Factors associated with farm-level variation, and farmers' perception and climate change adaptation in smallholder mixed-farming livestock production system in Nepal

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Abstract: To identify factors associated with farm-level variability, to understand farmers' perception on climate change impacts, and to assess livestock climate change adaptation, a full-fledged household survey was launched in May 2012 in the Thulokhola watershed of Nuwakot district in Nepal. Factors identified for farm-level variation included land holding size and land types (irrigated, non-irrigated), male and female labours in a household, number of goats and cattle owned, fodder and forages, forest products utilised, number of animal grazing days, and income diversification. Drought conditions, erratic rain events, livestock diseases and parasites, decreasing pregnancy rate in animals, fodder and water shortages, and forest degradation were major climate change impacts in this watershed. To cope with these impacts, farmers have practiced introducing new animal breeds, stall feeding, planting grasses, storing feed for feed shortage months, purchasing feed, constructing ponds, and installing pipelines for water supply. However, they are limited and lacking scientific rigors.

Keywords: farm-level variability; smallholder mixed-farming; livestock production; farmers' perception; climate change impacts; climate change adaptation.

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1 Introduction

Nepal consists of three unevenly populated physiographic units from east to west, the terai in the south, mid-hills in the middle, and the mountains to the north. The terai, mid-hills and the mountain regions consist of 23%, 42%, and 35% of the total land area and 47%, 46%, and 7% of the total population, respectively (Maltsoglou and Taniguchi, 2004; Wagley and Ojha, 2002). Elevation of the terai region extends from 60 m asl to < 600 m asl, hills from 600 m asl to 5,000 m asl, and the mountains from 5,000 m asl to 8,848 m asl (Chhetri and Easterling, 2010). The current population of 27 million is projected to reach 31.33 million in 2016 (CBS, 2003). The livestock population for the year 2009/2010 in Nepal was estimated at 7,199,000 cattle, 4,832,000 buffaloes, 797,000 sheep, 8,762,000 goats, and 1,062,000 pigs and the estimated increase in the number of livestock from previous year was 0.34% cattle, 3.25% buffalo, 3.4% goat and 1.72% pig (MoF, 2010). The mid-hills, terai and the mountain regions contain 40%, 52%, and 8% of the total cultivated land, respectively, and the corresponding livestock population for these regions respectively is 53.7%, 32.3%, and 14% (Pande, 2010). According to Pande (2010), the ratio between livestock unit and agricultural land (ha) for mid-hills, terai, and the mountains is 1.45, 1.19 and 1.3, respectively, suggesting that the mid-hills have the greatest pressure of livestock per unit area of agricultural land. Similarly, the mid-hills also represent the highest human population density per hectare of cultivated land (Pariyar, 2008). More than 80% of the Nepalese population depends on agriculture for their livelihood, accounting for 38% of the GDP (Maltsoglou and Taniguchi, 2004; Feed the Future, 2011). The smallholder mixed-farming system which constitutes livestock production as an integral component is the dominant agricultural production system in the mid-hill region of Nepal.

The smallholder mixed-farming livestock production system, which has been in existence for thousands of years in Nepal, operates with small land holding size, family labour, and includes a mixture of crops, animals, fruits and vegetable production mainly for family consumption. The system is designed to produce staple crops along with a variety of seasonal, fresh, and nutritious food items for a family year-round. This system consists of strong linkages between livestock, forest resources, crop production, family health, soil quality (Abington, 1992), and farm-level production of fodder and forages. Since there is a positive relationship between the amount of manure applied to the field and the number of livestock owned (Regmi and Zoebisch, 2004), it is critical to have sustainable livestock production in the smallholder mixed-farming system in order to improve overall agricultural productivity, food supply, and better human health. Sustainable development of this production system requires holistic considerations of land, water, forest, agricultural crops, manpower, and climatic conditions (Poudel, 2008).

Climate change has severely impacted Nepalese smallholder mixed-farming livestock production system, therefore climate change adaptation in recent years has become one of the major farming system concern in Nepal (Poudel et al., 2013a). Some of the major environmental issues and concerns in Nepal are degradation of resource and ecosystem services, earlier snowmelt and shorter winters, and natural hazards (Schild, 2007), as well as rise in temperature (Hua, 2009). Inundation of crop fields, riverbank erosion, and sand deposition, and unable to plant paddy field due to abnormal rainfall are other climate change issues and concerns (MoF, 2010), which are severely affecting the smallholder mixed-farming livestock production system. Meanwhile, there is a rapid and uncontrolled deforestation and land degradation in Nepal due to agricultural expansion, logging, encroachment, urbanisation/industrialisation, pasture land usage, shifting cultivation, need for firewood and forage for livestock (Panta et al., 2008; Dhital, 2009), overgrazing, development activities, and over-extraction of forest products (Acharya and Dangi, 2009). Nepal has a deforestation rate of 1.7% which is higher than the average global or Asian deforestation rate (Dhital, 2009). As forests are an integral part of the smallholder mixed-farming system in Nepal (Acharya and Dangi, 2009), deforestation and forest degradation has created many problems including shortages of fodder, grass, livestock bedding and compost for farming, as well as increased landslides, floods, and forest fires (Joshi et al., 2011). Meanwhile, soil fertility issues have become critical for agricultural productivity (Regmi and Zoebisch, 2004), and two-thirds of Nepal's 27 million people are experiencing severe food shortages, almost 50% are undernourished and half of all children under five are malnourished due to the increasing population and poor agricultural productivity (Feed the Future, 2011). All these factors are causing the downward spiral of the smallholder mixed-farming livestock production systems at the backdrop of climate change and immediate actions on livestock climate change adaptation are necessary if the resiliency of this system is to be improved and the sustainability is to be enhanced.

As a part of a larger study on strengthening livestock production systems and climate change adaptation in the mid-hill region of Nepal, this study was conducted to:

1 identify factors associated with the farm-level variability of the smallholder mixed-farming livestock production systems in the mid-hills region of Nepal

2 understand farmers' perceptions on climate change impacts

3 assess livestock climate change adaptation at the community level.

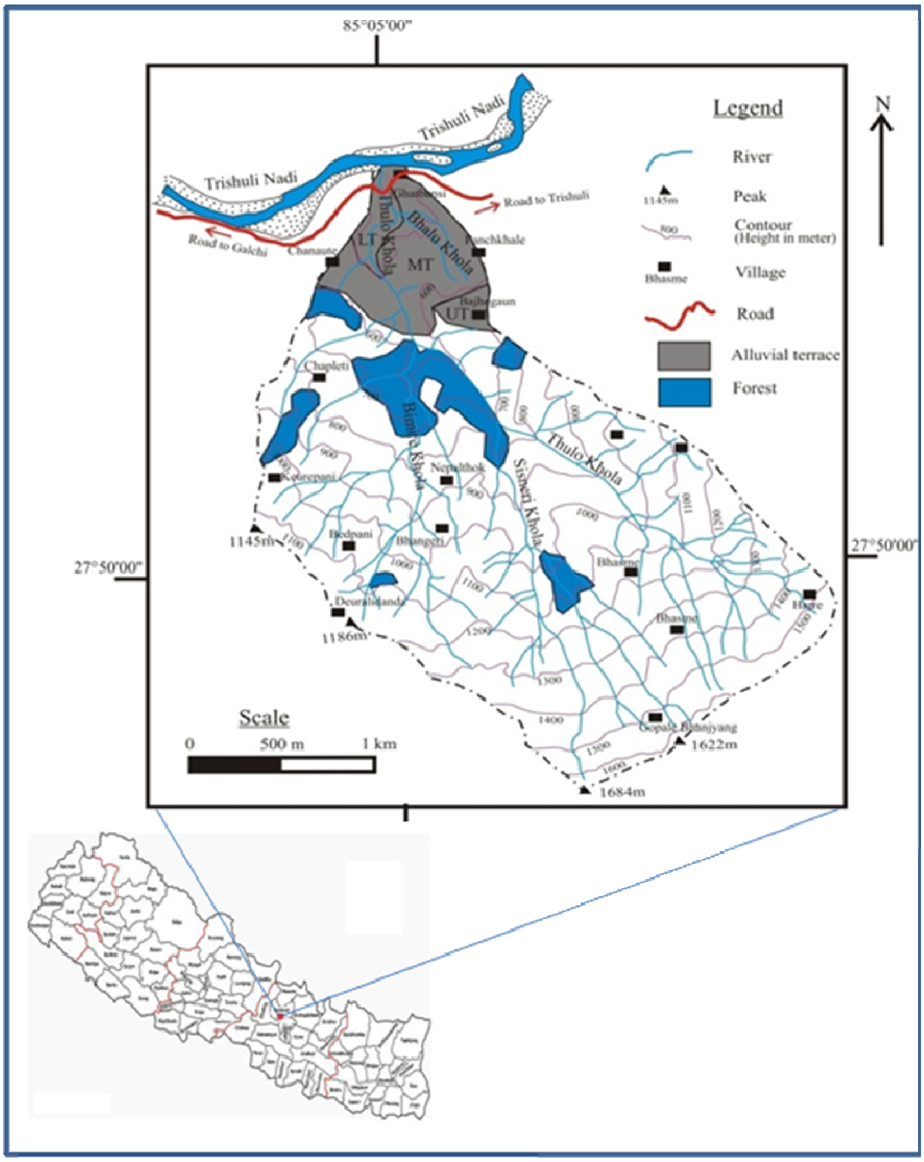
Identification of the factors associated with farm-level livestock production will help developers and governmental agencies in developing appropriate farm-level policies and programs in relation to livestock climate change adaptation. Similarly, an understanding of farmers' perception as well as an assessment of the status of climate change impacts and livestock climate change adaptation is necessary for enhancing community capacity-building and the resiliency of smallholder mixed-farming livestock production system.

