing sustainability of land use. International Institute for Applied System Umweltbundesamt, Dessau-Roßlau
22. MFSC(2015).Forest Sector Strategies (2016–2025).Ministry of Forest and Soil conservation, Government of Nepal Kathmandu, Nepal
23. Forest Act (1993) Ministry of Forest and Soil Conservation. Singh Darbar, Nepal
24. Forest Department Guidelines (2014) Babar Mahal Kathmandu, Nepal
25. Galloway MK (2010) Advance guard: Climate change impacts, adaptation, mitigation and indigenous peoples – A compendium of case studies. United Nations University – Traditional Knowledge Initiative, Darwin, Australia
26. Ghimire M (2017) Historical land covers change in the Chure-Tarai landscape in the last six decades: Drivers and environmental consequences. In: Li A, Deng W, Zhao W (eds) Land cover change and its eco-environmental responses in Nepal. (pp ??-??) Springer, Singapore
27. Ghimire A (2019) A review of studies on climate change in Nepal. The Geographic Base 6:11–20. DOI: https://doi.org/10.3126/tgb.v6i0.26163

28. GON (2010a) National adaptation programme of action for climate change. Ministry of Environment, Government of Nepal, Kathmandu
29. GON (2010b) Climate change vulnerability mapping for Nepal. National Adaptation Programme for Action to Climate Change. Ministry of Environment, Government of Nepal, Kathmandu
30. GON (2014) National biodiversity strategy and action plan (2014–2020). Ministry of Forest and Soil Conservation, Government of Nepal, Kathmandu
31. Gupta AK, Negi M, Nandy S, Kumar M, Singh. V, Valente D, Petrosillo I, Pandey R (2020) Mapping socio-environmental vulnerability to climate change in different altitude zones in the Indian Himalayas. Ecol Ind 109:105787. doi.org/10.1016/j.ecolind.2019.105787
32. Gurung CK (2014) Impact of climate change on socio -economic condition of Tsum Valley people, central hill, Gurkha, Nepal. A thesis submitted in partial fulfilment of the requirement for the degree of Doctor of Philosophy in economics, School of Humanities and Education, Singhania University, India
33. Hatfield JK, Boote P, Fay L, Hahn C, Izaurralde BA, Kimball T, Mader J, Morgan D, Ort W, Polley et al (2008) Agriculture. In: Backlund P, Janetos A, Schimel D (eds) The effects of climate change on agriculture, land resources, and biodiversity in the United States. U.S. Department of Agriculture, pp 27–92
34. Hajjar R, Newton P, Ihalainen M, Agrawal A, Alix-Garcia J, Castle SE, Erbaugh JT, Gabay M, Hughes K, Mawutor S, Pacheco P, Schoneveld G, Timko JA (2021) Levers for alleviating poverty in forests. For Policy Econ 132:102589. doi.org/10.1016/j.forpol.2021.102589
35. Herbst MA (2019) A cultural policy of the multitude in the time of climate change; with an understanding that the multitude has no policy. Doctoral thesis, Goldsmiths, University of London [Thesis]
36. Heikkinen RK, Luoto M, Virkkala K, Rainio K (2004) Effects of habitat cover, landscape structure and spatial variables on the abundance of birds in an agricultural–forest mosaic. J Appl Ecol 41(5):824–835. https://doi.org/10.1111/j.0021-8901.2004.00938.x
37. Hoffman J (2013) Theorizing power in transition studies: the role of creativity and novel practices in structural change. Policy Sci 46(3):257–275. doi:10.1007/s11077-013-9173-2
38. Jandel R, Spathelf P, Bolte A, Prescott CF (2019) Forest adaptation to climate change – is non-management an option? Ann For Sci 76(2):48–63. doi.org/10.1007/s13595-019-0827-x
39. Jangir B, Swain D, Ghose SK (2021) Influence of eddies and tropical cyclone heat potential on intensity changes of tropical cyclones in the North Indian Ocean. Adv Space Res 68(2):773–786. doi.org/10.1016/j.asr.2020.01.011
40. Karki S, Burton P, Mackey B (2020) Climate change adaptation by subsistence and smallholder farmers: Insights from three agro-ecological regions of Nepal. Cogent Social Sciences 6(1):1720555. https://doi.org/10.1080/23311886.2020.1720555
41. Khanal U, Wilson C (2019) Derivation of a CC adaptation index and assessing determinants and barriers to adaptation among farming households in Nepal. Environ Sci Policy 101:156–165. https://doi.org/10.1016/j.envsci.2019.08.006
42. Khan QS, Zubair M, Manzoor SA, Haq A, Baloch MS (2021) Socioeconomic determinants of climate change adaptations in the flood-prone rural community of Indus Basin, Pakistan. Environ Dev 37:100603. doi.org/10.1016/j.envdev.2020.100603

