Environ Dev Sustain (2019) 21:221–247
https://doi.org/10.1007/s10668-017-0031-9

Farmers' perception on agro-ecological implications of climate change in the Middle-Mountains of Nepal: a case of Lumle Village, Kaski

Rishikesh Pandey[1]

Received: 10 February 2017 / Accepted: 19 September 2017 / Published online: 30 September 2017

Abstract This study investigates the implications of climate change on agricultural ecology of Lumle Village as a representative example of the Middle-Mountains of Nepal. Primary data were collected through face-to-face interviews taken in 141 households. Supplementary data of public domain were collected from 9 Focus Group Discussions, 3 Historical Timeline Calendars, 20 Key Informant Interviews and sketches of 2 Crop Calendars. The findings suggest that traditional agro-livestock-based livelihood of the farming households of Lumle is ruined because of farmland abandonment and shift of agro-livestock activities to others options. A sharp decline in contribution of agro-livestock-based activities in household livelihoods in the last decade justifies this statement. Many factors might have been interplaying in abandoning agro-livestock activities. However, as the impacts of climate change are complex because of their spiral effects in existing poverty and marginality of households, it is contributing to agro-ecology through the effects of changes in weather pattern, increased invasive species and crop–livestock pest, as well as labour migration abroad caused by reduced farm output. The damage in agricultural ecology of mountain area in general and of Lumle in particular, however, has not yet been addressed by contemporary development policies of Nepal. Considering the importance of agricultural ecology for social-ecological sustainability and meeting the Sustainable Development Goal of eliminating hunger by 2030, Nepali agricultural policies should urgently recognise the need of agro-ecological restoration policy. It is expected that the integration of migration and climate change adaptation policies with agriculture and landuse policies to restrict farmland abandonment as well as provision of incentives for agricultural restoration would benefit in this regard.

✉ Rishikesh Pandey
itsmehimalaya@gmail.com

[1] Development Studies and Human Geography, School of Development and Social Engineering, Pokhara University, Pokhara-Lekhnath 30, Kaski, Nepal

Keywords Climate change impacts · Farmland abandonment · Agro-ecological restoration · Himalaya · Nepal

1 Introduction

Impacts of climate extremes manifested through natural hazards such as floods, cyclones, hurricanes and droughts are felt by people across the globe (IPCC 2012). Nepal is not an exception in relation to climate change impacts; rather, it is experiencing an abrupt level of alteration in climate system (Pandey 2016a) and associated implications. So the country is listed as the fourth extremely vulnerable country in the world in terms of climate change impacts.[1] Global temperature has risen by as much as 0.85 °C between 1880 and 2012; the projected rate of warming for the twenty-first century is 1.5 °C relative to 1985–1900 (IPCC 2013), while warming in Nepal and the Himalaya is remarkably higher, up to 0.06 °C per year on an average, than the global average (Shrestha et al. 1999, 2012). The rates of change within Nepal are variable spatially, ranging from 0.029 °C per year at Meghauli in the Tarai[2] (Pandey 2016b), 0.0.07 °C per year in the Middle-Mountains at Daman and 0.27 °C per year in the high Himalaya at Lamgtang (Chaulagain 2006).[3]

The IPCC (2014) stated that no one in the globe would remain 'unaffected' by the impacts of 'unequivocal' warming of the climate system. Agriculture is the way of life of billions of the poor globally, and South Asia is the hub of poor farming households where lives of hundreds of millions of people are dependent on agriculture (Aggarwal and Sivakumar 2011; Thapa et al. 2013). By its nature, agriculture cannot escape climatic vagaries. However, effects are complex and uncertain, particularly in reference to the questions such as when, where and how climate change affects agricultural production (Lal 2011b). The adverse impacts of climate change on agriculture are expected to exacerbate poverty that would challenge food security in subsistence farmers and may encourage for environmental migration.

Climate change implications on agriculture vary with the societies' ability to respond to the impacts. Researchers reported that the places where the majority of poor and hungry people are concentrated coincide with the places having higher level of climate change and associated impacts (Adger 2006; Mendelsohn et al. 2007; Holly et al. 2012). This indicates that being poor means an inability to respond climate change impacts but suffer the most. One of the UN Post-2015 Sustainable Development Goals (SDGs) is to eliminate poverty and hunger by 2030. It is well articulated that economic growth, particularly growth in agricultural income, is important in reducing hunger in developing countries (Cervantes-Godoy and Dewbre 2010). In this regard, without increase in agricultural production the goal of eliminating hunger is not attainable. Furthermore, as agriculture is a climate-sensitive livelihood option, the agriculture of poor communities has suffered from reduced investment in climate-sensitive agricultural infrastructure (Pandey 2016b). The negative impacts of climate change on agriculture would directly affect the objective of eliminating hunger in Nepal. In this context, it is important to conduct a study on climate change impacts on agricultural ecological system and provide feedback for appropriate agriculture policy that would help the country progress towards meeting one of the SDGs, i.e. zero hunger by 2030. In this context, this research intends to answer the research questions such

[1] https://maplecroft.com/about/news/ccvi.html Accessed on 14 July 2017.

[2] Between 1971 and 2010.

[3] Between 1971 and 2000.

as what sort of impacts of climate process and climate events on agro-livestock-based livelihood systems of the study area are experienced by studied population? Is the share of agro-livestock activity in household livelihoods changing over time?

Impacts of climate change on agriculture have prompted global concern, which are exhibited by various studies (Reilly 1995; Parry et al. 1999, 2005; Howden et al. 2007; Adger 2010; Rosenzweig 2011; Grasso and Feola 2012; Yufang et al. 2012). The literature indicated that the level of impacts of climate change differs with local biological conditions (soil content, type of crop) and management practices (Parry et al. 1999, 2005). They also vary with the objectives of agriculture (commercial vs subsistence) and the intensity of changes in climate system (warming, drought, precipitation, storms and their seasonal variations). The cumulative outcomes of the impacts are wide. Few of the frequently reported impacts are: changes in agro-ecological zones, changes in soil moisture and changes in timing and length of growing seasons, as well as availability of water, demand for irrigation and increase in fallow land or new land being brought under cultivation (Rosenzweig and Parry 1994; Hulme 1996; Darwin 2001). Such studies in Nepal, in general, are lacking on the one hand and the socio-spatial diversity of country demands for many location-specific studies on the other. In addition, Nepal has rich policy mechanism as there are over 10 policies, 18 acts, 9 regulations and 8 orders talking about agriculture. However, implementation issue is so weak that every new policy repeats almost the same objective and same indicators of the recently completed one. One Village One Product (OVOP) has been emphasised since long, which does not actually address the issue of food security that Nepal is facing. Majority households in Nepal are marginal holders who own less than 0.5 ha of land, followed by small holders having less than 2 ha. Furthermore, their farm-plots are located apart due to inheritance. However, policy clauses ask for consolidation of small farm-plots and make larger than 18 ha so farmers collectively get subsidies for irrigation infrastructure. Such clauses make it difficult to increase irrigation even in the Tarai as consolidating small plots is often unpracticable. Furthermore, The issue of land reform is getting its place in political debates and some 35 commissions have been formed and provided their recommendations in the last half-century in Nepal. However, none of the recommendations are executed yet. All of these show failed implementation mechanisms of Government of Nepal, particularly in relation to agricultural and land reform policies. In this context, this study explores agro-ecological impacts of climate change in the Middle-Mountains of Nepal with a case observed in Lumle Village, Kaski, to provide specific feedback for appropriate policy intervention.

This paper is divided into five sections. The first section introduces the issue of climate change and its agro-ecological implications in general. The second section provides a brief review of the literature in relation to the concept of agro-ecology and existing knowledge on agricultural implications of climate change. Methods used in this research are presented in the third section, while fourth section discusses results. At last, the paper provides concluding statements.

2 Concept of agro-ecology and the issue of climate change impacts

Agricultural ecology is a scientific (it is also used as a movement or as a practice, see Wezel et al. 2009) study of agro-ecosystems. An agro-ecosystem includes but is not limited to communities of plants, animals and microorganisms interacting with their physical and chemical environments under human-controlled system that produce food, fibre, fuel and other products for human consumption and processing. OECD (Agro-ecology, Glossary of Statistical Terms) defines agro-ecology as the study of the relation of agricultural crops and environment. This definition seems to be simple and can be elaborated since the agriculture and environmental interaction includes a number of components and their functioning such as farmer, technology, investment, land and soil, animals, and natural environment, in relation to the landscape of a place and politico-administrative functioning of a country. Gaba (n.d.) defines agricultural ecology as an application of ecological concepts and principles for the design and management of sustainable agro-ecosystems, while Wojtkowski (2002, 2006) defines agro-ecology as a human-governed system of interaction of organisms within planned and managed environments, mostly in terrestrial environments. So it is different from natural ecology.

Agro-ecology, in general, studies four major components of agro-ecosystems, namely productivity, stability, sustainability and equitability through an interdisciplinary lens. Agro-ecological impacts of climate change are socially constructed. Therefore, the climate process and climate events affect the agro-ecological systems in reference to the level of sensitivity of agro-ecology, stress of the change and the responses made by socio-political and economic institutions of affected area/community. This study focuses on climate change impacts on agriculture in reference to human–environmental interactions in Lumle Village that aimed to meet the goal of household food security. Therefore, in the present context, agro-ecology is a complex praxis derived from the theories of social-psychology and human intensions, which are not well predictable (Pandey 2016b). In the uncertain human praxis, the new driver such as 'anthropogenic climate change' has further impacted the agricultural system, challenging people to meet the economic goal of agriculture. The scope of this paper is to focuses on agro-ecological implications of climate change rather than elaborating the concept of agro-ecology. Therefore, existing knowledge on climate change impacts on agriculture is briefly reviewed here.

Climate change impacts can be understood through the risk associated with and vulnerability created by climate change in agricultural sector. The risk is the potentiality of harmful events, while vulnerability is the degree to which the agriculture is likely to suffer (Brooks et al. 2005). Adverse risks directly or indirectly lead to vulnerability, so agricultural impacts of climate change are associated with the ability of agriculture system to cope, adapt and recover from extreme weather events and hazards. In this paper, the state of susceptibility of agricultural system (sensitivity) to be harmed from exposure to extreme weather events (stresses) and its inability to adapt with such events (adaptive capacity) are defined as agro-ecological vulnerability (Adger 2006; IPCC 2007).