2 Methodology

2.1 Study area

The study area, the Thulokhola watershed, is located 2.5 km south of Devighat in the Nuwakot district of Nepal (Figure 1). The elevation of the Thulokhola watershed extends from less than 440 m asl at the Trishuli river to 1,585 m asl, faces north, and drains directly into the Trishuli river. The watershed has an estimated area of 6 sq. km and contains 359 households. For this study, the Thulokhola watershed was divided into three elevations: the lower elevation (< 640 m asl), the middle elevation (640 m asl–1,150 m asl), and the upper elevation (1,150 m asl–1,585 m asl). There were 81 households in the lower elevation, 159 households in the middle elevation, and 119 households in the upper elevation. The lower elevation consists of alluvial terraces, which are primarily formed by the alluvial deposits of the Trishuli River and has been continuously reworked by the Thulokhola. Some colluvial sediments were observed in the foothill side of this geomorphic unit. The middle elevation consists of soils developed from colluviums parent materials. Rock outcrops comprising of phyllite and quartzites in the lower and garnet schist in the upper part of the middle elevation zone were observed. The upper elevation zone showed some patches of granitic gneiss and consisted of some remnant forest areas. Soils in the upper reach of the watershed are developed from residual parent material. Heavy soil erosion from croplands, especially in *pakho* (rainfed, cultivated, hilly land), was evident.

Figure 1 Study area of the Thulokhola watershed in Nuwakot district, Nepal (see online version for colours)



Buffalo, goats, and cattle are the major livestock in the watershed. Rice (*Oryza sativa*), maize (*Zea mays*), wheat (*Triticum aestivum*), finger millet (*Eleusine coracana*), potato (*Solanum tuberosum*), ginger (*Zingiber officinalis*), and vegetable crops are the major crops grown in the watershed. Thulokhola watershed has very limited forest areas due to deforestation. The remnant forest in the lower elevation is dominated by *sal* (*Shorea robusta*) and other mixed vegetation, while the middle and upper elevations have *pine* (*Pinus spp*.) forests. In upper elevation, *uttis* (*Alnus nepalensis*) trees are common. In addition, *chilaune* (*Schima wallichii*) and *katus* (*Castanopsis indica*) are commonly found in the upper elevation. There are two community forests: the Simpani (83 ha and 127 households) community forest, and the Petarpakha community forest; both were found quite degraded. Community forests occasionally allow goats to graze. Forest floors were found lacking brush vegetation and leaf litter, which was due to overgrazing by goats and scrapping of leaf litter from the forest floor for mulch and bedding material.

Figure 2 Annual and average monthly rainfall and annual daily maximum, daily minimum, and daily average temperature in Nuwakot, Nepal (see online version for colours)

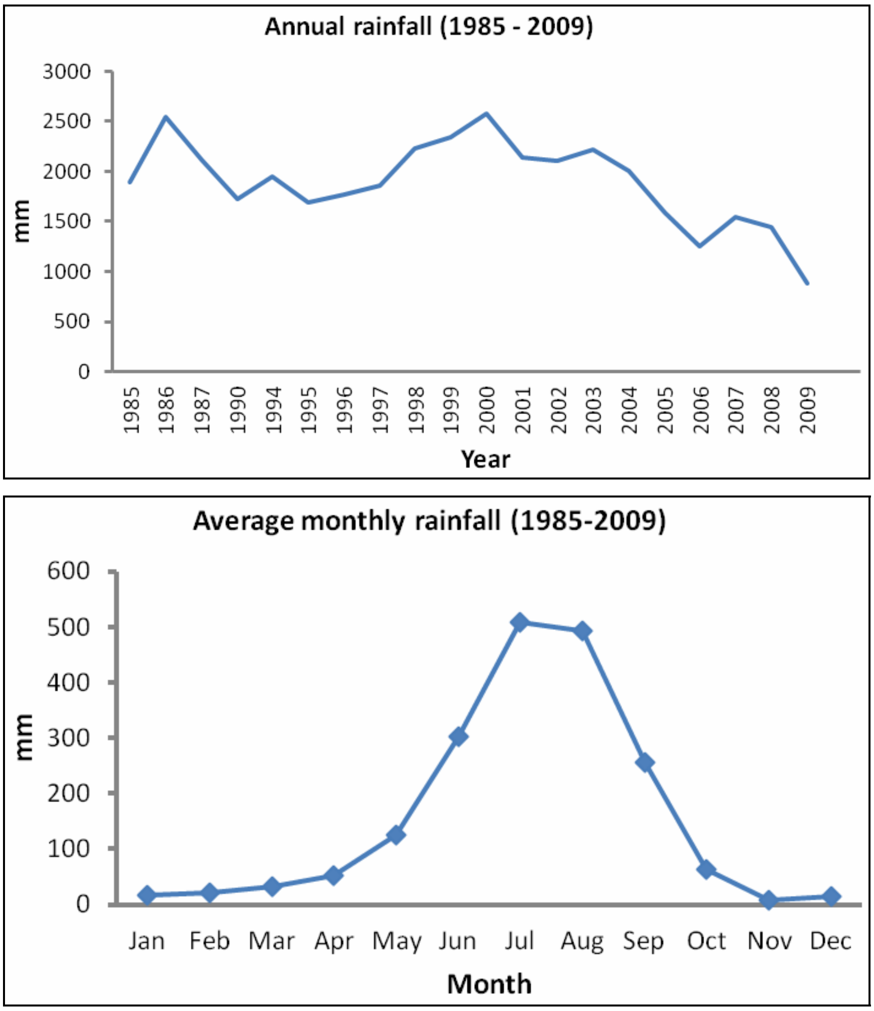
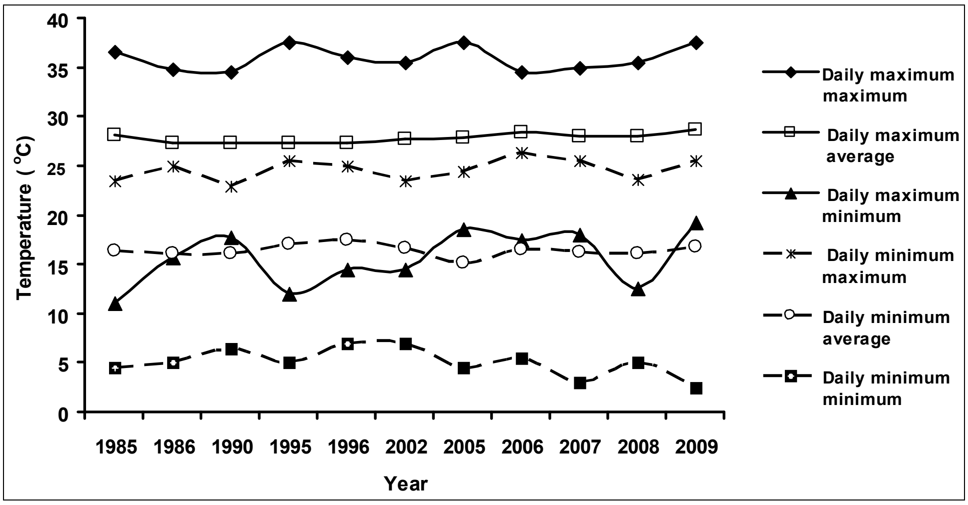


Figure 2 Annual and average monthly rainfall and annual daily maximum, daily minimum, and daily average temperature in Nuwakot, Nepal (continued) (see online version for colours)



2.2 Rainfall

Historical daily precipitation and temperature data for the Nuwakot station were obtained from the Department of Meteorology and Hydrology, Ministry of Physical Planning, Government of Nepal. This dataset was analysed for annual precipitation trends and minimum and maximum daily temperatures. While total annual precipitation peaked in 2000 (2,572.7 mm), it started declining in 2001 and reached as low as 881.9 mm in 2009 (Figure 2). The years that showed missing precipitation data were excluded from the analysis. And 1992 had no data available. Without precipitation data for the whole month of October, 2010 had a total of 1,263.4 mm of precipitation. Monthly analysis of the precipitation data also indicated that the monsoon season is shrinking and the months of October, November, December, January and February are becoming much drier. Rainfall was generally widespread from May through September in the past, while in recent years most of the rainfall occurred in June, July, and August. The maximum daily temperature recorded since 1985 was 37.5°C in 2009, and the minimum daily temperature recorded was 2.5°C also in 2009 (Figure 2), indicating the widening gap on the daily maximum and minimum temperatures in recent years.