43. Kumar M, Singh MP, Singh H, Madhukar PD, Ravindranath NH (2020) Forest working plan for the sustainable management of forest and biodiversity in India. J Sustainable Forestry 39(1):1–22. https://doi.org/10.1080/10549811.2019.1632212
44. Lewis SL (2005) Tropical forests and the changing earth system. Philosophical Trans Royal Soc B 361:195–210. http://doi.org/10.1098/rstb.2005.1711
45. Lin T, Htun KT, Gritten D, Martin AR (2019) The contribution of community forestry to CC adaptive capacity in tropical dry forests: Lessons from Myanmar. Int Forestry Rev 21(3):324–340
46. Lippke B, O'Neil E, Harrison R, Skog K, Gustavsson L, Sathre R (2011) Life cycle impacts of forest management and wood utilization on carbon mitigation: knowns and unknowns. Carbon Manag 2(3):303–333. DOI: 10.4155/cmt.11.24
47. Locatelli B, Djoudi H, Somorin OA, Pramova E (2012) Forests and trees for social adaptation to climate variability and change. WIREs CC 3:581–596. doi: 10.1002/wcc.195
48. Luoto M, Hjort J (2006) Scale matters – A multi-resolution study of the determinants of patterned ground activity in subarctic Finland. Geomorphology 80(3):282–294. doi.org/10.1016/j.geomorph.2006.03.001
49. Majaw B (2020) Climate change in South Asia. Routledge, London
50. Malla YB, Neupane HR, Branny P (2005) Why are not poor people benefiting more from community forestry? J For Livelihoods 3(1):78–91
51. Mansuy N, Burton P, Stanturf J, Beatty C, Mooney C, Besseau P, Degenhardt D, MacAfee K, Lapointe R (2020) Scaling up forest landscape restoration in Canada in an era of cumulative effects and climate change. For Policy Econ 116,102177 doi.org/10.1016/j.forpol.2020.102177
52. MacNally R (2000) Regression and model-building in conservation biology, biogeography and ecology: The distinction between – and reconciliation of – 'predictive' and 'explanatory' models. Biodivers Conserv 9:655–671. https://doi.org/10.1023/A:1008985925162
53. Mishra A, Appadurai AN, Choudhury A, Regmi BR, Kelkar U, Alam M, Chaudhary P, Mu SS, Ahmed AU, Lotia H, Fu C, Namgyel T, Sharma U (2019) Adaptation to CC in the Hindu Kush Himalaya: Stronger Action Urgently Needed. The Hindu Kush Himalaya Assessment, pp 457–490
54. MFSC (2015) Forest Policy Ministry of Forest and Soil Conservation. Government of Nepal, Kathmandu
55. Modak N, Poudyal AS, TGG-N Project Prof (2018) Potentials and challenges of scientific forest management in community forest in Nawalparasi district, Nepal. In Prof. Dr. Abhoy Kumar Das, Coordinator, TGG-N Project Dr. Bishwa Nath Oli, Secretary, Government of Nepal Prof. Dr. Carsten Smith-Hall, Project Head,. Dr. Santosh Rayamajhi, Coordinator, SCIFOR Project Dr. Suresh Ghimire, Central Department of Botany, TU Dr. Shiva Prasad Dhakal, Faculty of Agriculture; "AFUWild harvests, governance, and livelihoods in Asia" Proceedings from the International Conference held in Kathmandu 30 November to 2 December 2017
56. MOFN (2019) Climate change policy. Ministry of Forest and Environment, Kathmandu, Nepal
57. MoHA (2015) Nepal disaster report 2015. Ministry of Home Affairs (MoHA) and Disaster Preparedness Network Nepal (DPNet-Nepal)
58. Moomaw WR, Law BE, Goetz SJ (2020) Focus on the role of forests and soils in meeting CC mitigation goals: Summary. Environ Res Lett 15(4):045009