The global climate change trends have already demonstrated their impacts on agriculture (Howden et al. 2007). However, many impacts are still uncertain and are spatially different. Agricultural damage due to climate change can be expected globally (IPCC 2012) with a larger loss at lower latitudes of tropical developing countries such as Sub-Saharan Africa and South Asia, while increased greenhouse gases (GHG) can expand the yield at high and mid-latitudes and altitudes (McCarthy et al. 2001; Cruz et al. 2007). Although there are many uncertainties, it is expected that agriculture and food production at global scale would be manageable (Reilly 1995; Parry et al. 1999). However, the demand and supply of agro-production might be affected by other elements together with climate change (Rosenzweig 2011).

Ciais et al. (2005) identified major loss of crop production even in mid- and high latitudes such as in Europe due to the heat wave and drought of 2003, indicating that excessive warming and climate change not necessarily produce positive results in high latitudes and altitudes either. Heavy and frequent precipitation events damage crops, increase soil erosion and cause water logging in cultivated land, while drought can lead to land degradation, lower yields, crop damage and crop failure; increased temperature and drought can also lead to livestock deaths (McLeman and Smit 2006; IPCC 2007; Barbier et al. 2009; Grasso and Feola 2012). Increased temperatures and CO_2 concentrations can also lead to a decline in grain quality (Hocking and Meyer 1991; Ziska et al. 1997; Oh-e et al. 2007) and alter crop–pest interactions and pest's distribution, further leading to crop losses (Lal 2011a; Macchi 2011; Pruneau et al. 2012; Ramirez-Villegas et al. 2012; Paudel et al. 2014; Bhatta et al. 2015). In addition, climate change can alter the stages and the rates of development of the pathogen, modifies plant resistance and results in changes in the physiology of plant–pathogen interaction (Coakley et al. 1999). Limited studies also indicated negative impacts of climate change on stability, utilisation and access to food as well (Schmidhuber and Tubiello 2007), though uncertainties remain in regional context (Reilly 1995). For examples, estimations indicate that crop yields could decrease up to 30% by the mid of the twenty-first century in South Asia, even if the direct positive physiological effects of CO_2 are taken into account (Cruz et al. 2007; Aggarwal and Sivakumar 2011). An agricultural research study in Nepal showed a marginal increase (up to 7%) in rice yield when the temperature rises up to 4 °C with a rainfall rise of 20% but reduced maize production (Oxfam 2009).

The studies conducted in various parts of Nepal have shown different kinds of impacts of climate change on agriculture. Some of the examples include but are not limited to elimination of agro-biodiversity; tropical and warm-temperate crops becoming more feasible at higher altitudes (Dahal et al. 2009); and increased crop–livestock diseases and pathogens as well as increased farm weeds and invasive species and associated production loss (Paudel et al. 2014; Bhatta et al. 2015) together with farmland abandonment (Paudel et al. 2014; Chapagain and Gentle 2015). The unique traditional knowledge, socio-economic activities and social systems of *Manangis* have been facing pressure for change due to climate change and rapid melting of glacier (Chaudhary et al. 2007). The other research maintains that resource degradation, food scarcity and lack of basic services with the course of climate change have significantly challenged rural communities' livelihoods in north-western mountains of Nepal (Onta and Resurreccion 2011; Gentle and Maraseni 2012). Reductions in crop yield, increased crop pests and diseases, and farm weeds due to increased drought and reduced water availability, as well as increases in extreme rainfall events are at the forefront of the livelihood vulnerability of poor farmers in Nepal (Chhetri and Easterling 2010; Ghimire et al. 2010; Gentle et al. 2014; Palazzoli et al. 2015). In this background, present study analyses the perceived impacts of climate change on the state of mountain agriculture of Nepal with a case example from Lumle Village, Kaski, Nepal.

3 Methods[4]

3.1 Study area

This study was conducted in Lumle Village cluster in Kaski District of Nepal (Fig. 1). Lumle[5] is located in the Middle-Mountains in the central part of Nepal between 988 masl to 3667 masl (Human Settlements). The village is a part of the Annapurna Conservation

[4] Parts of this section overlap with original unpublished Ph. D. Thesis (Pandey 2016b) since the paper used information from the same project.

[5] Data used here are from VDC Profile of Lumle 2067BS (2010) if particular source is not given.

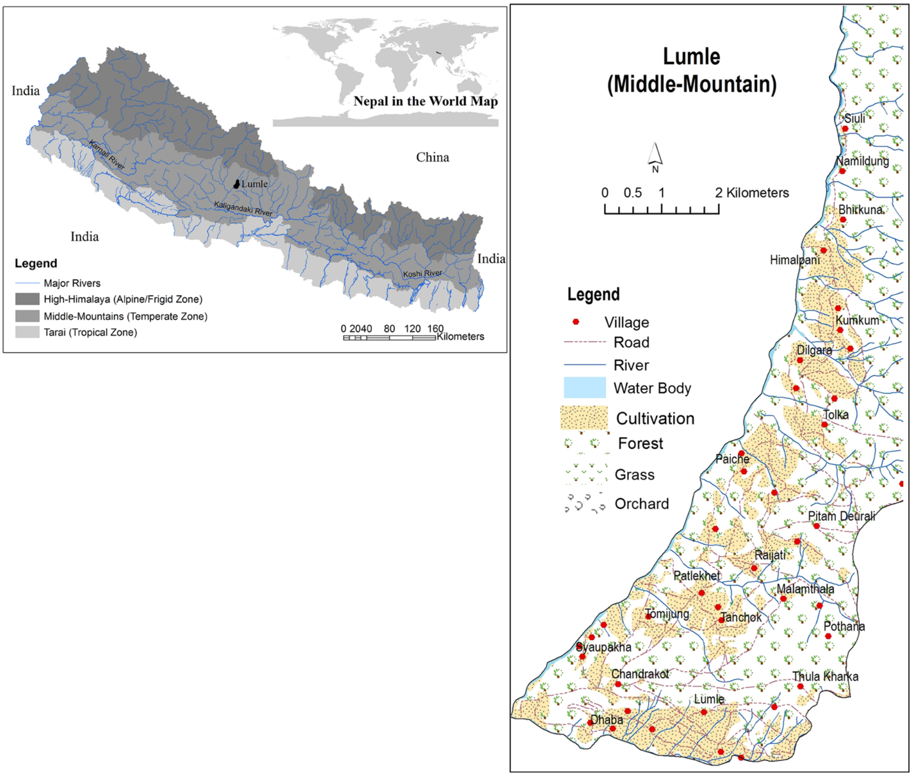

Fig. 1 Location of study area in Nepal and Lumle Village

Area Project (ACAP), which is aiming at harmonising physical nature and human communities. The population of the village is 4258 (2348 females) in 1056 households with an average household size of 4 persons and sex ratio of 81.4 males per 100 females. Long-term weather records (1971–2010) at the Lumle Meteorological Station show average mean values of 20^{O} Celsius for maximum temperature, 15 °C for minimum temperature and over 5400 mm annual precipitation (Pandey 2016b).

The VDC is inhabited by different castes[6] and ethnic communities such as the *Brahmins/Kshetries*, the *Magars*, the *Gurungs*, the *Newars* and the *Dalits*. Most of the land is covered by forest (over 68%), and agricultural lands make up only about 17%, and bushland and meadows cover about 5% of the total area (Village profile of Lumle 2067).

Some of the settlements in the village are electrified through local micro-hydropower projects, and some of the other are connected to national grid. The source of household energy for cooking is firewood and for light is electricity. The village is connected by a regional highway (Pokhara–Baglung), but many settlements within the village lack access to the road network. The nearest city (Pokhara) is about 25 km away from Lumle cluster. In such an environmental context, the agro-ecological system of the village is exposed to rapid climate change and experienced different impacts.

[6] Castes are endogamous divisions of society in which membership is hereditary and permanent (Berreman 1972). Caste has been an element in the social structure of Hinduism categorised based on the occupation, believed to be practiced since the *Licchavi* period (AD300—ca. 879).

3.2 Climate change scenario in the study area

The climate of Lumle area is changing rapidly. Table 1 shows level of changes in various meteorological variables recorded at Lumle Meteorological Station for the last 4 decades (1970–2010). The annual average of maximum temperature of Lumle is increased by 0.059 °C per year, and the linear regression coefficient shows the change being statistically significant (at 95%) with $p = 0.000$. This change is also significant in nonlinear examination of change investigated through the rank correlation test (the Mann–Kendall) at 99%. Other weather elements those experienced significant alternation are annual average of extreme maximum temperature, extreme minimum temperature and extreme rainfall events of >50 mm and >150 mm per 24 h. The alternation of weather variables in seasons rather than in annual average can have higher level of implications in agricultural ecology. Therefore, changing pattern of seasonal climate of Lumle is also analysed here. The findings indicate that the summer season followed by spring and autumn experienced higher level of changes, while alteration in winter is the least in general. However, in case of seasonal maximum temperature, winter season has the highest rate of warming that is 0.069 °C per year. This finding indicates the possibility of grave implications of climate change on agro-ecological livelihood systems of the study area.

3.3 Sampling procedure and sample size

This research has adopted both representative and non-representative sampling techniques. Lumle cluster is purposively selected considering the village being located at the highest rainfall regime of Nepal. A representative sample size of 144 was obtained from the total households ($N = 1056$) using 10% error ($e = 0.1$), 99% confidence level (significance = 0.01) and 50% of estimated probability of success (p) to collect household perception on climate change impacts. As few of the sampled households refused to participate in research, the actual sample size rested on 141 households. Among the sample, 28.4% (40 households) had women as the head of households so were the respondents. The households for face-to-face interviews were randomly selected from a lists of households prepared in consultation with the village secretary and key informants. In the absence of the household head, an adult member of the household was the respondent and proportion of such informants was about 10%. The dominant (87.9%) respondents were 30–74 years of age, followed by 8.5% young adults (below 30 years) and quite a little (3.5%) being senior citizen (75 years of age or above).

Purposive sampling that selects information-rich respondents is more relevant to collect qualitative information (Patton 1990). Therefore, for Focus Group Discussions (FGDs), Key Informant Interviews (KII) and Historical Timeline Calendars (HTC) as well as to construct Crop Calendar, the sites and participants were sampled purposively. A total of 9 FGDs, 3 HTC and 20 KII were conducted, and 2 Crop Calendars were constructed to obtain the information on public domain. Considering a small spatial unit of the study area, a rich information was collected, although not all of the data and information are utilised in this paper.

