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FULL-LENGTH RESEARCH ARTICLE

Agro-Biodiversity Management: Using Indigenous Knowledge to Cope with Climate Change in the Middle-Hills of Nepal

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Abstract A survey was conducted to explore people's indigenous knowledge in assessing the management and farming tactics of agro-biodiversity as adaptation strategies to climate change impacts on farms in the Pokhare Khola watershed in the Middle-Hills of Nepal. People observed the effects of decreasing rainfall, prolonged air temperature with intensity, short and warm winter with insufficient post-monsoon rainfall, and seasonal changes in rainfall patterns. Indigenous management techniques involved the modification of cropping pattern and season, introduction of new farming strategy (over 95 % farmers), approaching irrigation, and managing water from spring, wells, and carrying water from long distant area. The interchanged pattern (paddy–vegetables–paddy) from previous pattern and new introduced pattern (paddy–vegetables–fallow) were documented as popular in leveled terraced fields (*khet*). During survey in 2010, maize–vegetables pattern has become adapted instead of maize–millet pattern in around the homestead areas (*bari*). People perceived that short winter with insufficient rain declined wheat (*Triticum aestivum*) and changed annual rainfall pattern and water shortage lowered the millet (*Elusine coracana*) production. The use of improved varieties of plants, goat keeping, and planting fodder trees on *bari* were also perceived as coping strategy.

Keywords Cropping pattern · Diversification · Production · Rainfall

Introduction

Nepal is a small country with an estimated population of 29 million people [8]. The complementary relationship of crop, livestock, and tree components to fulfil the livelihood needs of resource-poor farmers and maintain ecological stability is paramount in the "Nepalese Hill Farming System," which offers the greatest ecosystem and species diversity in the Middle-Hills among the five physiographic zones of Nepal [14, 21, 24]. Around 80 % people are engaged in subsistence hill farming [9]. However, warming in Nepal has been much more pronounced with higher than the global average of 0.74 °C over the last 100 years in the Middle-Hills and the high Himalaya than in the Terai and Siwalik regions [19]. This is also where the population density is highest and consequently where vulnerability to climate change is most pronounced. Therefore, poor, marginalized, and disadvantaged people are less resilient to climate change [10]. Hence, fragile livelihoods and the vulnerability of hill biodiversity, ecosystems have highlighted the necessity for an assessment of indigenous knowledge on climate change with its effects and adaptation in the farmland of the Middle-Hills of Nepal. Therefore, local level management of agro-biodiversity around them might be one of the important adaptation strategies for farmers [12].

Conservation of agro-diversity in Nepal is based on diverse farming systems built upon indigenous knowledge, innovations, and experiences adapted by farmers for

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generations [10, 25, 38]. Thus, farmers with traditional farming systems incorporating in situ conservation (diversity, integration, and conservation) are contributing to agro-biodiversity [38]. Indigenous in situ conservation of agro-biodiversity is strength of Nepalese agriculture, which maintains crop and species diversity and conserves genetic resources [37]. Though numerous papers have revealed the importance of conservation of agro-biodiversity, much still needs to be learned about the utilization and management of agro-biodiversity, natural capital as adaptation strategy to climate change [31, 41, 42]. For this reason, society will need to invest more in agro-biodiversity research for both management and conservation of agro-biodiversity.

Indigenous knowledge—the wisdom, knowledge, and practices of indigenous people gained over time through experience and orally passed on from generation to generation—has over the years played a significant part in solving problems, including problems related to climate change [13]. The understanding about climate change and its response mechanisms to impact are likely to help in formulating the management strategies like adaptation, which can be integrated into development policy and planning [15]. Indigenous communities that live close to natural resources often observe the activities around them and are the first to identify and adapt to any changes. Indigenous people have used biodiversity as a buffer against variation, change, and catastrophe in case of failure of one crop as if another crop will survive [30]. Therefore, it is importantly needed to integrate the indigenous knowledge in such communities with scientific knowledge filtered through indigenous culture and language toward addressing adaptation strategies to vulnerable livelihoods to climate change [40].