59. Mustafa Y, Yusuf T (2009) Analysis of the benefit generated by using fuzzy numbers in a TOPSIS model developed for machine tool selection problems. J Mater Process Technol 209(1):310–317
60. N.B.P. Nepal national biodiversity strategy and action plan. Government of Nepal Ministry of Forests and Soil Conservation, Kathmandu, Nepal
61. Nash N, Capstick S, Whitmarsh L, Chaudhary I, Manandhar R (2019) Perceptions of local environmental issues and the relevance of climate change in Nepal's Terai: Perspectives from two communities. *Frontiers in Sociology*, 4(60), 1–18. DOI = 10.3389/fsoc.2019.00060
62. Nica A, Popescu A, Ibanescu DC (2020) Human influence on the climate system. Curr Trends Nat Sci 8(15):209–215. http://www.natsci.upit.ro
63. Nicholas H, Wolff YJ, Masuda EM, Jessie A, Wells ETG (2018) Impacts of tropical deforestation on local temperature and human wellbeing perceptions. Glob Environ Change 52:182–189
64. Nseka D, Mugagga F, Opedes H, Wasswa H, Mugume I, Nimusiima A, Nalwanga F, Ayesiga P (2021) The damage caused by landslides in socio-economic spheres within the Kigezi highlands of South Western Uganda. Environ Socio-economic Stud 9(1):23–34
65. Nuberg IK, Shrestha KK, Bartlett AG (2019) Pathways to forest wealth in Nepal. Australian Forestry 82(sup1):106–120. doi: 10.1080/00049158.2019.1614805
66. Omerkhila N, Chanda T, Valentec D, Valentec JM, Pandey R (2020) Climate change vulnerability and adaptation strategies for smallholder farmers in Yangi Qala District, Takhar, Afghanistan.Ecological Indicators, 110 page numbers? 105863
67. Pandey GS, Paudyal BR (2016) Protecting forests. improving livelihoods Community Forestry in Nepal, Kathmandu
68. Pandey R, Harrison S, Gupta AK (2014) Resource availability versus resource extraction in forests: Analysis of forest fodder system in forest density classes in Lower Himalayas, India. Small Scale Forestry 13:267–279. https://doi.org/10.1007/s11842-013-9253-3
69. Pandey R, Maithani N, Aretano R, Zurlini G, Archie K, Gupta AK, Pandey VP (2016) Empirical assessment of adaptation to climate change impacts of mountain households: Development and application of an adaptation capability index. *J. Mt. Sci.* 13, 1503–1514 (2016). https://doi.org/10.1007/s11629-015-3499-5
70. Panta AP (2017) Climate change and forest management in Nepal. Monogr Chap 197–224. DOI:https://doi.org/10.4337/9781786439499.00016
71. Panuccio M, Dell'Omo G, Bogliani G, Catoni C, Sapir N (2019) Migrating birds avoid flying through fog and low clouds. Int J Biometeorol 63(2):231–239. https://doi.org/10.1007/s00484-018-01656-z
72. Pandey S, Cockfield G, Maraseni TN (2016) Assessing the roles of community forestry in CC mitigation and adaptation: A case study from Nepal. For Ecol Manag 360:400–407. doi.org/10.1016/j.foreco.2015.09.040
73. Paudel B, Zhang Y, Yan J (2020) Farmers' understanding of climate change in Nepal Himalayas: Important determinants and implications for developing adaptation strategies. Clim Change 158:485–502. https://doi.org/10.1007/s10584-019-02607-2

74. Paudel G, Adhikari S, Bhusal P (2018) Integration of forest and climate change policies in Nepal. J For Nat Resource Manage 1(1):1–13

75. Pokhrel KP (2013) Chure forestry conservation and management plan: A case study of Arghakhanchi district, Nepal. J Geogr Reg Plann 6(5):172–183. https://doi.org/10.5897/JGRP12.088