2.3 Soil sampling and analyses

A total of 96 random composite soil samples were collected representing *khetland* (i.e. irrigated land) and *bariland* (i.e. non-irrigated land), 0–15 cm and 15–30 cm depth, from all the three elevations on February 1st, 2nd and 3rd, 2012 and were brought to Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur, for laboratory determinations. Soil samples were analysed for pH with 1:1 soil to water ratio, organic matter with modified titration method (Walkley and Black, 1934), nitrogen with Kjeldhal distillation method (Sarah et al., 2010), P_2O_5 with modified Olsen method (Olsen and Sommers, 1982), K_2O with ammonium acetate extraction method (Chapman, 1965), and soil texture with hydrometer method (Bouyoucos, 1962). In addition, 41 core samples were also collected for bulk density determination. Results of soil analyses are presented in Table 1. Textural determination of soil samples (0–15 cm) showed 86% of the samples as sandy loam and 14% as loam in the upper elevation (n = 14); 73% as loam, 22% as sandy loam, and 5% as clay loam in the middle elevation (n = 18); and 50% as loam, 22% as sandy loam, 21% as silt loam, and 7% as clay loam in the lower elevation (n = 14). At 15–30 cm depth, soil samples from the upper elevation predominantly showed sandy loam, the middle elevation showed loam and sandy loam, and the lower elevation showed loam textural classes. For *barilands*, average bulk density values in the upper (n = 7), middle (n = 10), and the lower elevations (n = 2) were 1.33 (±0.1) g cm^{-3}, 1.50 (±0.1) g cm^{-3}, and 1.50 (±0.2) g cm^{-3}, respectively. Similarly, average bulk density values for *khetland* in the upper (n = 7), middle (n = 7), and the lower (n = 8) elevations respectively were 1.36 (±0.10) g cm^{-3}, 1.31 (±0.1) g cm^{-3}, and 1.45 (±0.1) g cm^{-3}. These results clearly indicate that soils in this watershed were quite compacted. In terms of plant nutrition, soil analysis results showed, in general, medium level of nitrogen and medium to high levels of potassium content though the average nitrogen content for *khetland*, especially in the middle elevation, was relatively low (Table 1). Except for *bariland* in the lower elevation and *khetland* in the middle elevation where the phosphorus content was low, the rest of the lands sampled showed medium to high levels of phosphorus content. The upper and middle elevation *barilands* had remarkably high phosphorus content compared to the *barilands* at lower elevations and *khetlands* across the watershed. This higher phosphorus content in the middle and upper *barilands* could be mainly due to manure application as manure is regularly applied to *barilands*. With regard to soil acidity, for 0–15 cm depth samples from *khetland*, 20% of samples were extremely acidic (< 4.5 pH), 32% of samples were very strongly acidic (4.5–5 pH), 12% strongly acidic (5–5.5 pH), 20% were moderately acidic (5.5–6 pH), and 16% were slightly acidic (6–6.5 pH). All of the extremely acidic and half of the very strongly acidic samples represented *khetlands* from lower elevations. For *barilands* 0–15 cm depth, 4.7% samples were extremely acidic, 19.1% were very strongly acidic, 4.7% were strongly acidic, 38.1% were moderately acidic, 14.3% were slightly acidic, and 19.1% were at neutral pH. These results clearly indicate that the *khetlands* are much more acidified compared to the *barilands*, and soil acidity is certainly one of the major problems related to soil conditions in this watershed.

2.4 Household surveys

A total of 97 households were surveyed in May 17–23, 2012. Survey questionnaires were developed, pre-tested, and the survey was conducted by trained enumerators. Of the total respondents, 57.7% were female and 42.3% were male. The survey questionnaire contained questions in relation to the livestock composition, fodder and forages, exposure to climate change, climate change impacts, awareness and perceptions of farmers on climate change, women's empowerment, capacity-building, and livestock climate change adaptation. During this survey week, we observed that this watershed was at the middle of the drought and many crop fields were dry and farmers were complaining of the lack of rain.

Table 1 Soil physical and chemical properties of the three elevation zones of the Thulokhola watershed, Nuwakot, Nepal

	n	*pH*	*OM (%)*	*N (%)*	*P_2O_5 (Kg/ha)*	*K_2O (Kg/ha)*	*Sand (%)*	*Silt (%)*	*Clay (%)*	*Textural class*
					0–15 cm					
Bariland										
Upper	7	5.3(±0.25)ns*	5.5(±0.50)ns	0.19(±0.01)ns	190.5(±68.1)ns	429.7(±137.7)ns	58.1(±3.1)a	29.8(±2.4)b	10.6(±0.5)b	Sandy loam
Middle	11	6(±0.23)ns	4.2(±0.83)ns	0.15(±0.02)ns	187(±63.1)ns	462.8(±100.8)ns	45.9(±1.7)b	35.7(±0.9)a	18.3(±1.7)a	Loam
Lower	3	5.3(±0.32)ns	3.6(±1.17)ns	0.14(±0.03)ns	68.1(±41.6)ns	378.1(±141.9)ns	49.8(±4.1)ab	33.6(±1.8)ab	16.6(±4.3)ab	Loam
Khetland										
Upper	7	5.2(±0.20)ij	3.4(±0.65)ij	0.14(±0.01)ij	54.2(±30.6)ns	257.7(±101.8)ns	60.4(±2.6)i	28.3(±2.0)k	11.3(±0.7)j	Sandy loam
Middle	7	5.6(±0.19)i	2.3(±0.54)j	0.1(±0.01)j	53.6(±36.0)ns	357.4(±123.8)ns	51.9(±1.9)j	34.9(±1.6)j	12.9(±0.7)j	Loam
Lower	11	4.7(±0.21)j	4.9(±0.37)i	0.16(±0.01)i	54.6(±23.2)ns	164.7(±19.3)ns	38(±2.6)k	44.7(±2.1)i	17.8(±1.8)i	Loam
					15–30 cm					
Bariland										
Upper	7	5.2(±0.08)m	4.4(±0.53)ns	0.16(±0.01)ns	134.5(±53.1)ns	245.3(±84.9)ns	58.1(±2.1)l	30.4(±1.7)m	11.4(±0.5)m	Sandy loam
Middle	12	6(±0.18)l	3.7(±0.54)ns	0.14(±0.01)ns	181.3(±54.4)ns	495.5(±93.5)ns	49.5(±2.2)m	33.2(±1.4)m	16.5(±1.3)l	Loam
Lower	3	5.6(±0.08)lm	5.5(±0.98)ns	0.19(±0.02)ns	12(±1.9)ns	278.6(±130.9)ns	41.8(±3.8)m	40.3(±2.1)l	17.9(±1.9)l	Loam
Khetland										
Upper	7	5.2(±0.12)xy	3(±0.96)ns	0.12(±0.02)ns	69.4(±23.7)ns	349.4(±89.7)x	58.9(±3.0)x	29.5(±2.5)y	11.6(±2.2)y	Sandy loam
Middle	7	5.3(±0.27)x	2.5(±0.85)ns	0.17(±0.05)ns	30.1(±14.7)ns	248.7(±71.1)xy	53.2(±1.4)x	34.7(±1.1)y	12.16(±0.3)y	Loam
Lower	11	4.8(±0.11)y	4.4(±0.41)ns	0.16(±0.01)ns	74.2(±33.6)ns	146.4(±23.7)y	38.8(±2.3)y	43.9(±2.0)x	18.4(±2.2)x	Loam

Notes: *Numbers in parentheses are ±standard error of mean; same letters in a group across a column indicate means not significantly different at 0.05 probability level by pairwise comparison using Student's t test, ns = not significant.

From the survey dataset, a 23 variable subset of the dataset was developed for farm-level statistical analysis. The 23 variables identified for each of the 97 households surveyed included household Id (HHid), elevation zone (Elezone), *khetland* area in *ropani* (i.e. 1 *ropani* = 508.74 square metres) (Khetrop), *bariland* area in *ropani* (Barirop), *pakheroland* (i.e. sloping, poor land) area in *ropani* (Pakhrop), private forestry land area in *ropani* (Pvtforop), total land holding in *ropani* (TotLH), number of cattle (Cattle), number of buffaloes (Buffalo), number of goats (Goats), total number of animals (cattle + buffalo + goats) (Totanimals), number of major fodder trees (Ftrees), number of other minor fodder trees (Othftrees), total fodder trees (Totftrees), number of water sources currently in use (WSNON), back loads of fodder per year obtained from community forest (Fbacklod), back loads of grass per year obtained from community forest (Grbld), back loads of firewood per year obtained from community forest (Firebld), number of days of animal grazing per year (Grazdays), back loads of leaf litter per year obtained from the community forest (Leaflitter), number of female members in the household (Female), number of male members in the household (Male), and house hold size (HHSize). Except for correlation analyses, all statistical analyses were done by the three elevation zones. Simple statistics such as mean, standard deviation, frequency, range, as well as principal component and factor analyses were done in JMP 8.0., while regression analyses were done in SAS (2003).

3 Results and discussion

3.1 Livestock composition

Based on the survey results, cattle, buffalo, and goats were the major livestock species in the Thulkhola watershed. An elevation level analysis of the survey dataset revealed that there was a significant difference between the three elevations in relation to the average number of livestock per household, buffalo population per household, and land holding size (Table 2). On average, the total livestock population (cattle, buffalo and goats) per household (n = 97) in the watershed was 9.22 (± 0.51) [6.15 (±0.40) goats, 1.70 (±0.10) buffalo, and 1.37 (±0.15) cattle]. The average household size was 5.98(±0.19), and the average land holding size per household was 19.05 (±1.59) *ropani* which included average land holding of 8.84 (±0.73) *ropani khetland*, 7.81 (±0.82) *ropani bariland*, 1.49 (±0.26) *ropani pakheroland*, and 0.91 (±0.25) *ropani* private forest land. In line with the higher land holding size and larger family size, a household in the upper elevation, on average, contained 32.3% higher livestock population compared to a household in the lower elevation and 11.3% higher livestock population compared to a household in the middle elevation. Similarly, on average, a household in the upper elevation contained 32.4% higher buffalo population compared to a household in the lower and the middle elevations. Goats were the most common animal species in the watershed as 92.1%, 96.4%, and 93.6% of the surveyed households in the upper, middle and the lower elevations, respectively, owned goats, whereas buffalo was the second common species as the proportion of the households owning buffaloes in the upper, middle and the lower elevations respectively was 92.1%, 89.3% and 80.7%. The percentage of the households owning cattle in the upper, middle and lower elevations was 57.9%, 64.3% and 71%, respectively. These results indicate that while the owners of goats and buffaloes were well-distributed across the three elevations of the watershed, cattle owners tended to be more on the lower elevations. The percentage of surveyed households owning more than six goats in the upper, middle and the lower elevations were respectively 50%, 60.6% and 35.5% suggesting that a larger number of households in the middle elevation have higher stocking rate of goats than in the upper and lower elevations. The overall livestock composition for the watershed was 66.7% goats, 18.4% buffalo, and 14.9% cattle, and a similar proportion was observed across the three elevations.