Adaptation is adjusting to the natural or human system by learning to cope with temperature increases, floods, and other climatic risks and hazards associated with climate change [27]. Since Nepal's contributions to global greenhouse gas emissions (0.025 %) are relatively insignificant, therefore adaptation is more relevant [29]. However, small-scale, local level disturbances have a greater cumulative impact in terms of casualties than national level [2]. Moreover, a majority of the population is exposed to multiple stresses such as poverty and low adaptive capacity to climate change impacts. Therefore, local level copings options should be identified and prioritized for planning of adaptation through agro-biodiversity resource management among different adaptive ways [36]. While the importance of indigenous knowledge in the design and implementation of sustainable development projects, little has been done to incorporate this into formal climate change situation [31]. Incorporating local knowledge into climate change policies can lead to the development of effective adaptation strategies that are cost-effective, participatory, and sustainable [28]. Therefore, this study assesses management strategies of agro-biodiversity initiated by rural communities in the Pokhare Khola watershed of Middle-Hills of Dhading district in Nepal to cope with the impacts of climate change.

Materials and Methods

The study site is located about 60 km west of the Kathmandu. Geographically, it lies between 27°46/28/N and 27°48/06/N latitude and 84°53/32/E and 84°55/11/E longitude [9]. The Pokhare Khola watershed lies in Pida village of Dhading district in the Central Middle-Hills of Nepal from 400 m in the valley bottom to 800 m on the hill slopes which represents the "middle mountain farming system" (Fig. 1). The climate is sub-tropical with mean monthly temperature ranging from 13 to 27 °C, mean monthly rainfall from 7 to 341 mm, and average annual rainfall 1,699 mm, more than 80 % of which occurs from June to September as recorded at the nearest meteorological station of Dhunibeshi 30 km away. There are three distinct seasons: rainy (wet), winter, and hot or humid summer [34]. Cambisols and Luvisols make up the dominant soils in the study area, and the terrain is steeply sloping [35].

The major land uses in the study area were forestry and agriculture. Forest land covers about 55 % of the watershed area and is an integral part of the farming system. Two main cultivation systems are *khet*, which covers about 10 %, and *bari* 35 % of the watershed area. The *khet* land consists of bounded and leveled terraces, which are generally located near streams away from households. *Bari* land includes *bari* (around the homestead areas) and *pakhabari* (separate plots up to 30 min walking distance) [35]. This farming system includes trees, crops, and livestock. Farmers cultivate cereal and vegetables crops in their *bari* and *khet* land. *Khet* is the most valuable land as it yields two major cereal crops, rice and wheat, annually with irrigation facility, and *kharbari* land is set aside for grass production for roofing thatch and livestock feed [5].

A survey was conducted, stratified by villages at various altitudes (all over 400 m and six at 600 m and higher) in the year of 2010. Eight villages in Wards 2 and 3 in the Pokhare Khola watershed were selected, with random sampling of farm households within villages. A total of 148 farm households were selected, from 340 households. The head of the selected households (assumed to be the decision-maker in farming) or household members of 40 years and above were questioned, on the assumption that younger people would have less experience of climate changes and fewer relevant observations. Sample households of each village were selected proportionately according to the number of total households, supplied by Village Development Committee (VDC) offices. Two trained enumerators conducted personal interviews. Data were collected on climate change, its responses to agro-biodiversity, regular weather condition, physical features, and management and farming strategy.

Moreover, a total of 40 interviews of which five from each village and the group discussion were conducted with six groups each vary with 8–10 participants. The purpose of group discussion was to focus about climate, particularly, temperature increase, rainfall pattern and changes in natural phenomena, and utilization and management pattern of crop, trees, and livestock to adverse climate. They were mainly, experienced local farmers who could attest to noticeable changes in rainfall and temperature, and traditional elders and leaders who were involved in community decision-making.

Farm Area Categorization

Farms were categorized into four groups—marginal, small, medium, and large—based on the area of farmland owned (Table 1). The definition of farm sizes was agreed with the farmers during the survey.

Results and Discussion

Effects of Climate Change

The people in the study area might not understand the concept of global warming or climate change, but they could observe and feel the effects of decreased rainfall, increased air temperature, and increased sunshine intensity and seasonal changes in rainfall patterns. Drying up of water sources and soil erosion were appeared as perceived threats. At many places, water pools for livestock had disappeared. Similar stories were shared across rural Nepal and in Uganda where water springs and rivers were slowly degrading [3, 11]. Meteorological data are to a large extent consistent with the farmers' experiences and observations in this study site [3].