3.4 Method of data collection and analysis

Data on social demography, economic status and livelihood options as well as the climate change impacts perceived by the households were collected through face-to-face interview

Table 1 Rates of annual and seasonal changes in various weather elements at Lumle Meteorological Station, Nepal (linear regression coefficients−dependent variable = year)

Meteorological variables	Unstandardised coefficients		Standardised coefficients	t	Sig. (95% confidence level)	Model summary				LINEST
	B	Std. error	Beta			R	R^2	Adjusted R^2	Std. error of the estimate	Rates of change per year
Annual average of meteorological variables										
Maximum temperature	10.2935	1.3418	0.7795	7.6713	0.000*	0.78	0.608	0.597	7.419	0.059
Minimum temperature	4.8704	4.9298	0.1582	0.9879	0.329	0.158	0.025	−0.001	11.694	0.005
Extreme maximum temperature	10.043	1.9164	0.6477	5.2406	0.000*	0.648	0.420	0.404	9.023	0.042
Extreme minimum temperature	7.9896	1.9388	0.5558	4.1209	0.000*	0.556	0.309	0.291	9.846	0.038
Total precipitation	0.0059	0.0031	0.2943	1.8984	0.065	0.294	0.087	0.063	11.319	14.760
Total rainy days	−0.0438	0.135	−0.0526	−0.3248	0.747	0.053	0.003	−0.023	11.827	−0.036
Annual extreme rainfall events > 50 mm	0.7582	0.304	0.3751	2.4943	0.017*	0.375	0.141	0.118	10.979	0.1747
Annual extreme rainfall events > 100 mm	0.77	0.4631	0.2604	1.6628	0.105	0.26	0.068	0.043	11.435	0.095
Extreme rainfall events > 150 mm	2.4909	1.0544	0.3578	2.3623	0.023*	0.358	0.128	0.105	11.059	0.043
Seasonal changes: Winter										
Maximum temperature	6.071	1.152	.650	5.268	0.000*	0.65	0.422	0.407	9.004	0.069
Minimum temperature	2.581	2.763	.150	0.934	0.356	0.15	0.022	−0.003	11.710	0.009
Extreme maximum temperature	4.730	1.698	.412	2.786	0.008	0.412	0.170	0.148	10.792	0.141
Extreme minimum temperature	3.102	1.708	.283	1.816	0.077	0.283	0.080	0.056	11.360	0.026
Total precipitation	0.004	0.031	0.021	0.131	0.897	0.021	0.000	−.026	11.841	0.112

Table 1 continued

Meteorological variables	Unstandardised coefficients		Standardised coefficients	t	Sig. (95% confidence level)	Model summary				LINEST
	B	Std. error	Beta			R	R^2	Adjusted R^2	Std. error of the estimate	Rates of change per year
Total rainy days	−0.018	0.300	−0.010	−0.061	0.952	0.01	0.000	−0.026	11.843	−0.005
Seasonal changes: Spring										
Maximum temperature	5.211	1.303	0.544	3.999	0.000*	0.544	0.296	0.278	9.936	0.057
Minimum temperature	−1.577	2.433	−0.105	−0.648	0.521	0.105	0.011	−0.015	11.778	−0.007
Extreme maximum temperature	4.676	1.425	0.470	3.282	0.002*	0.47	0.221	0.200	10.454	0.050
Extreme minimum temperature	4.060	1.304	0.451	3.115	0.003*	0.451	0.203	0.182	10.570	0.047
Total precipitation	0.009	0.008	0.178	1.113	0.273	0.178	0.032	0.006	11.655	3.490
Total rainy days	−0.016	0.213	−0.012	−0.074	0.942	0.012	0.000	−0.026	11.842	−0.009
Seasonal changes: Summer										
Maximum temperature	10.837	1.771	0.705	6.119	0.000*	0.705	0.496	0.483	8.405	0.046
Minimum temperature	15.321	3.856	0.542	3.973	0.000*	0.542	0.293	0.275	9.955	0.019
Extreme maximum temperature	6.190	1.779	0.491	3.479	0.001*	0.491	0.242	0.222	10.314	0.038
Extreme minimum temperature	3.916	1.173	0.476	3.337	0.002*	0.476	0.227	0.206	10.415	0.057
Total precipitation	0.008	0.004	0.290	1.871	0.069	0.29	0.084	0.060	11.333	10.517
Total rainy days	0.538	0.612	0.141	0.879	0.385	0.141	0.020	−0.006	11.725	0.037
Seasonal changes: Autumn										
Maximum temperature	7.440	1.278	0.687	5.820	0.000*	0.687	0.471	0.457	8.611	0.063
Minimum temperature	0.964	4.423	0.035	0.218	0.829	0.035	0.001	−0.025	11.836	0.001

Table 1 continued

Meteorological variables	Unstandardised coefficients		Standardised coefficients	*t*	Sig. (95% confidence level)	Model summary				LINEST
	B	Std. error	Beta			*R*	R^2	Adjusted R^2	Std. error of the estimate	Rates of change per year
Extreme maximum temperature	7.224	1.666	0.575	4.336	0.000*	0.575	0.331	0.313	9.687	0.045
Extreme minimum temperature	4.412	2.242	0.304	1.968	0.056	0.304	0.092	0.069	11.283	0.021
Total precipitation	0.003	0.010	0.044	0.272	0.787	0.044	0.002	−0.024	11.832	0.721
Total rainy days	−0.269	0.303	−0.142	−0.887	0.381	0.142	0.020	−0.006	11.723	−0.075

*Statistically significant change at 95% as the value is <0.04

Source: Pandey 2016b

with the household heads of sampled households. The Guttman Scale and Scores (also called scalogram) are useful tools to measure attitudes and opinion in unipolar measurement (Hays and Ellickson 1990–1991; Abdi 2010; Blouin n.d.; encyclopaedia[7]). Therefore, the perceived climate change impacts in the last one decade were collected using a unipolar scalogram. The level of impacts was recorded and scored in a 1 to 5 scale (1 = little bit, 2 = moderate, 3 = high, 4 = severe, 5 = profound). Such face-to-face interviews with household heads lasted for about an hour.

Furthermore, the informants at FGDs and HTC discussions, KI interviews and Crop Calendar construction were the adult members (30 + years of age) of the communities, who were recognised as public figures or community leaders of different fields by the members of the respective communities. They were, in particular, the prominent farmers, executive members of resource management/user groups (such as forest, water supply, irrigation) and executive members of community-based disaster management committees. In the case of the HTC, the participants were the elderly members of the communities, who were mostly above the age of 60. The FGDs had 10 to 12 participants in general with some exceptionally larger groups of over 30 participants. Discussion in such a big groups lasted for about 3 h, while on smaller groups, it lasted for one and a half hours. Similarly, the HTC discussion and preparation of crop calendars lasted for an hour each in general. The author, together with three field assistants, graduated in social sciences, conducted field works for 10 days in Lumle. Primary data were collected in April 2013, and Nepali language was used in the field. Qualitative information was used to supplement household data. The qualitative information is narrated in the form of story-telling in the text whenever felt relevant.

To analyse quantitative data, each household was assigned a unique code and data were digitised into SPSS software. Such coding provided an opportunity to disaggregate data at the household level and re-aggregate at different categories as required for particular theme of analysis.

For the analysis, different levels of responses collected in a unipolar 1 to 5 scalogram were transformed into a single category to get the 'normalised responses'. The normalised response (percent) = (total score of actual response/total of the highest possible score) * 100 was used where the 'total score of actual response' refers to the cumulative score of the particular level of response from all the respondents (number of respondent * level of response); the 'total of highest possible score' denotes the total score of all the respondents if they have scaled their response to '5' in a particular question (total respondents multiplied by the highest score of 5), whereas 100 is the 'constant' applied to calculate percentile. The results are presented mostly in the form of charts using descriptive statistics. As this paper focuses on agro-ecological implications of climate change, the perceptions of respondents on climate change impacts are tested against social-demographic and economic variables of households using Chi-square test to identify the association among them.

4 Results and discussion

4.1 Means of living in Lumle

Rural Nepali households generally rely upon a range of on-farm and off-farm activities for livelihoods. So they sometimes puzzle outsiders. However, it is interesting to note that

[7] Viewed 22 September 2014 <http://www.encyclopedia.com/topic/Guttman_Scale.aspx#sthash.y1PaZjGs.dpuf>.

despite exploiting multiple sources of livelihood options and farming being contributing only for a small share of household livelihoods, rural Nepali households often report 'farming' (*Krishi*) as their principal occupation (Pandey 2016b). Farmland, hence, contributes little to the household livelihoods, yet the most people want to keep it as a safety net even if they are not practicing farming (Subedi et al. 2007a).

4.1.1 Occupational status of population

Figure 2 shows occupational status of households in Lumle. Among the options, a combination of cropping and livestock is adopted by 31.7% of population, while those engaged in activities supplying cash income such as foreign employment, wage labouring and business/entrepreneurship were 10.6, 9 and 8.2%, respectively. A significant part of the population (30.6%), mostly the young, are studying as well as helping with household chores. Although such help may not be accounted as an income-generating activity, engagement of students and minors in household chores is typical in Nepali rural households that makes it possible for working adults to allocate time for outdoor work and generate income or resources for household (Subedi et al. 2007b; Pun et al. 2009). The assistance these minors and students offer to the households makes a significant contribution to sustain agro-based livelihood systems in Lumle as well.

4.1.2 Land holding pattern, cropping intensity and irrigation

Inheritance practice in the country has given access to land to 70.6% of the country's households (CBS 2013). The proportion of households with land in Lumle is even higher (above 97% households), although majority of them are marginal (over 50%) and small holders (over 45%) with mean size of holding being 0.63 hectare and standard deviation of 0.56 ha. There is remarkable variation in land ownership pattern by gender of household heads that of the total, only 18.4% households has land registered under women's name. Such ownership is minimal in terms of size that over 70% women-headed households are marginal holders, while corresponding proportion of marginal holding men-headed household is less than 40%. Notwithstanding the predominance of owner–cultivator

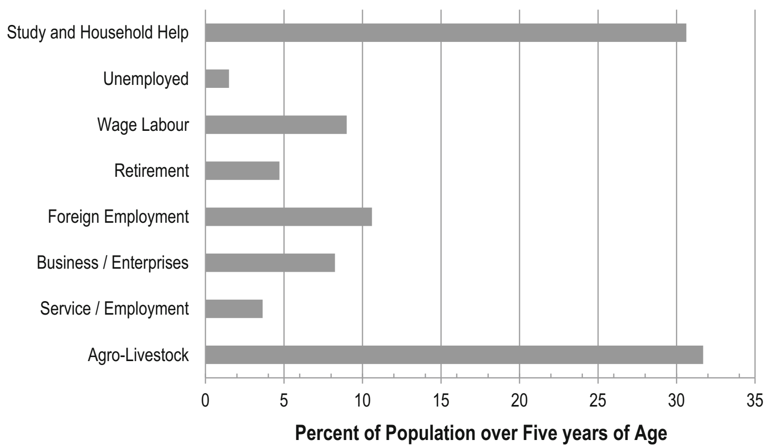

Fig. 2 Occupational status of population by type of occupation in Lumle, Nepal *Source*: Field Survey, 2013

household, complex tenancy arrangements are also common in Lumle, with 29.1% of households being landlords and 28.4% tenants. This indicates that most rental arrangements involve only part of a household's land.