Table 2 Average number of livestock heads, land holding size and number of family members per household in the upper, middle, and lower elevation zones of the Thulokhola watershed, Nuwakot, Nepal

	Upper elevation	*Middle elevation*	*Lower elevation*
Sample size (n)	38	28	31
Total livestock*	10.34(±1.08)a¶	9.29 (±0.71)ab	7.81(±0.57)b
Goats	6.87(±0.81)ns	6.43(±0.55)ns	5.03(±0.53)ns
Cattle	1.47(± 0.29)ns	1.36(±0.27)ns	1.26(±0.20)ns
Buffalo	2.00(± 0.17)a	1.50(±0.14)b	1.51(±0.19)b
Total land holding	24.55(±3.30)a	16.73(±1.94)b	14.40(±1.94)b
Khetland	11.02(±1.47)a	6.61(±1.05)b	8.16(±0.88)ab
Bariland	10.05(±1.41)a	8.28(±1.12)ab	4.64(±1.47)b
Pakheroland	1.93(±0.56)ns	1.12(±0.25)ns	1.27(±0.36)ns
Private forest	1.54(± 0.54)a	0.71(±0.43)ab	0.32(±0.12)b
Household size	6.57(±0.34)a	5.57(±0.32)b	5.61(±0.27)b

Notes: *Total livestock population includes goats, cattle, and buffalo. ¶Comparison of each pair using Student's t at alpha = 0.05. Means with different letters across the rows are significantly different at 0.05 probability level by pairwise comparison using Student's t test. ns = not significant. Numbers in parentheses are ± standard error of mean.

Total livestock population (cattle, buffalo, and goats) per household was significantly and highly correlated with goat population ($n = 97$, $r = 0.95$, $p \leq 0.001$) (Table 3). Goat production directly relates to the livelihood of the local communities as farmers tend to rely on goats for cash income. Thus, goats play a dominant role on resource utilisation and household incomes in this watershed. Total livestock population was also significantly correlated with household size ($n = 97$, $r = 0.45$, $p \leq 0.001$) and land holding size ($n = 97$, $r = 0.32$, $p \leq 0.01$), suggesting that family labour and the local availability of resources, especially private land and agricultural production, were the major characteristics of the livestock production system in the study area. Interestingly, there was a significant correlation between goat population and cattle population ($n = 97$, $r = 0.49$, $p \leq 0.001$) suggesting that those farmers who own goats also own cattle. This is primarily due to the fact that both animal species, goats and cattle, are grazed while buffaloes are stock fed. This result also illustrates the fact that larger family size households can afford to own more goats and cattle because their family members are available as farm labour for tending these animals. Thus, the smallholder mixed-farming livestock production system in this watershed was found to have large variations at the farm level primarily in relation to livestock composition and the number of livestock per household which will make a huge difference at the household level in terms of time and resource allocation to livestock production and farm management. This will also transpire into challenges in livestock climate change adaptation as different practices and measures will fit differently at different households.

3.2 Factors associated with the farm-level variability

Table 4 shows the principal components, cumulative proportion of variability, parameters with higher loadings and the factors identified that explain the farm-level variability of smallholder mixed-farming livestock production system in the Thulokhola watershed. Seven factors (from first to last), *khetland*, number of cattle, forest products, fodder and forages, female family labour, income diversification, and male family labour, with 84.13 cumulative proportion of the variability for the upper elevation, and fodder and forages, number of goats, male family labour, forest products, income diversification, female family labour, and *pakheroland* (sloping and poor quality land) with the cumulative proportion variability of 78.27 for the middle elevation were identified. Similarly, eight factors, *bariland*, number of goats, fodder and forages, *khetland*, forest products, animal grazing, male family labour, and female family labour, with 84.93% of the variability were identified for the lower elevation. *Khetlands* are more common in the lower elevations as there is more availability of irrigation water and flat terraces for agricultural production in this elevation. While households in the upper elevation own mostly *barilands*, households in the middle elevation generally own both *khetlands* and the *barilands*. As the four factors (i.e. forest products, fodder and forages, female family labour, and male family labour), were common to all three elevations, the supply of fodder and forages and the availability of farm labour for tending animals are the major concerns in relation to livestock production in this watershed. Farmers with larger land holding sizes will be able to allocate more land to fodder and forages or agricultural production, thus producing more feedstock to their livestock compared to those farmers who have smaller land holding sizes. Similarly, households with a larger family size will have more farm labour available for livestock production and management compared to those with a smaller family size. The health of community forests is also critical as a healthy community forest will supply larger amounts of fodder and forages and fuelwoods necessary for livestock and household maintenance, thus helping in building a climate change resilient livestock production system. Farmers who have relatively higher level of household income diversification (i.e. selling vegetable crops, agricultural commodities, livestock and livestock products, part-time jobs, etc.) will be able to better adapt to climate change impacts than those with less diversification of household incomes.

Table 3 Correlation coefficients of select variables for whole dataset in the Thulokhola watershed, Nuwakot, Nepal (n = 97)

	Khetrop	*Barirop*	*Pakhrop*	*Pvtforrop*	*Totlh*	*Cattle*	*Buffalo*	*Goats*	*Totanmls*	*Ftrees*	*Othrtrees*	*Tottrees*	*WSNON*	*Fbackld*	*Grbld*	*Firewbld*	*Grazdays*	*Leaflitter*	*Female*	*Male*	*Hhsize*
Khetrop	1																				
Barirop	0.51***	1																			
Pakhrop	0.31**	0.39***	1																		
Pvtforrop	0.47***	0.21*	0.43***	1																	
Totlh	0.81***	0.85***	0.57***	0.56***	1																
Cattle	0.23*	0.22*	–0.1ns	–0.02ns	0.2*	1															
Buffalo	0.12ns	–0.1ns	0.03ns	0.05ns	0.03ns	–0.01ns	1														
Goats	0.32**	0.34***	0.03ns	–0.02ns	0.33**	0.49***	0.1ns	1													
Totanmls	0.34***	0.32**	0.001ns	0.004ns	0.32**	0.68***	0.28**	0.95***	1												
Ftrees	0.18ns	0.26**	0.39***	0.08ns	0.29**	0.06ns	0.27**	0.11ns	0.16ns	1											
Othrtrees	0.16ns	0.3**	0.22*	0.17ns	0.29**	0.17ns	0.01ns	0.29**	0.28**	0.27**	1										
Tottrees	0.21*	0.32**	0.41***	0.12ns	0.35***	0.1ns	0.24*	0.19ns	0.23*	0.96***	0.54***	1									
WSNON	0.11ns	0.15ns	0.05ns	0.05ns	0.14ns	0.13ns	0.12ns	0.15ns	0.18ns	0.04ns	0.15ns	0.08ns	1								
Fbackld	–0.02ns	0.01ns	–0.07ns	–0.07ns	–0.03ns	–0.03ns	0.09ns	–0.04ns	–0.01ns	–0.11ns	–0.03ns	–0.11ns	0.29**	1							
Grbld	–0.08ns	–0.09ns	–0.14ns	–0.11ns	–0.13ns	0.05ns	0.06ns	0.05ns	0.07ns	–0.1ns	–0.05ns	–0.1ns	0.22**	0.64***	1						
Firewbld	–0.13ns	0.01ns	–0.01ns	–0.07ns	–0.07ns	0.01ns	0.02ns	0.05ns	0.04ns	–0.01ns	0.04ns	0.01ns	0.02ns	0.13ns	0.62***	1					
Grazdays	0.11ns	0.14ns	0.06ns	0.08ns	0.14ns	0.29**	–0.02ns	0.2*	0.24*	–0.08ns	0.01ns	–0.07ns	0.1ns	0.08ns	0.15ns	0.23*	1				
Leaflitter	–0.21*	–0.03ns	–0.01ns	–0.05ns	–0.12ns	–0.03ns	–0.11ns	–0.08ns	–0.1ns	–0.11ns	–0.03ns	–0.11ns	0.1ns	0.06ns	0.13ns	0.07ns	0.26**	1			
Female	0.3**	0.21*	0.01ns	0.12ns	0.26**	0.16ns	0.28**	0.29**	0.33**	0.14ns	0.26	0.2*	0.01ns	–0.05ns	–0.03ns	0.08ns	0.03ns	–0.1ns	1		
Male	0.14ns	0.33**	0.18ns	–0.07ns	0.25*	0.32**	0.08ns	0.24*	0.3**	0.21*	0.08ns	0.21*	0.06ns	–0.11ns	–0.11ns	–0.13ns	0.06ns	0.06ns	–0.03ns	1	
Hhsize	0.31**	0.39***	0.13ns	0.04ns	0.37***	0.34**	0.26*	0.38***	0.45***	0.25*	0.25	0.29**	0.05ns	–0.11ns	–0.1ns	–0.03ns	0.06ns	–0.04ns	0.7***	0.7***	1

Notes: *,**, and *** indicate significant correlations at 0.05, 0.01, and 0.001 probability level by Student's t test.