According to many peasants, agricultural crops and livestock due to outbreaks of pests [e.g., pest attack in lichi

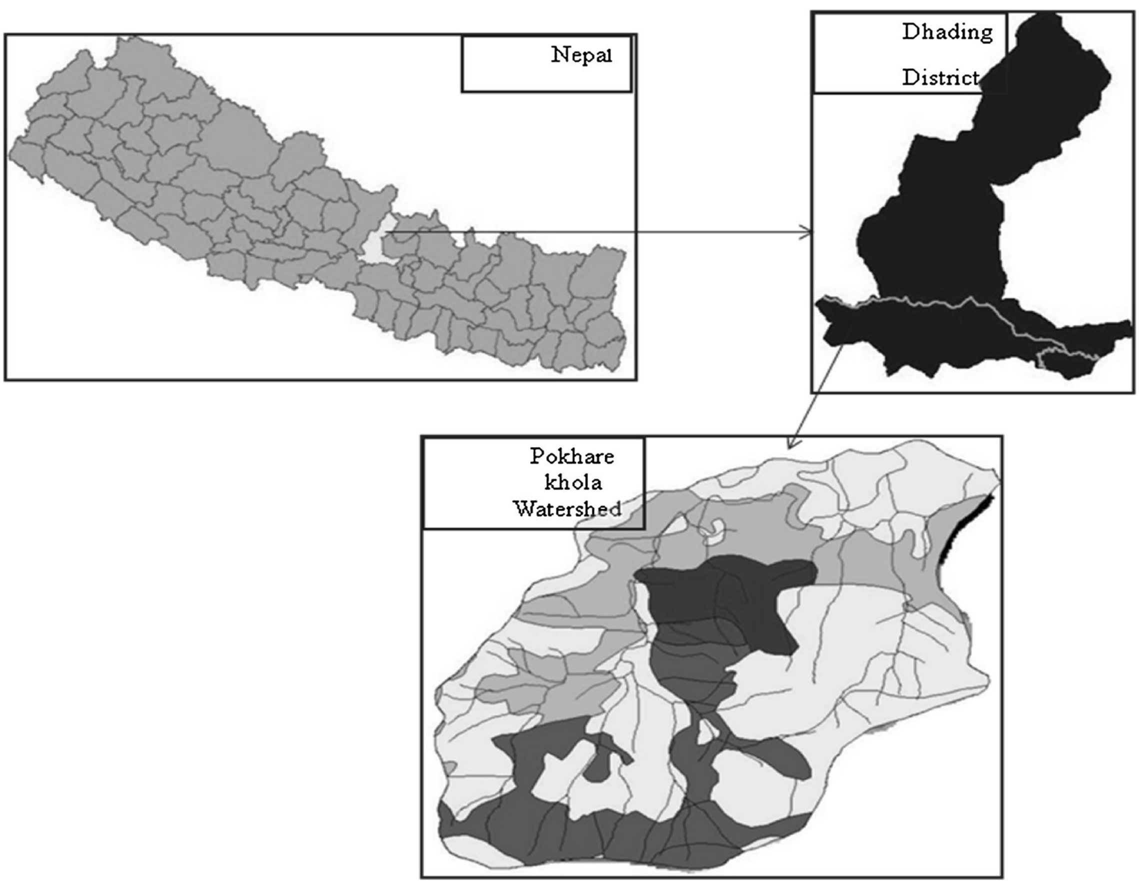

Fig. 1 Location map of Pokhare Khola watershed of Middle-Hill of Dhading district in Nepal

(*Litchi chinensis*)] and diseases, and invasion of new aggressive plants and weeds, grasslands were in critical condition. Farmers' observations in the field provided evidence of invasive species like Nilgandhe (*Ageratum* spp.), kalo banmara (*Ageratina adenophora*), and weeds. These were considered as a one of the major reasons of reduction of cereal crops like rice, maize, and vegetables production, which is agreement with [5]. Farmers also stated that increased unpredictability and intensity of weather events and hazards including insufficient monsoon and post-monsoon rain had disrupted rain-fed agricultural system, even causing loss of local landraces of crops, which require sufficient and timely rainfall (Table 2).

Management Techniques and Farming Strategies of Agro-Biodiversity

There were incidents of temperature increase, drought, delay monsoon break out and early break off, and shorter and heavy rainfall as impacts of climate change. Formal adaptation measures entail supplementation of indigenous management approaches and introduction of new approach as management and farming strategies in order to address these changes and impacts on regular weather, rain, vegetation and farming, physical features, and above all on livelihoods through supreme and sustainable utilization of agro-biological resources on and around the farm. Indigenous management supplementation involved the modification of cropping season, introduction of new farming strategy (over 95 % farmers), approaching irrigation, and managing water from spring, wells, and carrying water from long distant area. Thus, modified management and enabling sustainable use of agro-biodiversity had a huge potential for developing win–win strategies with multiple benefits such as coping to climate change, magnifying biodiversity, and improving human well-being [12]. Accordingly, new adapted farming strategies such as, introduction of improved varieties of plants (around 90 % farmers), new cropping pattern, crop diversification, intercropping, mixed cropping and goal keeping, planting fodder trees etc. Figures 2 and 3 are consistent with the study conducted in Asia [36].