The size of land available to households in the study area was generally insufficient to secure livelihoods through agro-based activities alone. The quality of land in terms of cropping intensity and availability of irrigation also affects farm outputs, and both are generally poor in Lumle, the former being relatively and latter profoundly weak. Cropping intensity of Lumle is 264.4% (two and a half crops) per year, while irrigation is minimal that less than 3% cultivated land has access to year-round irrigation.

Climate change is expected to increase the growing season in the high altitudes (Cruz et al. 2007). Some farmers of Lumle also reported such increase by a few days on an average. However, this increase is not sufficient for another crop, but the crops at higher altitudes are reaping earlier. Nevertheless, the households are not utilising all of the growing season due to the lack of irrigation on the one hand and decline in winter rainfall on the other. Furthermore, crop depredation by wildlife, higher wage of farm labour and poor farm output compared to the cost of farm input are other causes that are discouraging farmers to continue farming activities.

Since farming as a source of living is weak in Lumle, households are keeping some livestock and poultry. Livestock is a part of agriculture that forms integrated farming, and it is an integral part of crop farming in Nepali rural communities. Livestock such as cattle, buffaloes, goats, sheep, as well as poultry are an integral part of livelihoods in farming communities since they supply dairy and meat products for domestic consumption, manure for better farm production and earn cash through draught power. Selling livestock for cash is also a common coping strategy for rural poor households during periods of livelihood stress (Subedi and Pandey 2002; Davies et al. 2008). A lack of livestock can act to trap poor people in chronic poverty cycles (World Bank 2001; CPRC 2004). Of the total, 87.2% households of Lumle are keeping either only livestock or some poultry together. Buffaloes and oxen are the major types of livestock raised by the households. However, the number of livestock they are keeping is nominal. They are keeping 1.6 heads of buffaloes, 1.4 heads of goats, less than 1 head of cows and oxen and 4.1 heads of poultry.

Small size of landholding, poor irrigation and underutilisation of available cropping intensity as along with a few livestock have made households of Lumle poor. Their perception on household economy, however, is not that worse since there is a predominance of middle class (71.6%), followed by poor (17%) and upper-middle-class (8.5%) households. Few of the households reported themselves as affluent (only 1 household) or ultra-poor (3 households) out of the total 141 households.

Multiple occupations adopted by household members are positive aspects of household livelihoods in Lumle. They provide resilience if one income source fails. So far the discussion focussed above indicated weak, agro-livestock-based livelihood system in Lumle, so is further implicated by changing climate.

4.2 Agro-ecological implications of climate change

The changes in climate system have notably impacted agricultural ecological system of Lumle, and many of the respondents have perceived some of the primary and secondary impacts. A few of the visible and mappable impacts associated with various climatic elements observed by the respondents are discussed below.

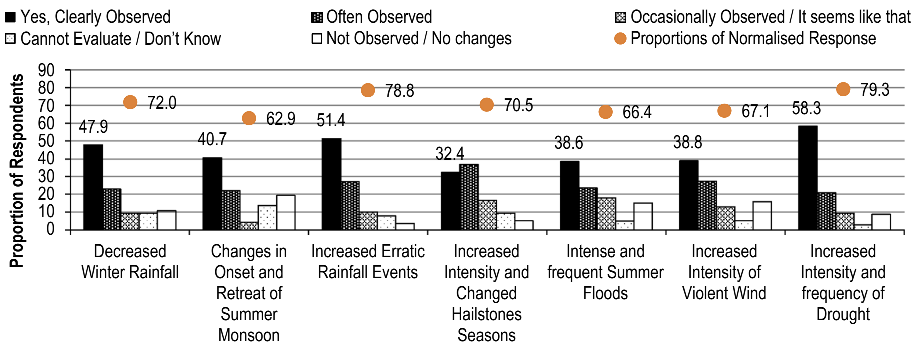

Fig. 3 Households perception on primary impacts of climate change in Lumle, Nepal *Source*: Field Survey 2013

4.2.1 Flood and landslides on farmland

Floods and landslides have seriously affected the agriculture of study area. Of the total, normalised proportion of 66.4% respondents perceived increased floods and landslide and associated implications into agricultural ecology in Lumle (Fig. 3). According to farmers, the frequency of floods is decreased; however, the intensity is increased that have put severe impacts. Among the different levels of perceived impacts, 38.6% of respondents expressed profound level of impacts of summer floods and landslides, while 23.6 and 17.9% respondents reported severe or high level of impacts. As stated by research participants, excessive flooding, landslides and soil erosion might have caused severe loss in farm production in Lumle as one study in Nigeria reported that 1 cm of soil loss caused a reduction in the yield of maize by 75% (Lal 1990).

Informants of HTC conducted in different locations in Lumle reported that floods and landslides have swept away a notable size of farmland and have killed a number of livestock in the last decade. According to them, the recent major floods were occurred in 2003, 2007 and 2011. Modikhola is the major river located in the western boundary of the village that damaged a large size of farmland that the FGD participants estimated a loss of over 800 Ropani[8] (nearly 40 ha) of farmland in those extremely wet years. All the flooded farmlands have been transformed into barren land, and no agricultural activities have been restored. The research participants emphasised that this involuntary landuse change has negatively implicated into agriculture and livelihoods of Lumle. The participants of FGD also mentioned that damages on drinking water and irrigation infrastructure, and houses and livestock sheds due to floods and landslides are common in each monsoon. The analysis of perception data indicated significantly increased extreme rainfall events of 50 and 150 mm per day in Lumle (Table 1), which also supports peoples' perception on increased summer floods and associated impacts in the study area.

4.2.2 Changed nature of rainfall and increased intensity of drought

Perceived impacts of changed nature of rainfall (changed onset of summer monsoon, increased erratic rainfall events and decreased winter rainfall) and increased intensity of

[8] *Ropani* is land measurement unit practice in the Middle-Mountains and in the Trans-Himalaya, 1 hector consists 20.7555 *Ropani.*

drought are presented in Fig. 3. The normalised proportion of 62.9% respondents reported an increase in negative impacts of changed onset and retreat of summer monsoon. The proportion of respondents who expressed profound level of impacts of changed onset and retreat of monsoon is 40.7%, while 22.1% respondents have evaluated the impacts being severe. The FGD participants reported delayed onset and early retreat of summer monsoon, although daily rainfall data analysis does not significantly support peoples' perception (Table 1). Rather, the onset of monsoon has become irregular that it is arriving early in some years, while it is late in other (Pandey 2016a). The farming households' perception is seemed to be shaped by recent phenomenon although in the last 4 decades, arrival date of summer monsoon at Lumle is deviated by a month.

People have also perceived increased impacts of erratic rainfall events as well in Lumle. Normalised proportion of 78.8% respondents reported increased impact of erratic rainfall events, while other 51.4, 27.1 and 10% respondents evaluated the impacts as being profound, severe and high. Meteorological data analysis also supports respondents' perception that there is a significant increase in erratic (extreme) rainfall events (Table 1). Furthermore, normalised proportion of over 70% respondents reported negative implications of decreased winter rainfall. Precipitation data analysis also shows decreased total rainy days in winter, although the change is not statistically significant. Out of the total respondents, 47.9% reported a profound level of negative implications of decreased winter rainfall in agriculture, while 22.9 and 9.3% respondents stated severe and high level of impacts, respectively.

Increased impacts of droughts are also reported by many respondents that proportions of households reporting the increase are about 80% (normalised proportion), followed by 58.3% reporting profound level of impacts. Other 20.9 and 9.4% respondents reported severe and high level of impacts of drought in agriculture of Lumle. The respondents also reported the changes in the nature of rainfall. The rainfall in the past used to be smooth and for a longer period that used to be facilitative to supply irrigation water. Rainfall events in these days were observed to be rain showers just for several minutes that create flash floods. Heavy surface run-off neither encourages infiltration and ground water recharge nor supports for irrigation systems. Rather, it harms agriculture and farming activities in many ways such as by flooding, siltation, erosion and by reducing the capacity of irrigation infrastructure as well as reduces the capacity of natural environment to provide ecosystem services.

The implications of droughts are neither small. Draught events of some 1–2 weeks are spelled even in monsoon period in recent years, reported the research participants of Lumle. Such dry periods in monsoon often affects rice transplantation, while pre-monsoon drought severely hits corn fields and rice seedling. The devastating impacts of climate change in agricultural ecology of the study area caused abandonment of a notable share of farmland (as of peoples' estimation, it goes over 70% of farmland in winter). The participants in FGDs also stated that:

> … there is no need of sowing seeds in winter as it cannot germinate in time because of moisture shortage in soil. No rainfall in November has affected sowing the winter crops, and heavy rain in February and March affected ready-to-harvest winter crops. In reality, the rain that helps crop production is decreased while that harms is increased…

This claim of research participants seems to be consistent with the result obtained from analysis of precipitation data that there is no specific trend of change in annual precipitation, but annual rainy days are decreased, inhibiting that heavy rainfall events are increased. Wheat and maize are the highly affected crops due to such irregularities in precipitation in the study area.

As households are withdrawing agriculture activities, the lands are transformed into barren land and are encouraged for natural growth of invasive species. The decrease in winter, spring and pre-monsoon rainfalls are reported to be the major causes of farmland abandonment, while labour migration has cyclical effect on farmland abandonment (Pandey 2017). Informants reported that winter rain, including snowing, is shifted to early-spring and post-monsoon rainfalls are extended to August through September. Also, the post-monsoon (autumn) rainfalls are becoming ever heavier. Although analysis of seasonal rainfall data does not strongly support these claims, there is conflicting information that few research participants also reported shrinking of monsoon period. The precipitation data analysis demonstrates irregularity in rainfall pattern in Lumle since there is no statistically significant trend in either direction (Pandey 2016a); respondents might have perceived and interpreted such nonlinear pattern variably. Yet, the implications of variable rainfall are complicated and wider than late eruption to early drying-up or reduced flow of natural springs, which is interfering traditional crop calendars together with secondary and tertiary effects in ecosystem services.