Table 4 Factors associated with the variability of livestock production systems at the upper, middle, and the lower elevations of the Thulokhola watershed in Nuwakot district, Nepal

Principal components (Y_i)	*Upper elevation*				*Middle elevation*				*Lower elevation*			
	Eigen values (λ_i)	*Cumulative proportion*	*Parameters with higher loadings*	*Factors identified*	*Eigen values (λ_i)*	*Cumulative proportion*	*Parameters with higher loadings*	*Factors identified*	*Eigen values (λ_i)*	*Cumulative proportion*	*Parameters with higher loadings*	*Factors identified*
Y_1	5.83	27.75	Khetrop, Totlands, Barirop	*Khetland*	4.49	21.42	Ftrees, Tottrees	Farm fodder and forages	4.31	20.55	Barirop, Totlands, Pakherop	*Bariland*
Y_2	3.26	43.29	Cattle, Totanimals, Goats	Cattle	3.1	36.2	Goats, Totanimals	Goats	2.79	33.84	Goats, Totanimals	Goats
Y_3	2.63	55.8	Fbacklod, Grbld, Firebld	Forest products	2.41	47.69	Hhsize, Male	Male family labour	2.71	46.72	Ftrees, Tottrees	Farm fodder and forages
Y_4	2.12	65.91	Ftrees, Tottrees	Farm fodder and forages	2.06	57.48	Firebld, Grbld	Forest products	2.3	57.68	Khetrop, Cattle	*Khetland*
Y_5	1.52	73.14	Female, HHsize	Female family labour	1.74	65.78	Leaflitter	Income diversification	1.89	66.71	Grbld, Fbackload	Forest products
Y_6	1.19	78.79	Leaflitter	Income diversification	1.48	72.84	Fbackload, Female	Female family labour	1.43	73.49	Grazingdays, Pvtforop	Animal grazing
Y_7	1.12	84.13	Male	Male family labour	1.14	78.27	Pakhorop	Pakhero land	1.32	79.83	Male, HHsize	Male family labour
Y8	-	-	-	-	-	-	-	-	1.07	84.93	Female, HHsize	Female family labour

Note: Sample size (n): upper elevation 38, middle elevation 28, and lower elevation 31.

3.3 Predicting total number of animals (cattle, buffalo, and goats) per household

Elevation-wise regression analyses of the survey dataset resulted in different equations for the upper (1), middle (2), and the lower (3) elevations, respectively, as:

$$\begin{aligned} Totanimals = {} & 4.59 + 0.45\ Khetrop - 0.78\ Pakhorop \\ & - 0.64\ Pvtforrop + 0.12\ Tottrees \\ & \left(r^2 = 0.44,\ p \le 0.05, \text{ and } n = 38\right) \end{aligned} \tag{1}$$

$$\begin{aligned} Totanimals = {} & 2.57 + 0.16\ Khetrop + 1.06\ WSNON + 1.32\ Female \\ & \left(r^2 = 0.43,\ p \le 0.05, \text{ and } n = 28\right) \end{aligned} \tag{2}$$

$$\begin{aligned} Totanimals = {} & 5.55 + 0.86\ Male \\ & \left(r^2 = 0.11,\ p \le 0.05, \text{ and } n = 31\right) \end{aligned} \tag{3}$$

As evidenced from these regression equations, the variables included in this study predicted the number of total animals per household reasonably well especially for the upper and the middle elevations. From these results, it can be safely stated that the total number of livestock per household largely depend on land holding sizes, fodder and forages, family labour, and water sources. The relatively poor predictability of total number of animals per household in the lower elevation clearly indicate that variables other than those included in this study such as access to roads, proximity to market centres, or education level might be better predictors for the total number of livestock per household in this elevation zone. It is interesting to note that the variable WSNON, the number of water sources being utilised by a household at present, appears as one of the independent variables in equation (2), which suggests that water availability has already been emerged as critical as other factors such as land holding sizes, family labour, fodder and forages, or feed supply for livestock production in the smallholder mixed-farming production system in Nepal.

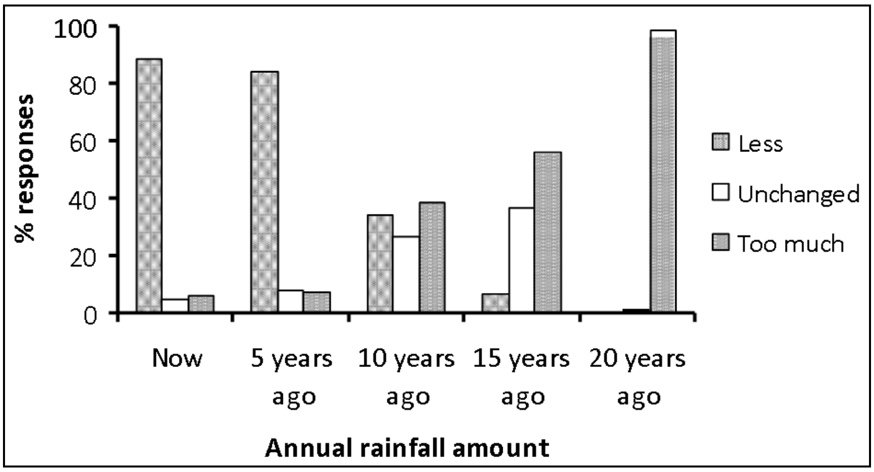
3.4 Farmers' perception and awareness on climate change impacts

Based on the survey results, farmers' perception and awareness in the Thulokhola watershed can be grouped into four broad categories: weather related changes and natural hazards, animal health and breeding conditions; crop production, and forest, soils, and water resources.

With regard to weather related changes and natural hazards, farmers in the Thulokhola watershed have perceived and are aware of the tremendous changes in rainfall, temperature, flood and drought, and occurrence of hurricanes over the past 20 years (Figure 3). While 88.7% of the respondents stated that they have less rainfall now compared to 20 years ago, over 90% of the respondents stated that they have warmer summers and 83.9% of the respondents stated they have had warmer winters in recent years. These perceptions and awareness match closely with the rainfall and temperature data (Figure 2) recorded for the Nuwakot district. This decline in rainfall has also decreased flood events: 75.3% of the respondents said they have a decreased frequency of flooding in recent years, 62.9% of the respondents stated that the magnitude of flooding has also decreased in recent years. There is no confusion with regard to drought, as

96.9% of the respondents reported increased frequency of drought and 81.4% reported an increased magnitude of drought in recent years. Similarly, erratic rain events, delay of the growth of grasses in pasture land, poor pasture quality, drying up water sources and shortages of water, and extreme weather events are also reported in the Khumbu region of Nepal (Sherpa and Kayastha, 2009). In the Thulokhola watershed, the local communities are also fully aware of the decrease in the frequency and the magnitude of hurricanes in recent years. While 23% of the respondents perceived less frequent hurricanes in recent years, 37.5% of the respondents feel they have more violent hurricanes now as compared to 20 years ago. These results indicate a decline in the occurrence of hurricanes in recent years is associated with the late arrival of the monsoon season. Except for more frequent floods in recent years due to increased deforestation and cultivation of marginal lands, Gurung and Bhandari (2009) have also reported similar farmers' perception of hotter summers, erratic rainfalls, more landslides, increasing droughts, and shorter winters in Chitwan, Nepal.

Figure 3 Local awareness and perception on changes in rainfall, temperature, flood, and hurricanes over the past 20 years in the Thulokhola watershed, Nuwakot, Nepal



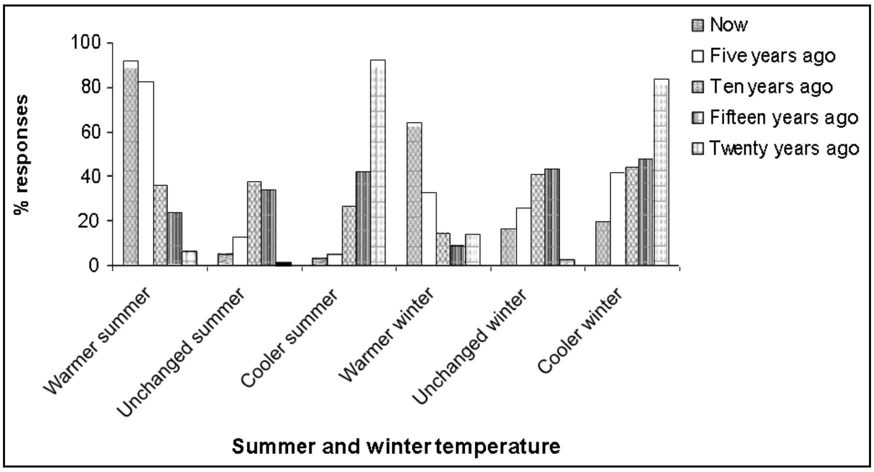
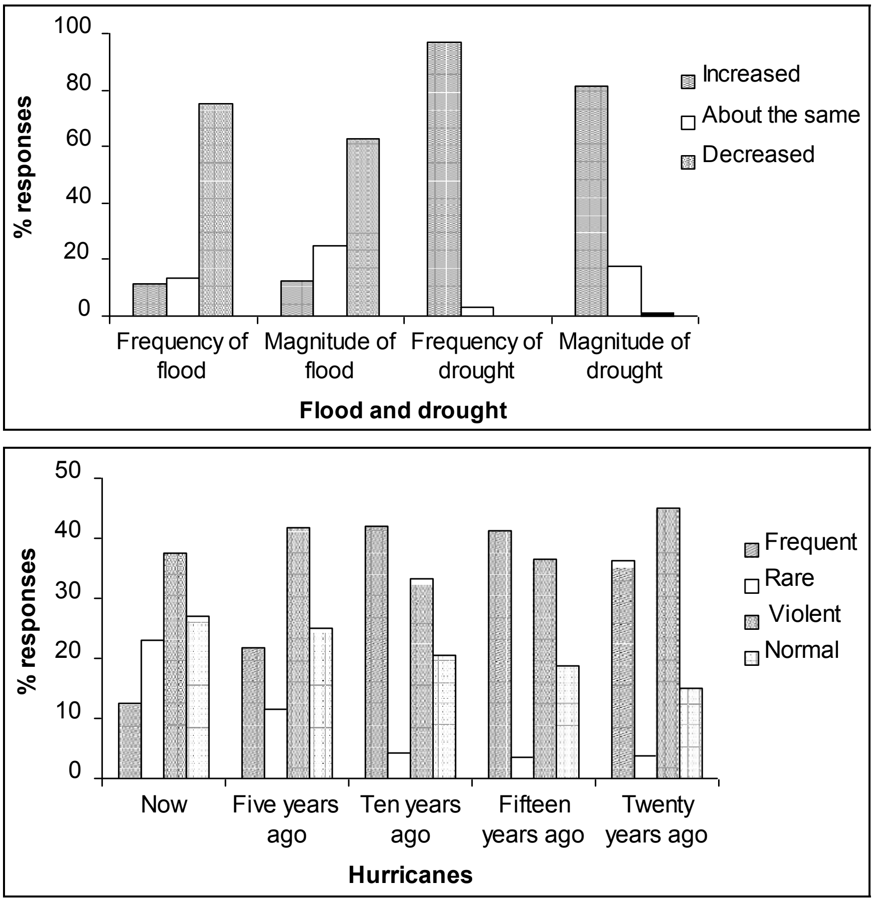