Adaptation Toward Change in Cropping Pattern

One important step in coping with the climatic hazard is the development of an early warning system for the prediction or forecast of the event through indigenous knowledge based on predicting weather and climate [1]. Farmers have developed intricate systems of gathering, prediction, interpretation, and decision-making in relation to weather. Farmers were known to make decisions on cropping patterns based on local predictions of climate, and decisions on planting dates based on complex cultural models of weather. Around 11 % of farmers did not have *khet*. Farmers who followed the previous pattern were considered as the farmers with unchanged

Table 1 Household categories based on the area of farm

Farm category	Farm area (Ropani)[a]	Farm area (ha)
Category 1 (Marginal farm)	Equal or less than 5	≤0.25
Category 2 (Small farm)	6–10	0.26–0.5
Category 3 (Medium farm)	11–20	0.51–1
Category 4 (Large farm)	More than 20	>1

[a] 20 Ropani = 1 ha

Table 2 Perceived impacts of climate change on different areas of ecosystems

Aspects of climate change and its impacts	Observed changes
Climate change	Hotter and longer summer
	Shorter and warm winter
Rain	Short but heavy downpour
	Insufficient rain during winter
	Delay of monsoon break out and early break off
	Unpredictable rainy season
Physical changes	Water shortage in spring
	Less soil moisture
	Soil erosion
(Agro-biodiversity) Vegetation and farming	Invasion of aggressive plants and weeds in farms
	New diseases, pests, insects in crops
	Grass shortage
	Big livestock reduced