Farmers of Lumle often expect timely onset of summer monsoon. Therefore, they sow paddy seedling. However, as seedling get ready to transplant, delayed onset of monsoon causes maturity of seedling if not burned and died of drought. The matured seedling ultimately reduces production even if better rainfall is received in later period. Also freshly transplanted rice fields develop cracks due to drought, while heavy rainfall in September damages blooming rice. Furthermore, heavy as well as untimely/off-seasonal rainfall events are experienced throughout the year that has affected the agriculture of all seasons, and both no rain in cropping season and heavy rainfall during the crop blooming or harvesting seasons cause severe crop loss. This study also obtained the information that there is a detachment between crop calendar and rainfall calendar and farmers have not been successful to adjust them due to unfavourable cropping seasons on the one hand and experience of nonlinear weather pattern but not having reliable weather information on the other.

4.2.3 Thunder and hailstone, and violent wind

Perceived impacts of hailstone and violent wind are presented in Fig. 3 that the normalised proportion of 70.5% respondents reported increased impacts of hailstone. Among the total respondents, 32.4 and 38.8%, respectively, felt that the impacts of hailstone and violent wind increased drastically (profoundly), while 36.7 and 27.3% respondents reported the impacts of the same being severe, respectively. Community people reported the increased frequencies, intensity and off-seasonality of thunderbolts and hailstorms as well. The FGD participants identified thunderbolts induced death of 3 individuals and some 10–12 livestock in the last decade within such a small village of Lumle. According to them, thunderbolts often damage house electrification systems and on-plugged electrical and electronic devices. The causes behind such damage could be associated with not installing earthing devices in electrification process since informants reported that there is a lack of practice of installing earthing devices in rural electrification in the study area.

The FGD participants reported severe damage of crops due to excessive hailstones, and they estimate that maize, spring paddy, summer paddy, fruits and vegetables are affected the most and the loss of crops being more than 50% of expected total production in some years. In some exceptionally extreme cases, such as in 2008 and 2012, the hails have caused almost 90% loss of maize crop. The sizes of hailstones are so big that peal-out/remove the skin of tree barks. The farmers of Lumle also identified the changes in the pattern, seasonality and nature of precipitation, thunder and hailstorm, and wind storms, which in turn have remarkably implicated in agricultural ecology of the area. According to them, hailstones are occurring even in night time, in mid-winter and in monsoon season, which they claim that it is completely a new and abnormal phenomenon happening in recent years. They also stated that such events were used to be more predictable earlier. However, no predictable weather is observed in these years that challenged farmers to be proactive to reduce the losses.

4.2.4 Increased invasive species, upward shift of plant and changed plant phenology

Increase in invasive species, changes in the vegetation types and composition, emergence of new species, disappearance of old species and changes in plant phenology (changes in the flowering and fruiting season) are associated with changes in temperature and rainfall pattern and seasonality. Such changes in turn have both direct and indirect implications in agricultural ecosystem. The farming households (normalised proportions of 76.4%) of Lumle have experienced such impacts in their localities (Fig. 4). Among the total respondents, nearly three-fifths observed profound level of increase and their altitudinal extension of invasive species, while nearly one-fifth mentioned a severe level of changes. Respondents also reported the changes in plant phenology that some plants are flowering and fruiting some 2 weeks earlier particularly the Rhododendron (some 2–3 weeks earlier) together with fruits like peach, pear, apricot, mangoes, *kafal* (*Myrica esculenta*), *aaiselu* (*Rubus ellipticus*). The respondents referred the changes in precipitation (moisture) condition and warming in temperatures as the factors leading to changes in plant phenology. However, early flowering events are mostly unsuccessful or partially successful (flowering but not fruiting, or reduced the quantity and quality of fruits/flowers), reported the research participants.

The impacts of climate change on agricultural ecology are also associated with the increase in invasive species. According to them changes in weather pattern in general have facilitated emergence of several kinds of new weeds in farmland and in the forest as well as in grazing lands. One of the widely reported invasive species of Lumle is *Banmara*

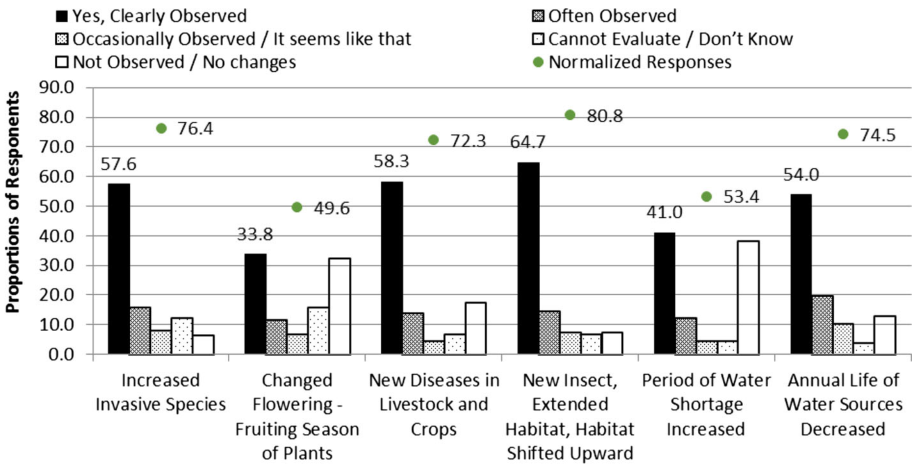

Fig. 4 Households perception on secondary impacts of climate change in Lumle, Nepal *Source*: Field Survey 2013

(*Mikania micrantha*), together with farm weeds like *Nilogandhe* (*Ageratum houstonianum*) and *Aalupate* (scientific name unknown). Apart from the impacts of farm weeds in farm production, research participants also reported decline production (natural growth and opportunity for harvest) of high-valued medicinal and aromatic plants (MAPs) such as *Chiraito* (*Swertia chirayita*), *Panchaunle* (*Datylorhiza hatageria*) and *Satuwa* (*Paris polyphylla*) in the forest of Lumle area. The respondents assume that the causes are abundant expansion of invasive species, particularly *Banmara*. According to the farmers, the growth of invasive species is also promoted informally by nature conservation programmes such as Annapurna Conservation Area Project (ACAP) and community forestry since they notably reduced human interventions in the forest that would have controlled invasive species. These programmes together with changing climate encouraged for rapid spread of invasive species which have notably influenced agro-livestock activities in Lumle. Although there is no research evidences in Nepal on how conservation programs have contributed for biodiversity conservation, as of the opinion of the respondents of Lumle, and few literature reporting the same, it is understood that conservation programme is mostly interested in forest biodiversity, which in turn caused notable erosion in agricultural biodiversity in Lumle (Bardsley and Thomas 2005).

The respondents further reported reduced availability of quality fodder and forage for herbivores wildlife due to increased invasive species in the forest. As a result, crop depredation of wild animals has been increased. The reduced availability of quality fodder also caused a notable reduction in livestock population in Lumle. Since climate change influences the geographical distribution and growth of plant species and the magnitude would vary depending on the growth pattern of species such as annuals vs perennials; and agricultural crops vs natural vegetation (Coakley et al. 1999), the impacts on managed system such as agro-ecology will depend largely on households' ability to use available knowledge, technology and financial resources to control negative implications. In the context of poor ability of rural households of Lumle to respond the climate change impacts (Pandey and Bardsley 2015), they are suffering from a heavy loss.

4.2.5 Crops and livestock diseases, emergence of new insects and changed habitat

New diseases including the pests and extended habitat (both seasonal and spatial) of insects and disease vectors in livestock and crops with the course of climate change are expected to increase (Parry et al. 1999; Howden et al. 2007; Rosenzweig 2011; Ramirez-Villegas et al. 2012). Such changes often negatively implicate into agro-livestock system, and the respondents of study area (normalised proportion of 80.8%) have reported such impacts. Among the total, 64.7% respondents observe extreme or profound level of increase in insect population and their changed habitats. The proportions of respondents who perceived the problem being severe and high are nearly 14 and 9%, respectively (Fig. 4). Farmers of Lumle think that increase in farm bugs, insects and disease vectors is due to warming, decreased and changed seasonality of rainfall. As the increase in maximum temperature in all seasons is significant in Lumle (Table 1), farmers' claim might be true in this regard. In addition, the respondents at the FGD reported that they have observed shift in winter precipitation towards spring season, which maintained warmer weather in winter and increased moisture supply in spring. Such weather conditions might have facilitated insects to be survived in winter and start reproductive process early in the spring. Consequently, the problems of insects and disease vector exist throughout the year in the study area. These insects and disease vectors are causing a number of diseases on crops and livestock and loss of agricultural production in turn.

The farming households of Lumle also reported increased incidents of crop–livestock diseases and associated loss in the production of various crops and vegetables as well as of livestock. Although farmers claimed that they do not use agro-chemicals because they produce only for household consumptions and are aware of health risk of agro-chemicals, they also stated that it is almost impossible to maintain even a minimum level of production without using agro-chemicals. Farmers have been using livestock medicine frequently because of livestock diseases. Yet, spread of livestock diseases is not only facilitated by the changes in climate system. Rather, some greedy and unethical slaughter is utilising poor quarantine mechanism of the country, Nepal as a profit-making window. An agro-livestock technician at Lumle Agriculture Centre (LAC) shared a case of spread of livestock disease in Lumle few years ago that claimed a score of livestock:

> "… *Bhyakute* disease (Haemorrhagic septicaemia) in livestock in Lumle originated from the illegal slaughter of infected animals in the village. It was the incident of some 15 years ago when *Bhyakute* killed 70 to 80 livestock within Lumle area. An investigation afterwards unveiled the facts that some vendors were carrying live male buffaloes from India to Baglung (a city located some 40 km west of Lumle and the road passes through Lumle). While transporting, one of the male buffalo died of *Bhyakute*. The vendors slaughtered the dead animal in the nearby bushland and sold the meat in local shops. Further, they left the remains of the slaughter of infected buffalo in open bushland, the disease vector find way to animals from water, fodder and forage. This led to a rapid diffusion of disease throughout the village and the farmers suffered a heavy loss. After the incident, the disease has not been fully controlled yet. The livestock get sick often and if not cured on time, they die. The transportation induced spread of disease vectors is common on human health problems as well that expansion of mosquitoes and other farm insects, as well as invasive species are also brought to the place (unintentionally) but climate change, particularly warming, is facilitating for their adaptability. We did not had mosquitoes here in Lumle before the opening of Pokhara-Baglung Highway. …".