76. Pokhriyal P, Rehman S, Areendran G et al (2020) Assessing forest cover vulnerability in Uttarakhand, India using analytical hierarchy process. *Model. Earth Syst. Environ.* 6, 821–831 (2020). https://doi.org/10.1007/s40808-019-00710-y

77. Pokharel AK, Hallett J (2015) Distribution of rainfall intensity during the summer monsoon season over Kathmandu, Nepal. Royal Meteorological Society 257–261. doi:10.1002/wea.2493

78. Poudel A, Cuo L, Ding J, Gyawali AR (2020) Spatio-temporal variability of the annual and monthly extreme temperature indices in Nepal. Int J Climatol 40:1–22. https://doi.org/10.1002/joc.6499

79. Poudyal BH, Maraseni TN, Cockfield G (2019) Impacts of forest management on tree species richness and composition: Assessment of forest management regimes in Tarai landscape Nepal. Appl Geogr 111:1–11. 102078 doi.org/10.1016/j.apgeog.2019.102078

80. Pradhan B, Sharma P, KPradhan P (2019) Impact of cold wave on vulnerable people of Tarai region, Nepal

81. Puri L, Nuberg I, Ostendorf B, Cedamon E (2020) Locally perceived social and biophysical factors shaping the effective implementation of community forest management operations in Nepal. *Small Scale Forestry*, volume and page numbers. https://doi.org/10.1007/s11842-020-09438-5

82. Richman L, Devkota BP, Richman MA (2016) Users' priorities for good governance in community forestry: Two cases from Nepal's Terai Region. 65:69–78. doi.org/10.1016/j.forpol.2015.11.005. Forest Policy and Economics

83. Robert L, Wilby RK (2012) Adapting to flood risk under climate change. Progress in Physical Geography Earth and Environment 36(3):348–378. https://doi.org/10.1177/0309133312438908

84. Robock A (1978) Internally and externally caused of climate change. Am Meteorological Soc 35:1111–1122

85. Roka K (2019) Promoting climate agenda and biodiversity conservation at the local level: A case for Nepal’s rural and urban municipalities. In: Leal FW, Barbir J, Preziosi R (eds) Handbook of CC and Biodiversity. Springer, Cham, pp 305–323

86. Rasul G, Thapa GB, Karki MB (2011) Comparative analysis of evolution of participatory forest management institutions in South Asia. Soc Nat Resour 24(12):1322–1334. doi: 10.1080/08941920.2010.545966

87. Roy D, Datta A, Kuwornu JKM, Zulfqar F (2020) Comparing farmers’ perceptions of climate change with meteorological trends and examining farm adaptation measures in hazardprone districts of northwest Bangladesh. *Environment, Development and Sustainability* volume and page numbers? https://doi.org/10.1007/s10668-020-00989-3

88. Saalu FN, Oriaso S, Gyampoh B (2020) Effects of a changing climate on livelihoods of forest dependent communities: Evidence from Buyangu community proximal to Kakamega tropical rain forest in Kenya. Int J Clim Change Strateg Manag 12(1):1–21. https://doi.org/10.1108/IJcc SM-01-2018-0002

89. Sapkota R, Rijal K (2016) Climate change and its impacts in Nepal. Central Department of Environmental Science Institute of Science and Technology, Tribhuvan University, Kirtipur, Kathmandu, Nepal

90. Shackleton CM, Shackleton SE (2002) Household wealth status and natural resource use in the Kat River valley, Eastern Cape. Unpubl. report. Rhodes University, Grahamstown

91. Shrestha S, Moore GA, Peel MC (2018) Trends in winter fog events in the Terai region of Nepal. Agric For Meteorol 259:118–130. doi.org/10.1016/j.agrformet.2018.04.018

92. Shrestha AK, Thapa A (2019) Solar radiation, air temperature, relative humidity, and dew point study: Damak, Jhapa, Nepal. Int J Photoenergy 7. https://doi.org/10.1155/2019/8369231. Gautam, H.