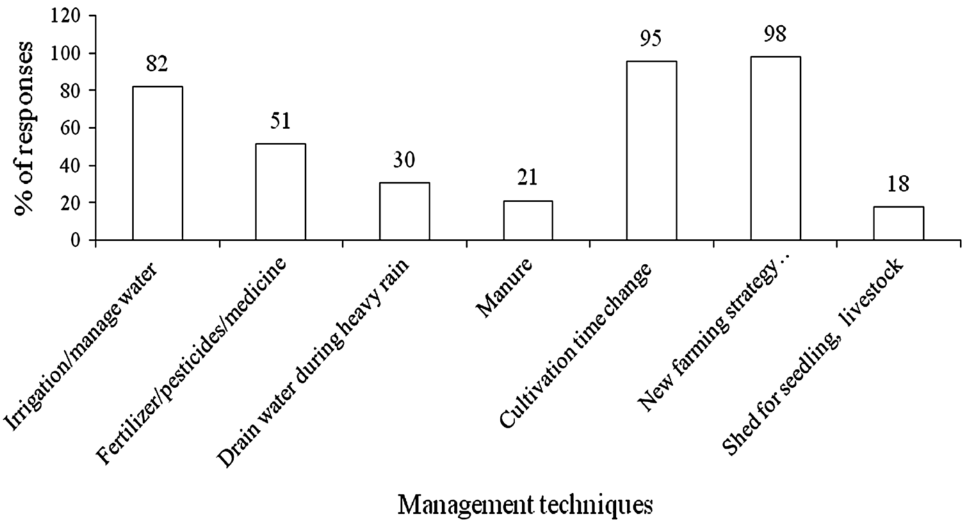

Fig. 2 Various management techniques executed by farmers

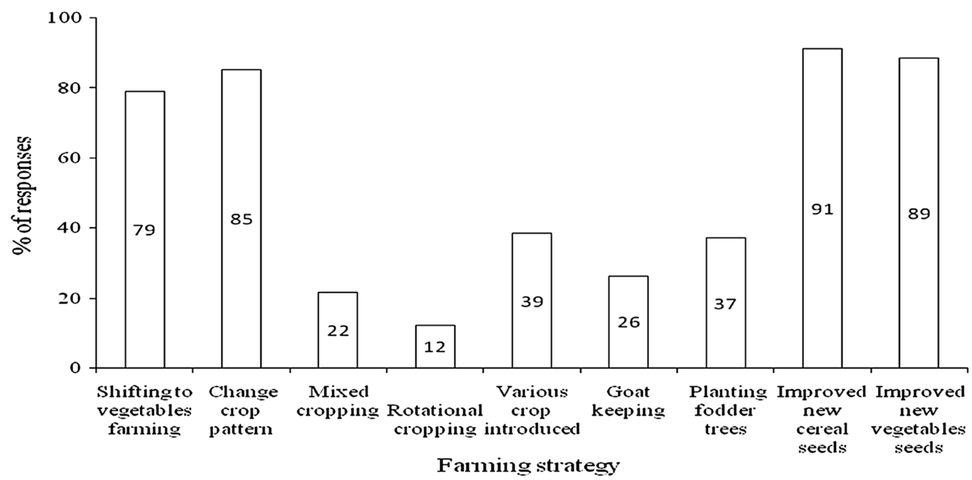

Fig. 3 Various farming strategies practiced by farmers

pattern. In case of cropping pattern noticed during survey in 2010, type "A" & "B" were being also practiced in the past (type "1" & "2") and past type "3" & "4" were collectively considered as type "C." The new pattern type introduced was "D." In connection to this, paddy–vegetables–paddy (interchanged pattern) and paddy–vegetables–fallow (new pattern) were appeared as popular pattern. Most of the farmers introduced vegetables cultivation and shifted to rice cultivation instead of wheat in *khet* for last 8 years. Consequently, the wheat cultivation declined with compared to the past with contribution of only 13 % of farmers during survey. The perception toward changing from wheat to rice cultivation (shifted "4" to "A") was short winter with insufficient rain (Tables 3, 4). They also thought that fertility can be maintained leaving as fallow for one season instead of growing wheat, which was useful for rice production as main crop. Farmers (mainly *Brahmin, Chettri*) with comparatively large- and medium-sized area were leaving land fallow for one season during water shortage.

There had been declined in upland paddy and millet cultivation in the *bari* since 2002. In 2010, maize–vegetables pattern was appeared as popular instead of maize–millet pattern in water and soil moisture stressed condition (Tables 5, 6). In Ramche of Rasuwa district of Nepal, focus was given on vegetables farming instead of cereal crops [29]. Jones and Thornton (2003) [18] mentioned that reduction of maize production in the tropics will be by 10 % on average. It can be postulated that changes in rainfall pattern and amount, and changes in temperature will influence crop growth through changes in soil water content [39]. Therefore, changes in cropping pattern seemed to be relevant to the site. A total of 85 % of interviewed farmers were able to change past cropping pattern and the rest was not able to change. Regarding the time since when they first introduced the pattern, it can certainly be said that most farmers (71 %) introduced and adapted new pattern in 2004–2006, followed by 22 % in 2008–2009 and by 7 % in 2001–2003, respectively.

Table 3 Percentage of user of present (in 2010) and past cropping pattern in *khet*

	Present cropping pattern type				
	A	B	C	D	E
% of user	27	33	13	15	12
	Past cropping pattern type				
	1	2	3	4	
% of user	30	4	9	57	

A = Paddy + paddy, B = Paddy + vegetables + paddy, C = Paddy + wheat + maize/paddy, D = Paddy + vegetables + fallow, E = No Change

1 = Paddy + paddy, 2 = Paddy + vegetables + paddy, 3 = Paddy + wheat + maize, 4 = Paddy + wheat + paddy

Table 4 Shifting (%) of past pattern into present (in 2010) pattern in *khet*

Past pattern (%)				Distribution of past pattern into present pattern shifted (%)				
1	2	3	4	A	B	C	D	E
30				–	33	15	24	28
	4			33	–	–	50	17
		9		17	17	41	17	8
			57	43	37	8	8	4

A = Paddy + paddy, B = Paddy + vegetables + paddy, C = Paddy + wheat + maize/paddy, D = Paddy + vegetables + fallow, E = No Change

1 = Paddy + paddy, 2 = Paddy + vegetables + paddy, 3 = Paddy + wheat + maize, 4 = Paddy + wheat + paddy

Table 5 Percentage of user of present (in 2010) and past cropping pattern in *bari*

	Present cropping pattern type				
	A	B	C	D	E
% of user	53	19	3	11	14
	Past cropping pattern type				
	1	2	3		
% of user	60	34	6		

1 = Maize + maize/millet + vegetables, 2 = Maize + maize + millet, 3 = Maize + millet/vegetables + fallow

A = Maize/vegetables + vegetables + vegetables, B = Maize + millet/other cereal + vegetables, C = Maize + millet/vegetables + fallow, D = Maize + maize/other cereal + vegetables, E = No change