Some of the other reported impacts of increased insects and disease vectors in Lumle are fungal disease in potato farms, *rate* (local name that makes paddy red and die) in paddy fields and increase in various kinds of bugs (stink bug, big horns bug) in fruits and crops (they mostly harm citrus fruits and paddy). Research participants also informed the increase in insect population and associated impacts on farm production: increase in some harmful ants, various kinds of moths and leach, various kinds of caterpillars and worms (cutworms/tent caterpillars—*Khumrekira*), all harm root roots, leaf/bud and steam of vegetables and crops. Many kinds of grass hoppers and aphids damage leafy vegetables and crops, while wood ants (white, red, brown) harm the roots and steams of sugarcane and maize. Diseases like phytophthora (fungal-*Laikira*) in lettuce, legumes, mustard, cabbage, broccoli, cauliflower and other leafy vegetables have also harmed their production in Lumle. Furthermore, insects like snail (*Sankhekira*) and slug (*Chiplekira*) that damage valuable vegetables by their slime are increased dramatically in the last decade, reported the research participants. One of the prominent farmers of Lumle also described the death of 10–12 livestock in the last decade after being infected of '*Khadke*', a communicable livestock disease. *Namle*, *Juka* (abdominal parasites/worm) and *Bhyakute* (Haemorrhagic septicaemia) in livestock have also become common in Lumle in recent years. Increased crop–livestock diseases and disease vectors led to an increase in production cost and in turn reduced the output from farming occupation. All of these are causing agriculture to be a deficit business. In this regard, farmers feel themselves suppressed by climate change impacts and they are increasingly abandoning agro-livestock-based occupation.

4.2.6 Decreased annual life of water sources and increased duration of water shortage

The term 'annual life of water sources' is used to refer decreased flow size and reduced duration of flow (used to flow for longer period/throughout the year but drying-up in few months in recent years). Studies have already suggested growing water scarcity in terms of supply, storage and access in South Asia (Winiger et al. 2005; Rees and Collins 2006; Kehrwald et al. 2008; Sullivan 2011). Agro-ecological impacts of and implications to ecosystem services of decreased annual life of water sources, particularly associated with reduced rainfall, variable seasonal distribution of rainfall and drought, are immense and complex. A majority (over a half of the total) of respondents of Lumle reported increased duration of water shortage and associated impacts on agro-livestock system (Fig. 4). Among the total, 41% respondents felt a dramatic shortage (profound) of water, while one-tenth respondents conveyed severe level of water shortage that has negatively implicated into farm production. In addition, almost three-fourths of the total respondents observed notably decreased annual flow, in terms of both size and duration, of natural springs. The survey results illustrated that 54% of the total respondents reported profoundly decreased annual life of water sources, while one-fifth and one-tenth felt the problem being severe and high. The respondents think that the causes are associated with reduced rainfall and rainy days, particularly in the winter. The analysis of meteorological data also shows decreased rainy days (Table 1) except in summer (the monsoon period) and also justifies that peoples' perception is fairly correct. The most recent trend of rainfall and rainy days (2002–2012) shows declined rate except in few exceptionally wet years such as 2004, 2008 and 2011 (Pandey 2016a). This recent phenomenon might have influenced peoples' perception on declined rainfall and rainy days. Respondents reported the changes in water availability and reduced moisture conditions have remarkably affected rice cultivation, sowing of winter crops, maize and production of off-seasonal vegetable. Studies from other parts of Nepal have also reported that the extended length of the dry season in the last two decades has reduced agricultural production and altered other aspects of life in the country (Chhetri and Easterling 2010; Devkota et al. 2011; Macchi 2011; Manandhar et al. 2011; Gentle and Maraseni 2012). Due to drought, Nepal experienced a deficit of agricultural production by 22,000 metric tones in 2005/2006 and 180,000 metric tones in 2006/2007 (Aryal and Rajkarnikar 2011). The situation of Lumle is fairly consistent.

This paper investigated the association of respondents' perception on different impacts with various household characteristics using Chi-square test. The observed p value of many of the impacts in association with various social-demographic and economic variables (age, gender, caste/ethnicity, perceived economic status, land holding, and the share of livelihood of agro-livestock activity and of remittance) of respondents is higher than the expected p value of 0.05. This indicates that the impacts of climate change, as perceived by respondents, are not significantly associated with their social-demographic and economic status. However, few of the impacts are observed to be significantly associated with the age of respondent: perception on impacts of 'drought' ($p = 0.076$) and 'decreased annual life of water' ($p = 0.071$) at 90%, with the size of landholding of household: decreased winter rainfall ($p = 0.035$), increased intensity and changed hailstone season ($p = 0.001$), and new insects and extended habitat of insects ($p = 0.026$) at 95%. Similarly, the impacts such as changes in onset and retreat of summer monsoon ($p = 0.048$), increased intensity of violent wind ($p = 0.043$) and increased intensity and frequency of drought ($p = 0.049$) are also significantly associated at 95% with the share of livelihood contribution of agro-livestock activity, while impacts such as changes in onset and retreat of summer monsoon ($p = 0.000$) are perfectly associated and increased intensity of violent wind ($p = 0.067$) is significantly associated at 90% with the share of livelihood contribution of remittance. As the implications of climate change in the agricultural ecology of Lumle are extensively discussed and severe impacts were identified, the livelihood implications of climate change-induced agro-ecological change are discussed below.

4.3 Implications in existing livelihood systems: changes in livelihood options and their share of contribution on household livelihoods

Changing occupation, particularly unskilled and semi-skilled individuals, often takes place when the existing livelihood option is not enough to meet the livelihood needs. Studies on the Himalayan livelihoods have demonstrated that many households have changed their livelihood options over time (Subedi and Pandey 2002; Subedi et al. 2007b; Onta and Resurreccion 2011). However, the process of change is challenging, especially for poor households and unskilled individuals because they lack the minimum financial resources or the skills required to shift to a new option. Among the changes, normalised proportion of 26.1% households of Lumle have changed occupations over last decade. Among the households who changed their previous occupation, quite a little (1.4% households) have changed it completely, while one-fifth of household changed a major portion of previous occupation. Of the total, 13.8% households moderately changed (or they are running two occupation parallel) and little over one-tenth households partially adopted new occupations. This change is often directed towards employment, entrepreneurship and foreign employment. As a result of the change in occupation, livelihood contribution of traditional agro-livestock based is decreasing, while the contribution of the cash-based occupations is increasing in Lumle.

Table 2 shows the proportion of households who experienced the changes in contribution of different livelihood activities in household livelihoods. During the last decade (2002–2012), about a quarter of households experienced a reduction in the livelihood contribution of agro-livestock activity by 25%, while another 13 and 7% households

Table 2 Proportions of households with changed share of livelihood contribution of different sectors in Lumle, Nepal, in the last decade (2002–2012)

Changed proportions	Agro-livestock	Employment	Business/enterprises	Remittance	Wage labour
− > 75%	2.84	1.42	0.00	1.42	0.00
−50 and 75%	7.09	1.42	1.42	0.00	1.42
−25 and 50%	13.48	3.55	0.00	3.55	4.26
− Up to 25%	24.11	2.13	2.13	5.67	5.67
+ Up to 25%	6.38	5.67	4.96	9.93	7.80
+ 25 and 50%	2.13	4.26	4.96	14.18	2.84
+ 50 and 75%	0.71	0.00	1.42	7.09	0.71
+ Over 75%	0.71	1.42	3.55	4.26	0.71

Source: Calculated from Field Survey Data 2013 experienced a reduction of up to 50 and 75%, respectively. This reduction in livelihood contribution of agro-livestock activity is primarily substituted by remittance that almost 10% households increased the livelihood contribution of remittance by 25%. The proportion of household who derived up to 50% of livelihood resource from remittance is increased by little over 14% and other 7.1% household maintain up to 75% of livelihoods from remittance. There are a few households (4.3%) in Lumle whose dominant source of livelihood, i.e. over 75% of the total requirement, is remittance. These data clearly demonstrated that agro-livestock-based livelihoods of Lumle have been changing rapidly to the remittance-based. Therefore, strategies such as ecosystem-based adaptation to climate change have been neglected in Lumle (Pandey 2016b). The farmland abandonment associated with climate change impacts and increased opportunities for foreign labour migration is only the representative cause of Lumle since other studies also indicated that the problem of land abandonment has been becoming severe across the mountain region of Nepal (Khanal and Watanabe 2006; Åse et al. 2010; Poudel et al. 2014). Along with increased contribution of remittance, the share of other sources of cash income such as employment and petty business is also increasing, while the role of wage labour locally (mostly used to be farm-based) is decreasing in Lumle.

5 Conclusion

An extensive review of the literature by the IPCC shows that none of the systems in the globe remained ‘unaffected’ by the global climate change (IPCC 2014) although the impacts are unevenly distributed and they are biased to low-income societies. None of the ecological problems are solely the ecological. The impacts of changing climate in agricultural ecology are also determined by the socio-political and economic institutions at micro-, meso- and macro-levels. Poverty and inadequate capacity of Nepali state mechanisms to respond to climate change impacts in agriculture have caused the country in general, and the study area in particular suffers from severe effects of the change. This study documented perceived impacts of climate change in agricultural ecology. The identified impacts are the damage of farmland and crops by floods, landslides, reduced farm output due to drought, scarcity of water, changed nature and season of rainfall, as well as increased crop losses from storms and hailstones. Furthermore, losses of agro-biodiversity and forest ecosystem due to invasive species, increased crops and livestock diseases and insects as well as abandonment of farmland have also reduced agricultural production. Similarly, early flowering and early ripening of fruits and crops have reduced the quantity and quality of fruits and cereals. In such context, young generations are reluctant to adopt agro-livestock activity labelling it dirty and degraded and not-for-profit occupation. They are, rather, willing to adopt labour migration strategy to meet the household need.

In addition, the change in monsoon characteristics is leading to reduced infiltration and groundwater recharge. Rather it is creating severe flash floods on the one hand and reducing the annual life of natural springs on the other. Such changes have reduced the irrigation potentials in turn, further leading to decrease in agricultural output and sustaining mountain ecosystem services. Increased crop pests and diseases, and farm weeds due to increased drought and reduced water availability, as well as increase in extreme rainfall events are cumulatively affecting farm production of Lumle. These findings are consistent to the existing literature (Chhetri and Easterling 2010; Ghimire et al. 2010; Gentle et al. 2014; Palazzoli et al. 2015) as well.

Ferede et al. (2013) estimated that a 3.26 °C increase in temperature and 12.02 mm decline in precipitation result in 9.71% loss in crop production in Ethiopia and such loses are even higher in poor households. The rates of changes in climate system of Nepal are even serious based on both observed and perceived warming and changes in precipitation. The domination of poor and marginal holding farmer and a major loss of farm production due to negative effects of climate change are encouraging farmers to abandon the farmland at first and agro-livestock activities later. This has ultimately damaged rich agricultural ecological system of Lumle.