93. Shyamsundar P, Sauls LA, Cheek JZ, Sullivan-Wiley K, Erbaugh JT, Krishnapriya PP (2021) Global forces of change: Implications for forest-poverty dynamics. For Policy Econ 133(1):1–17. https://doi.org/10.1016/j.forpol.2021.102607

94. Stoy PC, El-Madany TS, Fisher JB, Gentine P, Gerken T, Good SP, Klosterhalfen A, Liu S, Miralles DG, Perez-Priego O, Rigden AJ, Skaggs TH, Wohlfahrt G, Anderson RG, Coenders-Gerrits AMJ, Jung M, Maes WH, Mammarella I, Mauder M, Migliavacca M, Nelson JA, Poyatos R, Reichstein M, Scott RL, Wolf S (2019) Reviews and syntheses: Turning the challenges of partitioning ecosystem evaporation and transpiration into opportunities, *Biogeosciences*, 16, 3747–3775. https://doi.org/10.5194/bg-16-3747-2019, 2019

95. Thapa K, Gnyawali TP, Chaudhary L, Chaudhary BD, Chaudhary M, Thapa GJ, Joshi D (2018) Linkages among forest, water, and wildlife: A case study from Kalapani community forest in Lamahi bottleneck area in Terai Arc Landscape. Int J Commons 12(2):1–20. DOI: http://doi.org/10.18352/ijc.777

96. Tazeze A, Haji J, Ketema M (2012) Climate change adaptation strategies of smallholder farmers: The case of Babilie District, East Harerghe zone of Oromia Regional State of Ethiopia. J Econ Sustainable Dev 3(14):1–13

97. Temperli C, Santopuoli G, Bottero A, Barbeito I, Alberdi I, Condés S, Gschwantner T, Bosela M, Neroj B, Fischer C, Klopčič M, Lesiński J, Sroga R, Tognetti R (2021) National forest inventory data to evaluate climate-smart forestry. In: Tognetti R, Smith M, Panzacchi P (eds) Climate-smart forestry in mountain regions. Managing Forest Ecosystems book series, vol 40. Springer, Cham. https://doi.org/10.1007/978-3-030-80767-2_4

98. Tiwari K, Kashab R, Awasthi D, Balla MK, Sitaula BK (2010) Local people's perception on climate change, its impact and adaptation practices in Himalaya to Terai regions of Nepal. (2010). https://digitalrepository.unm.edu/nsc_research/48

99. Tognetti R, Valentini R, Marchesini LB, Gianelle D, Panzacchi P, Marshall JD (2021) Continuous monitoring of tree responses to climate change for smart forestry: A cybernetic web of trees. In: Tognetti R, Smith M, Panzacchi P (eds) Climate-smart forestry in mountain regions. Managing Forest Ecosystems book series, vol 40. Springer, Cham. https://doi.org/10.1007/978-3-030-80767-2_10

100. USAID (2016) Nepal land and natural resource tenure assessment for proposed emission reductions program in the Terai arc landscape. The generous support of the American people through the United States Agency for International Development (USAID)

101. World Bank (2020) Revising public agricultural support to mitigate climate change. The World Bank

102. Xie B, Marilynn B, Brewer BK, Hayes RI, McDonald B, Newell R (2019) Predicting climate change risk perception and willingness to act. J Environ Psychol 65. page numbes? doi.org/10.1016/j.jenvp.2019.101331
103. Yadav Y, Chhetri BBK, Raymajhi S, Tiwari K, Sitaula B (2019) Dynamics of land use land cover change and mapping of trees outside forest (TOF) in Terai, Nepal. Int J Environ Sci 19(1):556002. doi:10.19080/IJESNR.2019.19.556002
104. Yadav BD, Shrestha KK, Acharya BP (2021a) Contested forest management and the Nepalese Government's policy. World Dev Perspective 23:100355. doi.org/10.1016/j.wdp.2021.100353
105. Yadav BD, Shrestha KK, Acharya BP (2021b) Socioecological and environmental impacts from forest commons: Insights from local Nepalese stakeholders. Int J Forestry 2(1):1–28. http://www.scirea.org/journal/PaperInformation?PaperID=5677
106. Yousefpour R, Nakamura N, Matsumura N (2020) Forest management approaches for climate change mitigation and adaptation: A comparison between Germany and Japan. J Sustainable Forestry 39(6):635–653. doi: 10.1080/10549811.2020.1771376
107. Zhang K, Hou Y, Li G, Huang Y (2020) Tourists and air pollution: How and why air pollution magnifies tourists' suspicion of service providers. J Travel Res 59(4):661–673 : sagepub.com/journals-permissions. DOI: 10.1177/0047287519859710