Shifting to Vegetables Cultivation and Crop Diversification

Farmers were adapting to the constraints like water shortage, droughts, crop losses, or failure. Crops that thrive well under the prevailing conditions were increasingly being planted in areas that previously did not support their cultivation. Trend of farming explored the gradual increase of vegetables farming since 2004. This is consistent with another study conducted in this area by Baul et al. (2013) [4] where 18 types of vegetables, of which some principal crops—including cauliflowers (*Brassica oleracea*), beans (*Pheseolus vulgaris*), bitter gourd (*Momordica charantia*), gourd (*Cucurbita pepo*), and brinjal (*Solanum melongena*)—were cultivated by most of the farmers. As a consequence, wheat and millet production declined in *khet* and *bari*. This agreed with growing of blackgum and millet in place of rice in *khe*t when it had dried up for delayed rainfall [26]. Introduction of mixed cropping through encouraging crops diversification by mixed cereals and various types of vegetables (patterns B, D in *bari*) in their small patch of farmland was likely for promoting the food security from diverse products and making them more resilient to adverse climate condition (Tables 5, 6). Further,

Table 6 Shifting (%) of past pattern into present (in 2010) pattern in *bari*

Past pattern (%)			Distribution of past pattern into present pattern shifted (%)				
1	2	3	A	B	C	D	E
60			17	62	2	8	11
	34		46	24	4	12	14
		6	11	11	0	33	45

1 = Maize + maize/millet + vegetables; 2 = Maize + maize + millet; 3 = Maize + millet/vegetables + fallow

A = Maize/vegetables + vegetables + vegetables; B = Maize + millet/other cereal + vegetables, C = Maize + millet/vegetables + fallow; D = Maize + maize/other cereal + vegetables; E = No change

diverse cropping through mixing different types of cereal crops rather reduced susceptibility to pest and diseases. Thus, crop diversification was the indication of increased production enterprises per farm, which helps assure the crops against various types of risks [6]. Some also took initiatives to grow another crop in the same plot if one crop failed by sequential cropping which is in agreement with [24]. However, a total of 16 % did not change the cropping pattern. This was due to the insufficient knowledge defined as major reason (48 % farmers), followed by irrigation problem and water scarcity (35 % farmers) and insufficient land (17 % farmers). They perceived that changing pattern required more effort and knowledge and sufficient land as well. Therefore, they could have changed the pattern on trial basis, if there would have sufficient land.

Adaptation Toward Change in Cropping Season

Farming is sensitive to short-term changes in weather that affect the production of crops. The production varies with rain brought by monsoon which was observed in Nepal [23]. That's way another coping strategy to the seasonal change of climate was changing or/and adjusting the cropping time. Growing of rain-fed rice completely depends on when monsoon starts, so cropping times of rice and maize have changed to around a month later than the past owing to delay of monsoon. Accordingly, the rain-fed rice and maize cultivation commenced on Late June/July and Late July/August, respectively. Due to short and less post-monsoon (winter) rainfall, wheat cropping period (November/Early December–April) followed new cropping season (Late December–March/April), since wheat as winter crop requires some rainfall in winter. Regmi et al. (2009) [26] found the same type of pattern change of cropping season for maize and millet was postponed for 2 months, which coincide with the gradual reduction of millet cultivation in this study. On the other hand, the previous study observed pattern changes of cropping time in case of potato and maize 1 month earlier than before in Rasuwa district of Nepal [27]. Thus, this has become difficult to plan the cropping season to coincide with rain in ensuring maximum crop yield because of unpredictable and late commence of rainy season.

Introduction of New Crops and Improved Varieties of Plants

There was a growing demand of cultivation of new variety of seeds of rice and maize. Most farmers (92 %) preferred IV seeds of crops (maize, rice, and vegetables). However, a total of 84 % farmers raised the farming with introduced IV of rice seeds. Among 13 IVs of rice, the most commonly used were *surekha* and *Shankar*. A farmer could crop more than one type of IVs through mixed combination while some were cropping only single type (Table 7; Fig. 4). In this regard, farmers' perception appeared IV of seeds as fast and high yield, drought resistance, and time flexible of planting. However, few farmers reported that they were susceptible to insects, pests, and diseases with higher amount of chemical fertilizer and pesticides had contribution in lowering the land productivity. Locally bred varieties were well adapted to local climate [26]. Importantly, introduced IV of rice named—*surekha*, *shankar*, *tara*, *manisha*, and *sabitri* replaced LV of rice and hence, resulted in loss of landraces and genetic diversity in the study site. The intensified crop production by modern varieties of wheat and rice become untenable and might be vulnerable to changes in ecosystems [16]. These need to be investigated further to conserve the LV. Therefore, the conservation of LV of seeds and landraces adapted to the site to sustain the high productivity through reduced application of fertilizer is paramount.