Figure 3 Local awareness and perception on changes in rainfall, temperature, flood, and hurricanes over the past 20 years in the Thulokhola watershed, Nuwakot, Nepal (continued)



In relation to animal health and breeding conditions, farmers in the watershed have perceived increased vulnerability of livestock to diseases and parasites and breeding conditions in recent years. Nearly two thirds of the total respondents (n = 21) in the lower elevation believed adult female goats to be the most vulnerable of local livestock to diseases and parasites (note: most male offspring are sold at an early age for meat). More than half of the respondents in this elevation considered young goats to be equally vulnerable to the diseases and parasites in recent years. When asked about buffalo and cattle, two thirds of the respondents (n = 23) in the lower elevation thought adult female buffalo were highly vulnerable, and about half of the respondents considered cows to be highly vulnerable to diseases and parasites. In contrast, the proportion of respondents stating higher vulnerability of cows, female buffalo, and goats in the middle elevation were 6%, 22%, and 17%, respectively, and in the upper elevation were 17%, 25%, and 28%, respectively. These results suggest that animals in the lower elevations are more prone to diseases and parasites than the animals in the higher elevations. Farmers in the lower elevation who have an access to road service seek veterinary services and administer drugs to their animals more frequently compared to their counterparts in the middle and the upper elevations who do not have access to road services. In relation to cattle, 53.3% in the middle elevation and 47.6% respondents in the lower elevations reported decreased pregnancy rates in recent years as opposed to 29.4% in the upper elevation. Similarly, the proportion of surveyed households stating decreased pregnancy rates in buffalo in recent years for the middle, lower and upper elevations respectively was 42.9%, 36% and 35.5%. Slightly higher proportions of respondents in the middle and lower elevations reported decreased pregnancy rates in goats compared to the respondents in the upper elevation. These results indicate that there are greater decreases in pregnancy rates in the middle and lower elevations than in the upper elevations. However, higher proportions of the respondents in the upper elevations expressed abortion as one of the major problems in recent years in their livestock. The abortion problem was serious in goats, as the proportion of respondents stating abortion problems in goats in recent years in the upper, middle and lower elevations was 51.4%, 33.3% and 34.5%, respectively. A relatively less number of respondents in the middle elevation complained about abortion of their buffalo (4%), cattle (11%), and goats (33%) than respondents in the upper and lower elevations. Repeated breeding conditions in buffalo, cattle and goats were reported by 52%, 50% and 41.4% of the surveyed respondents, respectively, in the lower elevation, which were relatively higher than the respondents in the middle and the upper elevations indicating the magnitude of this problem is probably more serious in the lower elevation than in the middle and upper elevations. On average, 15.7% of the surveyed households reported anoestrous conditions, and 16.8% of the surveyed households reported infertility as increasing livestock problems in recent years in the watershed. Among these breeding complications, the need for repeated breeding of their livestock and the abortion of goats were the major concerns for the smallholders across the watershed. Poor animal health due to parasites, diseases, and nutritionally inadequate diets (Poudel et al., 2012a, 2012b) has negatively impacted the pregnancy rates of livestock in this watershed.

Farmers in the Thulokhola watershed are aware of increased incidences of diseases and pests on crops, impacts of drought on crop yields, and changes in planting and harvesting time. Based on the survey results, leaf blight and aphid infestation in potatoes (*Solanum tuberosum*), rhizome rot in ginger (*Zingiber officinale*), leaf blight and yellow rust in wheat (*Triticum aestivum*), head smut, stalk rot, and borers on corn (*Zea mays*), and borers in rice (*Oryza sativa*) were major crop pests and diseases in the Thulokhola watershed. The decline in crop productivity, increasing requirement of pesticide application on the crops, delay of crop planting and maturity due to lack of timely rainfall, and crop failures were reported. Lama and Devkota (2009) have also reported similar farmers' perceptions shifting of growing and harvesting time of crops, changes on flowering and fruiting patterns, increased incidence of diseases and pests, and the occurrence of new species of trees and crops due to changing climate in Solukhumbu district in the eastern region of Nepal.

As far as farmers' perceptions and awareness in relation to forests, soils, and water resources in recent years is concerned, the participants identified drying or dying of forest trees, deforestation, stunted growth of forest trees, lack of vegetation on the forest floor, extinction of tree species, increasing incidences of wildlife (such as monkeys) on crop lands and even houses, and invasive plants such as *blue ganne* (*Ageratum spp*.), *banmara* (*Lantana camara*), and *tite pati* (*Artemesia vulgaris*). Farmers in the watershed have also observed decline in soil fertility. They believe that due to soil erosion their soils are changed to more clayey and infertile now as opposed to previously friable and fertile soils, and they have exposed pebbles and rocks in recent years which were hard to notice in the past. They have also perceived that the soil in the *barilands* are not supporting plant growth well due to the compacted, clayey, and sticky conditions. Farmers in the Thulokhola watershed are quite aware of dried up water sources, migration of water sources downhill, and the collapse of the land with diminishing water sources. On average, a household which was using five or more water sources ten years ago in this watershed has been using less than three water sources in recent years (Table 5). The average number of dried up water sources that a household had been using for the past 20 years in the upper, middle, and the lower elevation was 2.32, 2.54 and 3.22, respectively, suggesting that the farmers in the lower elevation are experiencing a greater loss of water sources than the farmers at the higher elevation. As high as, 94.6% respondents in the upper elevation, 81.5% respondents in the middle elevation, and 90.3% respondents in the lower elevation stated significant decrease in flows of their water sources in recent years compared to 20 years ago. More specifically, the reduction in water flow has occurred within a decade as 36.8% respondents in the upper, 53% in the middle, and 56.7% in the lower elevation stated they had experienced significant reduction in the flow of their water sources during the past ten years. A small portion of respondents said that as of now they have experienced constant flow in their water sources, which might relate to several factors including geology, groundwater recharge, forest cover and land use types in relation to these water sources. Duex and Poudel (2012, 2013) and Poudel et al. (2013a) reported 85% of the water sources either dried up or was reduced in flow over the past ten years with a great toll on agricultural production, drinking water supply, and the forest health. They also reported impairment of the surface water quality in the watershed. Drying up water sources in the middle and the upper elevations would have impacted the recharge of the aquifer negatively, resulting in the higher number of dried up water sources at lower elevations. Those water sources that once were perennial in nature have been turned into seasonal sources in recent years. Therefore, in order to strengthen the livestock production system as well as restore forest and ecological systems, it is important to explore the possibilities of groundwater development as well as rejuvenation of the springs in the Thulokhola watershed.

Table 5 Changes on the average number of water sources that are available for use for a household over the past 20 years in the Thulokhola watershed

	Number of active water sources					
	Upper elevation		*Middle elevation*		*Lower elevation*	
	n	*Mean*	*n*	*Mean*	*n*	*Mean*
Now	38	2.71(±0.33)*	28	2.07(±0.32)	31	2.0(±0.23)
5 years ago	38	3.81(±0.81)	28	3.46(±0.71)	31	3.64(±0.69)
10 years ago	38	5.0(±1.10)	27	4.37(±0.96)	31	4.67(±0.78)
15 years ago	32	4.85(±0.76)	25	4.96(±1.11)	28	5.5(±0.86)
20 years ago	30	5.03(±0.80)	22	5.8(±1.27)	27	5.7(±0.91)

Note: *Numbers in parentheses are ± standard error of mean.

Table 5 Changes on the average number of water sources that are available for use for a household over the past 20 years in the Thulokhola watershed (continued)

	Number of dried water sources					
	Upper elevation		*Middle elevation*		*Lower elevation*	
	n	*Mean*	*n*	*Mean*	*n*	*Mean*
Now	34	2.32 (±0.55)	26	2.54(±0.84)	27	3.22(±0.81)
5 years ago	33	1.66(±0.41)	24	1.04(±0.37)	25	1.80(±0.43)
10 years ago	30	0.76 (±0.31)	21	0.52(±0.25)	24	0.87(±0.30)
15 years ago	22	0	20	0.30(±0.17)	22	0.22(±0.14)
20 years ago	21	0	16	0	19	0.15(±0.15)

Note: *Numbers in parentheses are ± standard error of mean.