Figures

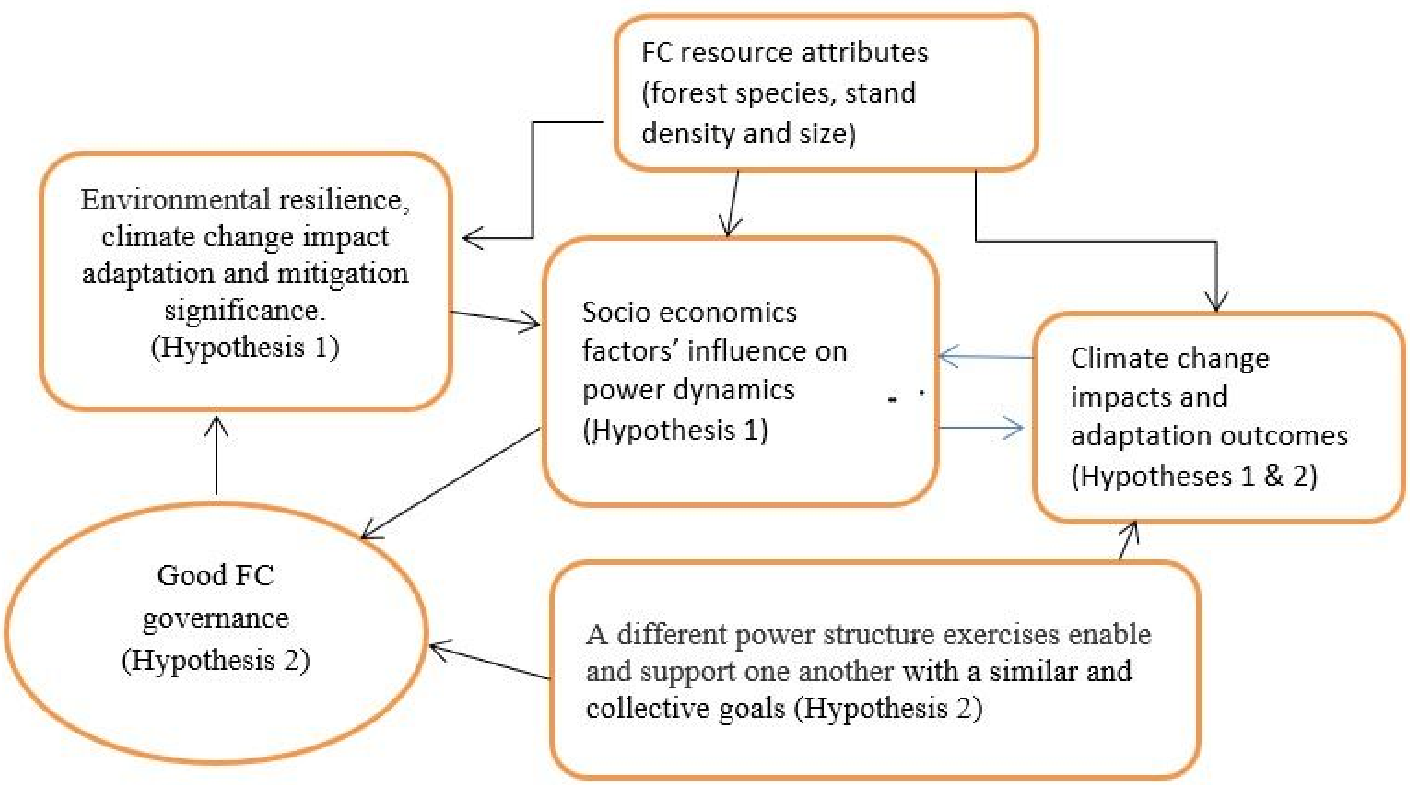

Figure 1

The empirical framework of the power influence model in CFOMP to climate initiatives

Figure 2

Local respondents' perceptions of climate change

Figure 3

3.1 (left) Inner Terai fuzzy sky 3.2.(right) Fuzzy sky over Terai paddy fields, Udaypur