Farmers argued that loss of top soil and intensive use of land with same crop again and again for years induced reduction of soil fertility. Farmers preferred cultivation of sandy land with to grow mostly tomatoes (*Lycopersicon esculentum*), pumpkins (*Cucurbita pepo*), and bitter gourd. And newly introduced crops like beans (*P. vulgaris*) grown in *bari* land to augment soil fertility. Farmers emphasized the change in cropping pattern by replacement with less water-required crops such as mustard (*Brassica* sp.) and tomato to ensure wise use of water. This corroborates with the study conducted in Mustang district of Nepal [10, 23] where, mustard, cauliflowers, chilli (*Capsicum annum*), tomato, and cucumber were adapted. Very few farmers started to plant bamboo, amriso (Broom grass) in degraded land like *kharbari* to make undesirable land to desirable land aim at mitigating grass shortage. This was also one type of adaptation by modification of strategy on the same plot of land.

Goat Keeping

Livestock husbandry was a vital component of farming system in the study area. Buffaloes and cows were kept mainly for milk, manure production and draught power; and goats for meat. Commonly, buffaloes were stall-fed all-round the year, and goats were grazed only during fallow and rain-free period. Cows were grazed all-round the year. But since last few years buffaloes and cows were appeared as big headache for farmers due to grass and fodder shortage in adverse climate during heavy rain and drought. Consequently, keeping big livestock has been seen as an expensive due to managing their voracious amount of feeds. In coping with this situation, goat keeping as small livestock seemed as a new strategy, since goats are fast growing and require small investment for fodder, water, and taking care. Another study in this area also revealed that farmers rear goats (6/household), cattle (2/household), and lowest number of buffaloes (1/household) with irrespective of farm category [4]. This finding corroborate with the study of SAGUN (2009) [29] in Rasuwa district of Nepal for chicken and goats, as these require less water [36].

Table 7 Farmers' usage of different improved varieties of rice

No.	Name of improved variety (IV) of rice	% of user
1	Surekha	78
2	Shankar	65
3	Tara	38
4	Lokanath	29
5	Sabitri	18
6	Jetho budo	12
7	Manisha	10
8	Kanchana	9
9	Boiswari	8
10	Surya	3
11	China bora	3
12	345	2
13	Joon	2
14	Unknown hybrid	8

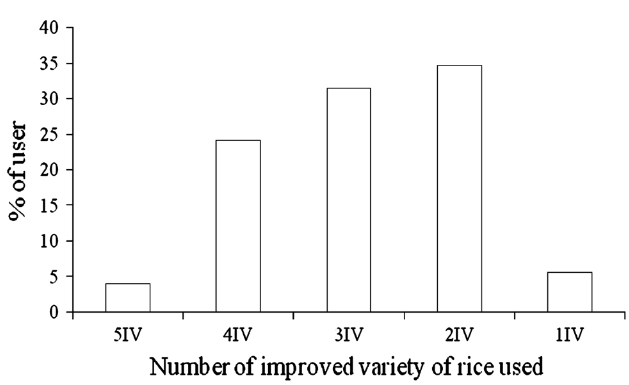

Fig. 4 Farmers' usage of mixed/single IV of rice * *IV* Improved variety, *5IV* 5 types of IV together used by same farmer

Introduction of Fodder Trees on Farmlands and Farmers' Preferences

A total of 64 % farmers planted fodder, followed by fruit tree species and multipurpose tree species (MPTS). Plantation of fodder trees have been designed as a new farming strategy in *bari* was mainly due to fact that to face the grass shortage problem, insufficient fodder supply from natural forest, and to provide shelter and bedding material for livestock in heavy rain and drought period. Only large farms had *kharbari* for grass production that now has become abandoned (Fig. 5). Trees like *Bauhinia purpurea* and *Leucaena leucocephala* of fast growing nature were documented as second important reason. Accordingly, Baul et al. 2013 [4] documented total 53 tree and one crop species including fodder, fruits, and MPTS on landholdings in this study site, out of which most abundant 10 species are fodder tree species except one fruit (banana) and one multipurpose species (Sal, *Shorea robusta*) indicating the importance of fodder species to the farmers. The findings are consistent with [7] who also found evidence of increased number of fodder and other trees on farm lands due to reduction of fodder supply from forest area. Several studies indicated improvements in tree growing on the farmlands to compensate the loss of trees in the forest [33] and hence, a key to the sustainable supply of fodder, fuel wood, and fruits in crisis like crop failure. But, farmers did not prefer presence of trees in the *khet* to avoid the shade to the paddy crop. They thought the attractions of birds in the presence of trees disturb the cereal crops. Few farmers opined about soil fertility loss because of water and nutrients uptake from soil and induction of pests and disease to crops on account of presence of trees with crops. *Khet* was the main source of annual food demand of rural households in the study area. Furthermore, large and medium farm owners had large *bari*, therefore, it was great