Farmers in the Thulokhola watershed perceive that they will have a very bleak future due to the changes in rainfall, the occurrence of drought and natural hazards, the overall degradation of the natural resource base, and the drying up of water sources. Over 90% of the respondents (n = 82) stated that they expect decreased rainfall, increased temperatures, and more erratic rainfall in the future, which will adversely impact their natural resources and livelihood. Nearly 90% of the respondents stated that these changes in rainfall and temperature (especially due to drought) will result in adverse impacts on forest resources, wildlife, crop production, crop yields, and livestock production. While 87.6% of the respondents mentioned drought as the major factor affecting their daily life, the remainder mentioned temperature rise, extreme rain events, landslides, and hurricanes as their major concerns for the future. About one third of the total respondents were worried about hurricanes that may blow off house roofs and destroy farm trees in the future. Farmers were also worried about future food crises. In relation to livestock production, 69.2% of the respondents (n = 91) stated that livestock production will decrease due to lack of labour, emerging diseases, fodder shortages, water shortages, and general lack of interest in livestock farming. However, 15.3% of the respondents expect increases in livestock production if they had access to improved breeds and sufficient water resources. While 55.4% of the respondents (n = 92) expect declines in forest resources, wildlife disappearance, and water shortages, about one third of the respondents believe that they will have increasingly degraded land in the future. Besides climate change impacts, farmers also perceive that factors such as forest fire, deforestation, illegal logging, road construction, unmanaged forest grazing, and overall lack of awareness and education will exacerbate further degradation of the natural resource base in the future, if appropriate actions and education are not immediately implemented. These results clearly show that farmers are quite concerned about their future situation in light of possible climate change impacts; however, according to Poudel et al. (2012a, 2012b, 2013b), farmers in this watershed are ready to take action for climate change adaptation if appropriate support, training, and educational opportunities are provided. In order to enhance climate change adaptation, it is critical to promote community capacity-building considering locally available natural, financial and human resources (Pokhrel and Pandey, 2011). Community capacity-building is an ongoing process and requires a high level of commitment of individuals, community organisations, businesses, academic institutions, governmental agencies, and other stakeholders (Poudel, 2012).

3.5 Livestock climate change adaptation

Climate change adaptation measures implemented by the farmers in the Thulokhola watershed can be grouped into the five categories: livestock management, crop production, drinking water supply, soil erosion control, and income diversification.

In livestock management, farmers have implemented several measures including decreasing animal heads, adding new animal breeds, stall feeding, planting grasses and fodder trees, storing feed for feed shortages during the year, and consulting veterinary services and administering drugs to their animals (Figure 4). They have preserved fodder trees such as *tanki* (*Bauhinia purpurea* L.), *kutmiro* (*Litsea polyantha* Juss.), *khanayo* (*Ficus cunia* Buch.-Ham. ex Roxb.) in terrace risers despite crop losses. Some of the recently introduced forage species in the farms, in a limited scale, included napier (*Pennisetum purpureum*), stylo (*Stylosanthes guianensis*), and oats (*Avena sativa*). Farmers also ensure future planting of corn, wheat, and millet crops so that livestock get crop residue as feed. Purchasing fodder and forages, feed, rice straw and other feed stock for their animals, collecting fodder and forages from forest and community forest, collecting small grasses from terrace risers and edges of the fields (if available), and bringing animals (especially cattle and goats) to graze on more distant pastures were other measures undertaken by local communities for coping with climate change impacts in this watershed. Farmers also keep rice straw and corn husk leaves for the shortage period. They admitted that they had fed low quality feed to their livestock during these seasons. Farmers in the Thulokhola watershed have also constructed shade areas for daytime resting and have planted trees around their houses as additional measures for climate change adaptation, and have given frequent baths to the buffalo to protect them against heat. The proportion of respondents who have made some changes on their cattle production practices in the past ten years in the upper, middle and the lower elevations respectively were 52.7%, 64.3% and 67.8%. Similarly, the proportion of surveyed respondents making changes in buffalo production for the upper, middle and the lower elevations respectively were 76.3%, 89.3%, and 83.9%, and for goats production respectively were 78.5%, 96.4% and 87.1%. These results clearly indicate a large proportion of livestock producers have been making changes to their production practices in the past ten years, and relatively more farmers in the middle and the lower elevations have made such changes than in the upper elevation. Also, a relatively higher proportion of farmers had made changes in goats production practices in the past ten years compared to cattle and buffalo production practices. With regard to the reasons for introducing these livestock production practices in recent years, farmers cited insufficient labour, loss of pasture land, limited feed supply, new diseases and parasites, droughts, and water shortages (Figure 5). In the lower elevation, insufficient labour was cited as the main reason for changing production practices by as high as 35.5% of respondents for cattle, 51.7% for buffaloes, and 35.5% for goat production. Loss of pastureland was cited as a major reason for changing practices in the lower elevation by 29.3%, 29.1%, and 19.3% of the respondents, respectively, in cattle, buffalo and goat production in the past ten years, and 32.3% of the respondents cited water shortage as one of the major reasons for changes in buffalo production practices. Farmers in the lower elevations are experiencing more shortages of farm labour, loss of farm pasturelands, and shortages of water compared to farmers in the middle and the upper elevations.

Figure 4 Changes made in livestock production practices over the past ten years in the Thulokhola watershed, Nuwakot, Nepal

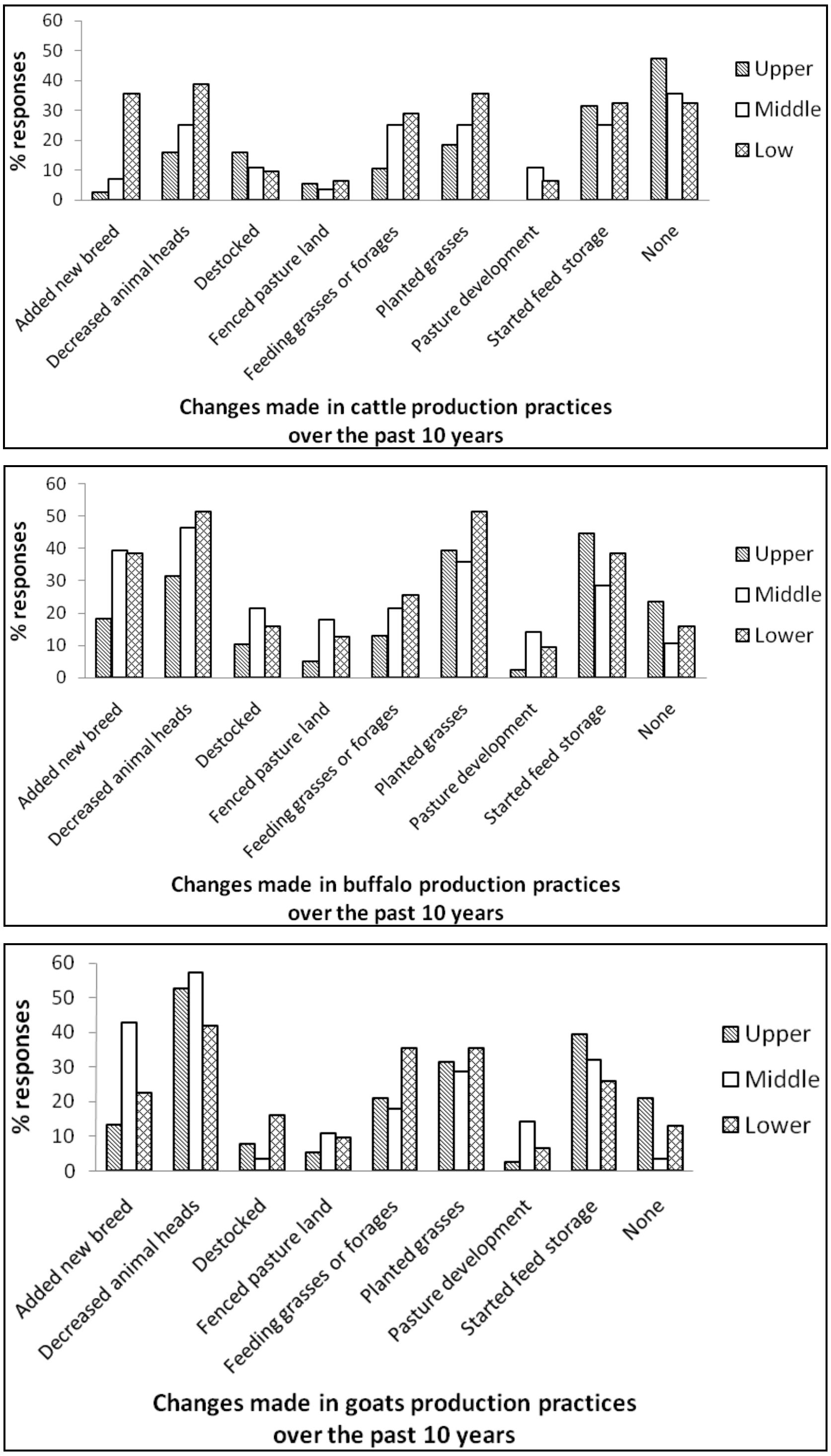
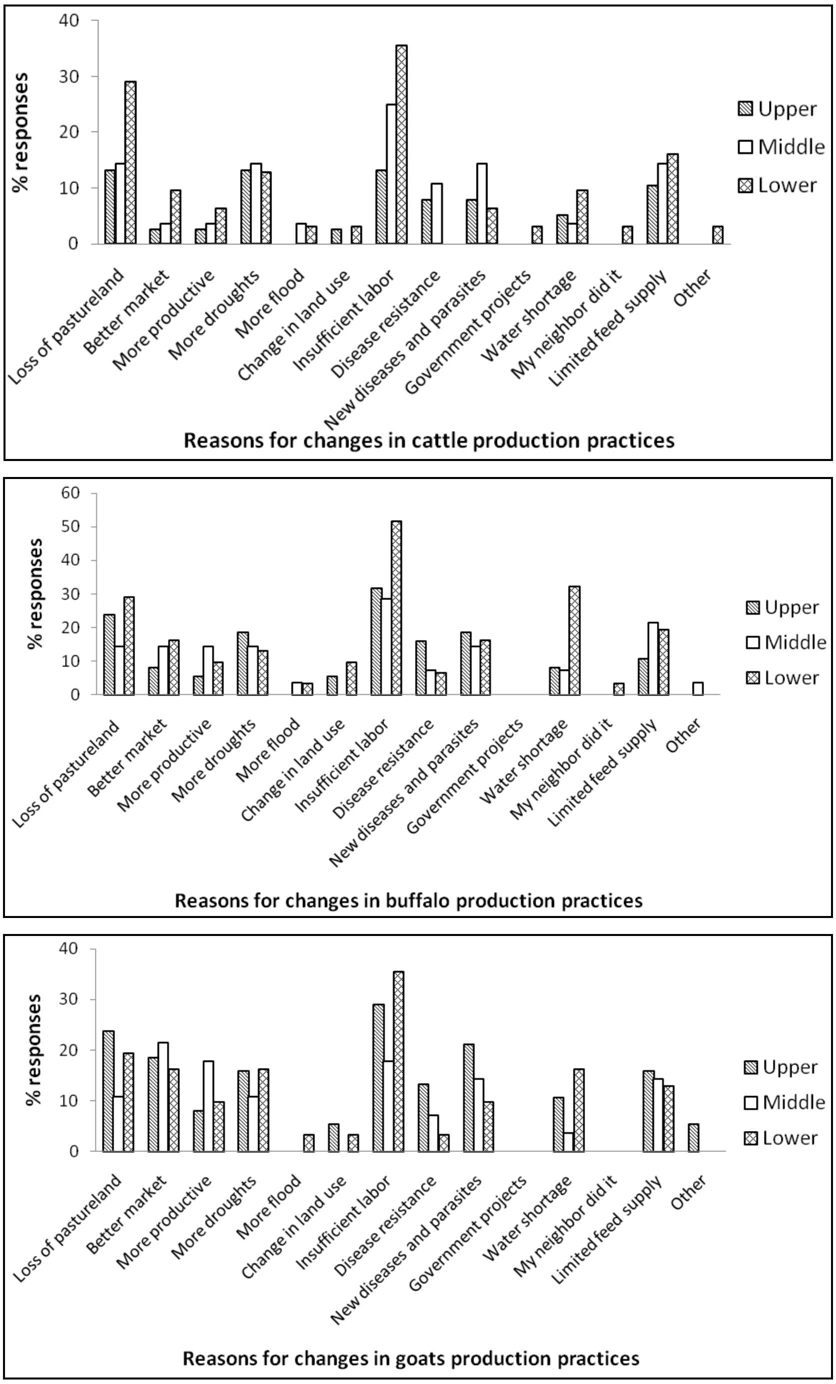