Since climate change adds a new layer of complexity and uncertainty into a (agro-ecological) system (Coakley et al. 1999), the agro-ecosystem of Lumle is already exceedingly at the difficulties of management on a sustainable basis because of technological, environmental and socio-economic limitation of the community and the country. However, despite the suffering of agricultural ecology of the study area from climate change-induced impacts, and the case being representative to a wider spatial context of Middle-Mountains of Nepal, adaptation policies of Nepal have not yet recognised the importance of agricultural ecology to achieve the goal of zero hunger by 2030. Evidence is that thousands of youths are flocking towards international labour markets although such opportunities are poorly paid, unsustainable, and are highly exploitative as well as abusive together with many cascading effects in social and agro-ecological system of the country (Pandey and Adhikari 2013; Pandey and Bardsley 2013). In such context, Nepal must urgently design and implement an agricultural policy that integrates the issues of labour migration and landuse plan to promote ecosystem-based adaptation to climate change by controlling the process of farmland abandonment and providing incentives to repair and restore the damaged agricultural ecology of the country. This can be done through providing incentives to those youths who continue agricultural works rather than pork barrelling the youth unemployment fund by the political parties in power. In addition, government should invest in agricultural infrastructure rather than political infrastructure such as constructing office buildings for political parties and memorial gates of the leaders. The international labour migration of unskilled youths can be reduced through strong monitoring if aspiring youth has higher productivity abroad than within the country due to lack of land holding in the household. Or in other words, going abroad for labour work by abandoning farmland should be discouraged.

Acknowledgements The data used in this paper were collected under author's Ph. D. research project at the University of Adelaide, Australia. The university is acknowledged for financial support for field work. I would like to acknowledge Pokhara University Research Centre for providing me Faculty Research Grant (03/2072/73) to conduct this part of analysis. My friends Pawan Chitrakar and Ram Prasad Sharma and my students Kamal Singh Thapa, Dharma Raj Parajuli and Deependra Pandit are remembered here for their help during the field work. My colleague Bharat Raj Dhakal for thoroughly reading the manuscript and identifying language-related issues and Ananta Raj Dhungana for helping me to perform statistical tests are also acknowledged. I would also like to acknowledge the anonymous reviewers of the paper and the editors of the journal for their munificent comments in the manuscript.

References

Abdi, H. (2010). Guttman scaling. In N. Salkind (Ed.), *Encyclopaedia of research design*. Thousand Oaks, CA: Sage.

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

Adger, W. N. (2010). Climate change, human well-being and insecurity. *New Political Economy, 15*(2), 275–292. doi:10.1080/13563460903290912.

Aggarwal, P. K., & Sivakumar, M. V. K. (2011). Global climate change and food security in South Asia: An adaptation and mitigation framework. In R. Lal, M. V. K. Shivakumar, S. M. A. Faiz, A. H. M. M. Rahman, & K. R. Islam (Eds.), *Climate change and food security in South Asia* (pp. 253–277). Dordrecht: Springer Netherlands. doi:10.1007/978-90-481-9516-9_16.

Aryal, R. S., & Rajkarnikar, G. (Eds.) (2011). *Water resources of Nepal in the context of climate change*, Water and Energy Commission Secretariat (WECS), Government of Nepal, viewed 27 May 2015. http://assets.panda.org/downloads/water_resources_of_nepal_final_press_design.pdf.

Åse, T. H., Chaudhary, R. P., & Vetås, O. R. (2010). Farming flexibility and food security under climatic uncertainty: Manang, Nepal Himalaya. *Area, 42*(2), 228–238.

Barbier, B., Yacouba, H., Karambiri, H., Zoromé, M., & Somé, B. (2009). Human vulnerability to climate variability in the Sahel: Farmers' adaptation strategies in northern Burkina Faso. *Environmental Management, 43*(5), 790–803.

Bardsley, D. K., & Thomas, I. (2005). In situ agrobiodiversity conservation for regional development in Nepal. *GeoJournal, 62,* 27–39. doi:10.1007/s10708-004-1941-2.

Berreman, G. D. (1972). *Hindus of the Himalayas: Ethnography and change*. Delhi: Oxford University Press.

Bhatta, L. D., van Oort, B. E. H., Stork, N. E., & Baral, H. (2015). Ecosystem services and livelihoods in a changing climate: Understanding local adaptations in the Upper Koshi, Nepal. *International Journal of Biodiversity Science, Ecosystem Services & Management, 11*(2), 145–155. doi:10.1080/21513732.2015.1027793.

Blouin, D. C. n.d. Guttman scale analysis, viewed 27 May 2015. http://www.sascommunity.org/sugi/SUGI80/Sugi-80-82%20Blouin.pdf. pp. 444–447.

Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change, 15*(2), 151–163. doi:10.1016/j.gloenvcha.2004.12.006.

CBS. (2013). *National sample census of agriculture, Nepal 2011/12, National Report*. Kathmandu: GoN/NPC/CBS.

Cervantes-Godoy, D., & Dewbre, J. (2010). Economic importance of agriculture for poverty reduction. *OECD Food, Agriculture and Fisheries Working Papers*, No. 23, OECD Publishing. doi: 10.1787/5kmmv9s20944-en.

Chapagain, B., & Gentle, P. (2015). Withdrawing from agrarian livelihoods: Environmental migration in Nepal. *Journal of Mountain Science, 12*(1), 1–13. doi:10.1007/s11629-014-3017-1.

Chaudhary, R. P., Åse, T. H., & Vetås, O. R. (2007). Globalization and peoples' livelihoods: Assessment and prediction for Manang, Trans-Himalaya, Nepal. In R. P. Chaudhary, T. H. Åse, O. R. Vetås, & B. P. Subedi (Eds.), *Local effects of global changes in the Himalayas: Manang* (pp. 1–22). Nepal: Tribhuvan University Nepal and University of Bergen Norway.

Chaulagain, N. P. (2006). Impacts of climate change on water resources of Nepal: The physical and socioeconomic dimensions. Ph. D. Thesis, (Dissertation Zur Erlangung des Grades: Doktor der Wirtschaftswissenschaften (Dr. rer. Pol.) an der Universität, Flensburg.

Chhetri, N. B., & Easterling, W. E. (2010). Adapting to climate change: Retrospective analysis of climate technology interaction in the rice-based farming system of Nepal. *Annals of the Association of American Geographers, 100*(5), 1156–1176.

Ciais, P., Carrara, A., Chevallier, F., De Noblet, N., Friend, A. D., Friedlingstein, P., et al. (2005). Europe-wide reduction in primary productivity caused by the heat and drought in 2003. *Nature, 437*(7058), 529–533. doi:10.1038/nature03972.

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

CPRC. (2004). The chronic poverty report 2004–05. Manchester, UK: Chronic Poverty Research Centre (CPRC), Institute for Development Policy and Management, University of Manchester.

Cruz, R. V, Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C., & Ninh, N. H. (2007). Asia. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C. E. Hanson (Eds.), *Climate change 2007: Impacts, adaptation and vulnerability* (pp. 469–506), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, UK: Cambridge University Press.

Dahal, N., Ojha, H., Baral, J., Branney, P., & Subedi, R. (2009). *Impact of climate change on forests and livelihoods: issues and options for Nepal*. Kathmandu: DFID Livelihood Forestry Programme.

Darwin, R. (2001). Climate change and food security. *Agriculture Information Bulletin, 765*(8), 1–2.

Davies, M., Guenther, B., Leavy, J., Mitchell, T., & Tanner, T. (2008). Adaptive social protection: Synergies for poverty reduction. *IDS Bulletin, 9*(4), 105–112.

Devkota, R. P., Bajracharya, B., Maraseni, T. N., Cockfield, G., & Upadhyay, B. P. (2011). The perception of Nepal's Tharu community in regard to climate change and its impacts on their livelihoods. *International Journal of Environmental Studies, 68*(6), 937–946. doi:10.1080/00207233.2011.587282.

Ferede, T., Ayenew, A. B., & Hanjra, M. A. (2013). Agroecology matters: Impacts of climate change on agriculture and its implications for food security in Ethiopia. In Hanjra, M. A. (Ed.), *Global food security: emerging issues and economic implications* (pp. 71–111). New York, NY, USA: Nova Science Publishers (Global Agriculture Developments).

Gaba, S n.d., The SFE thematic group 'Agricultural ecology' proposes a context and a focus for this topic, Viewed on 14/7/2017 (https://sfecologie2016.sciencesconf.org/conference/sfecologie2016/agricultural_ecology_thematic.html).

Gentle, P., & Maraseni, T. N. (2012). Climate change, poverty and livelihoods: Adaptation practices by rural mountain communities in Nepal. *Environmental Science & Policy, 21,* 24–34.

Gentle, P., Thwaites, R., Race, D., & Alexander, K. (2014). Differential impacts of climate change on communities in the middle hills region of Nepal. *Natural Hazards, 74,* 815–836. doi:10.1007/s11069-014-1218-0.

Ghimire, Y. N., Shivakoti, G. P., & Perret, S. R. (2010). Household-level vulnerability to drought in hill agriculture of Nepal: Implications for adaptation planning. *International Journal of Sustainable Development and World Ecology, 17*(3), 225–230.

Grasso, M., & Feola, G. (2012). Mediterranean agriculture under climate change: Adaptive capacity, adaptation, and ethics. *Regional Environmental Change, 12*(3), 607–618.

Hays, R. D., & Ellickson, P. L. (1990–1991). Guttman scale analysis of longitudinal data: Methodology and drug use applications. *The International Journal of Addictions, 25*(11A), 1341–1352.

Hocking, P. J., & Meyer, C. P. (1991). Carbon dioxide enrichment decreases critical nitrate and nitrogen concentrations in wheat. *Journal of Plant Nutrition, 14,* 571–584.

Holly, P. J., David, G. H., & Erika, S. Z. (2012). Harnessing nature to help people adapt to climate change. *Nature Climate Change, 2*(7), 504–509. doi:10.1038/nclimate1463.

Howden, S. M., Soussana, J.-F., Tubiello, F. N., Chhetri, N., Dunlop, M., & Meinke, H. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences of the United States of America (PNAS), 104*(50), 19691–19696. doi:10.1073/pnas.0701890104.

Hulme, M. (Ed.). (1996). *Climate change and Southern Africa*. Norwich, United Kingdom: University of East Anglia, Climatic Research Unit.

IPCC. (2007). *Climate change 2007: Impacts, adaptation and vulnerability, summary for policymakers.* Geneva: Working Group II Contribution to the Intergovernmental Panel on Climate Change, Fourth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC Secretariat.

IPCC. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation.* A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change, [C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor & P. M. Midgley (Eds.)], Cambridge, UK: Cambridge University Press.

IPCC. (2013). Summary for policy makers. In T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P. M. Midgley (Eds.), *Climate change 2013: The physical science basis,* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, UK.

IPCC. (2014). Summary for policymakers. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea & L. L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability.* Part A: Global and Sectoral Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pp. 1–32.

Kehrwald, N. M., Thompson, L. G., Tandong, Y., Mosley-Thompson, E., Schotterer, U., Alfimov, V., et al. (2008). Mass loss on Himalayan glacier endangers water resources. *Geophysical Research Letters, 35*(22), L22503. doi:10.1029/2008GL035556.

Khanal, N. R., & Watanabe, T. (2006). Abandonment of agricultural land and its consequences. *Mountain Research and Development, 26*(1), 32–40.

Lal, R. (1990). *Soil erosion in the Tropics: Principles and management*. New York: McGraw-Hill.

Lal, M. (2011a). Implications of climate change in sustained agricultural productivity in South Asia. *Regional Environmental Change, 11*(1), 79–94. doi:10.1007/s10113-010-0166-9.

Lal, R. (2011b). Adapting to climate change: Research and development priorities. In R. Lal, M. V. K. Shivakumar, S. M. A. Faiz, A. H. M. M. Rahman, & K. R. Islam (Eds.), *Climate change and food* *security in South Asia* (pp. 587–596). Dordrecht: Springer Netherlands. doi:10.1007/978-90-481-9516-9_35.

Macchi, M. (2011). *Framework for community-based climate vulnerability and capacity assessment in mountain areas*. Kathmandu, Nepal: International Centre for Integrated Mountain Development (ICIMOD).

Manandhar, S., Vogt, D. S., Perre, S. R., & Kazama, F. (2011). Adapting cropping systems to climate change in Nepal: A cross-regional study of farmers' perception and practices. *Regional Environmental Change, 11,* 335–348. doi:10.1007/s10113-010-0137-1.

McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & White, K. S. (Eds.) (2001). *Climate change 2001: Impacts, adaptation and vulnerability*, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

McLeman, R., & Smit, B. (2006). Migration as an adaptation to climate change. *Climatic Change, 76*(1), 31–53. doi:10.1007/s10584-005-9000-7.

Mendelsohn, R., Basist, A., Kurukulasuriya, P., & Dinar, A. (2007). Climate and rural income. *Climatic Change, 81,* 101–118.

Oh-e, I., Saitoh, K., & Kuroda, T. (2007). Effects of high temperature on growth, yield and dry-matter production of rice grown in the paddy field. *Plant Production Science, 10*(4), 412–422. doi:10.1626/pps.10.412.

Onta, N., & Resurreccion, B. P. (2011). The role of gender and caste in climate adaptation strategies in Nepal: Emerging change and persistent inequalities in the far-western region. *Mountain Research and Development, 31*(4), 351–356. doi:10.1659/mrd-journal-d-10-00085.1.

Oxfam, (2009). *Even the Himalayas have stopped smiling: Climate change, poverty and adaptation in Nepal*. Patan, Nepal: OXFAM.

Palazzoli, I., Maskey, S., Uhlenbrook, S., Nana, E., & Bocchiola, D. (2015). Impact of prospective climate change on water resources and crop yields in the Indrawati basin, Nepal. *Agricultural Systems, 133,* 143–157. doi:10.1016/j.agsy.2014.10.016.

Pandey, R. (2016a). Dynamics of the Himalayan climate: A study of the Kaligandaki Basin, Nepal. *Pertanika Journal of Social Sciences and Humanities, 24*(2), 737–756.

Pandey, R. (2016). Human ecological implications of climate change in the Himalaya: Investigating opportunities for adaptation in the Kaligandaki Basin, Nepal. Ph. D. Thesis, The University of Adelaide, School of Social Sciences. Available at: http://hdl.handle.net/2440/99095.

Pandey, R. (2017). Adaptation efforts to climate change and migration pattern in the Himalaya: A study of Kaligandaki Basin, Nepal. *Applied Geography* (paper under review).

Pandey, R., & Adhikari, R. (2013). *Nepalese migrant women worker and their socio-spatial exclusion: A study of Pokhara Valley*. Unpublished research report submitted to University Grants Commission, Nepal.

Pandey, R. & Bardsley, D. K. (2013). Human ecological implications of climate change in the Himalaya: Pilot studies of adaptation in agro-ecosystems within two villages from Middle-Hills and Tarai, Nepal. In *Proceeding of Impacts World 2013, International Conference on Climate Change Effects*, Potsdam, May 27–30. Accessed 20 January 2015 from http://www.climate-impacts-2013.org/files/wism_pandey.pdf.

Pandey, R., & Bardsley, D. K. (2015). Social-ecological vulnerability to climate change in the Nepali Himalaya. *Applied Geography, 64,* 74–86.

Parry, M. L., Rosenzweig, C., Iglesias, A., Fischer, G., & Livermore, M. (1999). Climate change and world food security: A new assessment. *Global Environmental Change, 9,* S51–S67. doi:10.1016/s0959-3780(99)00018-7.

Parry, M. L., Rosenzweig, C., & Livermore, M. (2005). Climate change, global food supply and risk of hunger. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences, 360*(1463), 2125–2138. doi:10.1098/rstb.2005.1751.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. Newbury Park, California: Sage Publications.

Paudel, B., Acharya, B., Ghimire, R., Dahal, K., & Bista, P. (2014a). Adapting agriculture to climate change and variability in Chitwan: Long-term trends and farmers' perceptions. *Agricultural Research, 3*(2), 165–174. doi:10.1007/s40003-014-0103-0.

Paudel, K. P., Tamang, S., & Shrestha, K. K. (2014b). Transforming land and livelihood: Analysis of agricultural land abandonment in the Mid Hills of Nepal. *Journal of Forest and Livelihood, 12*(1), 11–19.

Pruneau, D., Lang, M., Barbier, P.-Y., Kerry, J., Mallet, M.-A., Freiman, V., et al. (2012). The competencies demonstrated by farmers while adapting to climate change. *International Research in Geographical and Environmental Education, 21*(3), 247–259. doi:10.1080/10382046.2012.698085.

Pun, D. P., Subedi, B. P., Pandey, R., & Pokhrel, S. (2009). *Social change and the senior citizen in Nepal: Their socio-spatial exclusion*. Unpublished research report submitted to Social Inclusion Research Fund (SIRF), Kathmandu.

Ramirez-Villegas, J., Salazar, M., Jarvis, A., & Navarro-Racines, C. E. (2012). A way forward on adaptation to climate change in Colombian agriculture: Perspectives towards 2050. *Climatic Change, 115*(3–4), 611–628. doi:10.1007/s10584-012-0500-y.

Rees, H. G., & Collins, D. N. (2006). Regional differences in response of flow in glacier-fed Himalayan Rivers to climatic warming. *Hydrological Processes, 20*(10), 2157–2169. doi:10.1002/hyp.6209.

Reilly, J. (1995). Climate change and global agriculture: Recent findings and issues. *American Journal of Agricultural Economics, 77*(3), 727–733. doi:10.2307/1243242.

Rosenzweig, C. (2011). *Climate change and agriculture* (pp. 31–41). New York: Springer. doi:10.1007/978-1-4419-7695-6_3.

Rosenzweig, C., & Parry, M. L. (1994). Potential impact of climate change on world food supply. *Nature, 367*(6459), 133–138. doi:10.1038/367133a0.

Schmidhuber, J., & Tubiello, F. N. (2007). Global food security under climate change. *Proceedings of the National Academy of Sciences of the United States of America (PNAS), 104*(50), 19703–19708. doi:10.1073/pnas.0701976104.

Shrestha, U. B., Gautam, S., & Bawa, K. S. (2012). Widespread climate change in the Himalayas and associated changes in local ecosystems. *PLoS ONE, 7*(5), e36741. doi:10.1371/journal.pone.0036741.

Shrestha, A. B., Wake, C. P., Mayewski, P. A., & Dibb, J. E. (1999). Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971–94. *Journal of Climate, 12,* 2775–2789. doi:10.1175/1520-442(1999)012<2775:mttith>2.0.co;2.

Subedi, B. P., & Pandey, R. (2002). Livelihood strategies of *Rai* communities in Arun Valley: Continuity and change. In R. P. Chaudhary, B. P. Subedi, O. R. Vetås, & T. H. Åse (Eds.), *Vegetation and society: their interaction in the Himalayas* (pp. 157–170). Tribhuvan- Bergen Program, Tribhuvan University and University of Bergen.

Subedi, B. P., Subedi, V. R., Dawadi, P. P., & Pandey, R. (2007a). *Land holding pattern in Nepal: Finding from the selected VDC from Mid-western Nepal*. Kathmandu: Informal Sector Service Centre (INSEC).

Subedi, B. P., Subedi, V. R., Dawadi, P. P., & Pandey, R. (2007b). *Livelihood at risk: Finding from Mid-western Nepal*. Kathmandu: Informal Sector Service Centre (INSEC).

Sullivan, C. A. (2011). Quantifying water vulnerability: A multi-dimensional approach. *Stochastic Environmental Research and Risk Assessment, 25*(4), 27–640. doi:10.1007/s00477-010-0426-8.

Thapa, G., Gaiha, R., Kaur, S., Kaicker, N., & Vashishtha, P. (2013). *Agriculture-pathways to prosperity in Asia and the Pacific*. Occasional Papers, Knowledge for development effectiveness, The seventeenth in a series of discussion papers produced by the Asia and the Pacific Division, IFAD, the International Fund for Agricultural Development (IFAD).

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C. (2009). Agroecology as a science, a movement or a practice: A review. *Agronomy for Sustainable Development, 29,* 503–515.

Winiger, M., Gumpert, M., & Yamout, H. (2005). Karakorum–Hindukush-western Himalaya: Assessing high-altitude water resources. *Hydrological Processes, 19*(12), 2329–2338.

Wojtkowski, P. A. (2002). *Agroecological perspectives in agronomy, forestry and agroforestry*. Enfield, NH: Science Publishers Inc.

Wojtkowski, P. A. (2006). *Introduction to agroecology: Principles and practices*. Binghamton, NY: Haworth Press.

World Bank. (2001). *World development report 2000/2001: Attacking poverty*. Washington, DC: World Bank (WB).

Yufang, Su, Jianchu, Xu, Andy, W., Juliet, Lu, Qiaohong, Li, Yao, Fu, et al. (2012). Coping with climate-induced water stresses through time and space in the mountains of Southwest China. *Regional Environmental Change, 12*(4), 855. doi:10.1007/s10113-012-0304-7.

Ziska, L. H., Namuco, O., Moya, T., & Quiland, J. (1997). Growth and yield response of field grown tropical rice to increasing carbon dioxide and air temperature. *Agronomy Journal, 89*(1), 45–53.