Figure 5 Reasons for changes in livestock production practices over the past ten years in the Thulokhola watershed, Nuwakot, Nepal



To cope with climate change impacts on crop production, farmers in the Thulokhola watershed have constructed ponds to collect irrigation water, have increased application of herbicides, chemical fertilisers, and pesticides on crops, have introduced hybrid seeds, and have started planting wheat crops, and in some cases have stopped planting corn due to drought conditions. For irrigation water, they have tried (in limited scale) pumping water and drip irrigation. These adaptation measures are at a limited scale and apparently have not been able to impact the production system sufficient to compensate for climate change impacts in any significant way. Similar to the Thulokhola watershed communities, farmers in Chitwan, Nepal, have also undertaken several climate change adaptation strategies including the replacement of rice crop with maize, fruits or vegetable crops, intensive farming by increasing the number of crops per year on a piece of land, income and agricultural diversification, groundwater utilisation, planting trees on farmlands, public awareness and developing and implementing climate change adaptation watershed plans (Gurung and Bhandari, 2009).

To augment their drinking water supply, residents in the Thulokhola watershed have accomplished a number of community improvements to the drinking water supply (i.e. constructing community ponds and water storage tanks, installing pipelines, digging shallow wells), as well as managing community forest, planting trees in public spaces, and raising community awareness. In some cases, they have planted stinging nettle (*Urtica dioica*), locally known as *sisnu* (plants that deter human activities) around water sources, practiced rainwater harvesting, controlled water flow, practiced judicial use of water, and have attended community workshops on water conservation practices. Despite these efforts, drinking water shortages remain a persistent problem in the watershed. Although water pipes were installed in many localities, minimal flow from the faucets were observed suggesting problems with these water sources. Degraded surface water quality due to very high levels of fecal coliform, turbidity, and phosphate in the watershed (Poudel et al., 2012b) is a matter of another environmental and health concern.

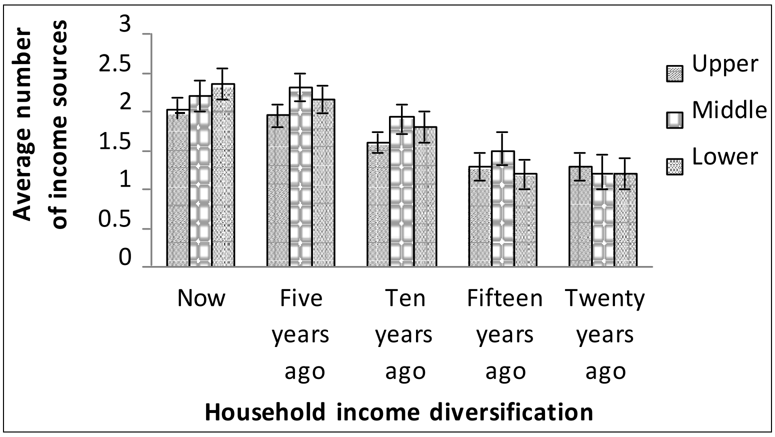
Table 6 Percent responses in relation to various soil conservation measures that have been implemented by landowners in the Thulokhola watershed, Nuwakot, Nepal

	Upper elevation	*Middle elevation*	*Lower elevation*
Planting trees	26.3	17.9	38.7
Stone walls	23.7	21.4	32.2
Netting	5.2	0	3.2
Diversion ditches	21.1	14.3	12.9
Fencing	0	7.1	9.7
None	52.6	60.7	29.1

For soil erosion control, farmers have planted trees in the farm lands, constructed stone walls and diversion ditches, have installed erosion control nets, and have fenced out the erosion prone areas of their farms (Table 6). It is important to consider here that more than half of the surveyed households in the upper elevation, 60.7% in the middle elevation, and nearly one third of the surveyed households in the lower elevation have not implemented any erosion control measures in their fields. This large number of farmers not implementing erosion control measures is certainly a matter of great concern, especially in such a sloping and agricultural watershed. By implementing appropriate water conservation practices in their farm lands, the local communities can retain runoff water for future use or they can enhance groundwater recharge. If the groundwater recharge zones are identified in the watershed, the diversion ditches can be constructed in such a way that the runoff water is diverted to these areas so that the aquifers can be recharged and groundwater becomes, to some extent, a viable source of drinking and irrigation water in the watershed. This requires a better understanding of the groundwater hydrology and aquifer recharge system in the watershed.

The Thulokhola watershed communities are also responding to climate change impacts by diversifying household incomes (Figure 6). In the past five years, the average number of sources of income per household has increased to more than two as opposed to less than two ten years ago. Major sources of household income in recent years include selling agricultural products, selling livestock products and livestock, earning daily wages, setting up small businesses, and pursuing part-time employment. For diversification of their household incomes, some farmers in the watershed have taken jobs outside, initiated poultry farms, practiced commercial agriculture, and made handicrafts. As diversification of household income is one of the major indicators of community resiliency, it is important to consider household income diversification measures as part of an effective climate change adaptation strategy.

Figure 6 Household income diversification over the past 20 years in the Thulokhola watershed, Nuwakot, Nepal



4 Conclusions

Smallholder mixed-farming livestock production system in Nepal is struggling for its survival due to climate change impacts and other factors. Smallholder mixed-farming system varies greatly at the farm level in relation to the level of intensification, livestock composition and stocking rate, resource utilisation, adoption of agricultural practices, and farm productivity.

Factors associated with the farm-level variability of this production system include land types (irrigated vs unirrigated), land holding size, availability of fodder and forages on farm lands, family size, household income diversification, number of livestock owned, and forest resources. It is necessary to consider these factors while designing or implementing climate change adaptation strategies for a successful livestock climate change adaptation especially in the mid-hill region of Nepal. Farmers have perceived widespread impacts of climate change in recent years. These impacts include drought conditions, erratic rain events, drying water sources, and rising temperatures. They have also perceived serious decline on forest resources, soil quality, and animal health in the recent years. Although farmers can relate the problems that they have been experiencing in the system reasonably well, there is a lack of scientific understating and explanation of the problems they are facing. Nonetheless, they have tried implementing some measures such as water storage tanks, water pipes, adding new breed of livestock, planting grasses in the farmlands, storing feeds, and consulting veterinary services and administering drugs for livestock climate change adaptation, they are limited and lack scientific rigors specifically for complex issues such as animal health and productivity, soil and water conservation and soil fertility management. Farmers have found it much more difficult to ameliorate livestock issues like diseases, parasites, delayed pregnancies, and breeding difficulties. In order to enhance livestock climate change adaptation and sustainable production in the smallholder mixed-farming system, it is important to have comprehensive and holistic climate change adaptation strategies that pay attention to the improvement of land quality (*khetland* and *bariland*), agroforestry interventions, soil and water conservation, income diversification, groundwater utilisation, forest development, improvement on animal health and breeding conditions, feed supply, community capacity-building, and infrastructural development.

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