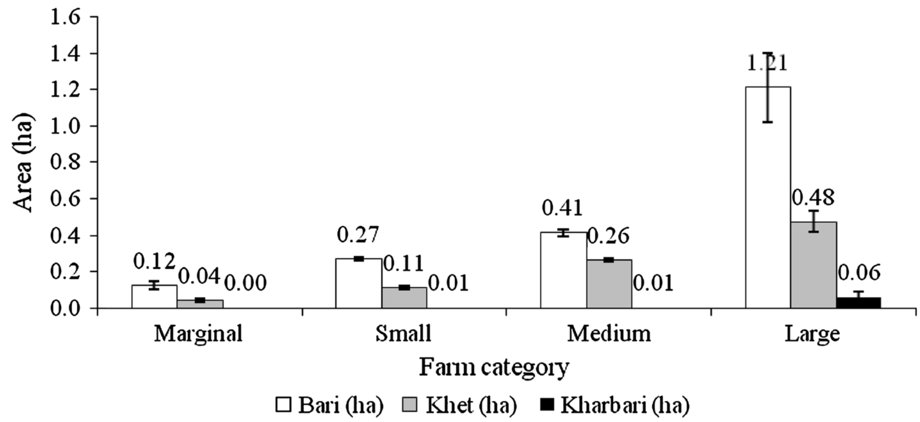

Fig. 5 Mean area of *bari*, *khet* and *kharbari* under different categories of farms. *Bars* represent ±SE

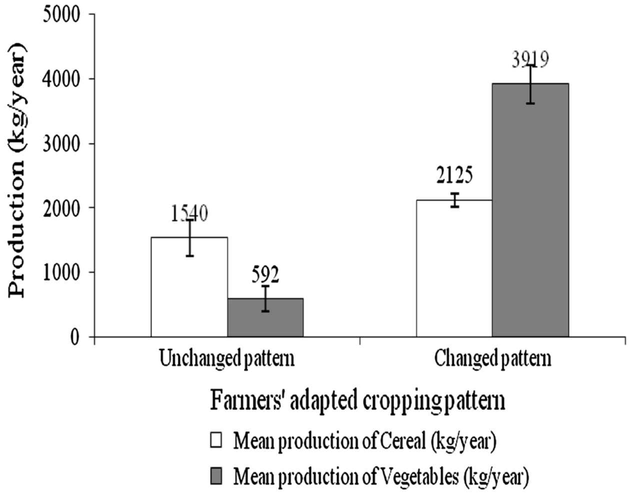

Fig. 6 Production of cereal and vegetables (kg/year) under changed and unchanged pattern group. *Bars* represent ±SE

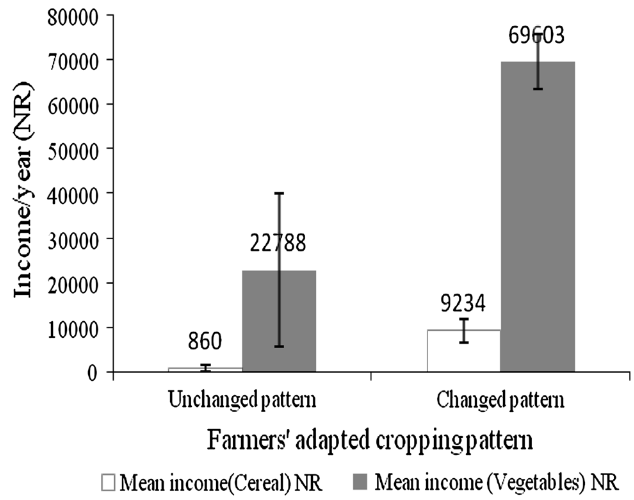

Fig. 8 Income (after home consumption) from cereal and vegetables (NR) under changed and unchanged cropping pattern. *Bars* represent ±SE * 72 NR = 1 $, Date of relevance: 30 July 2010

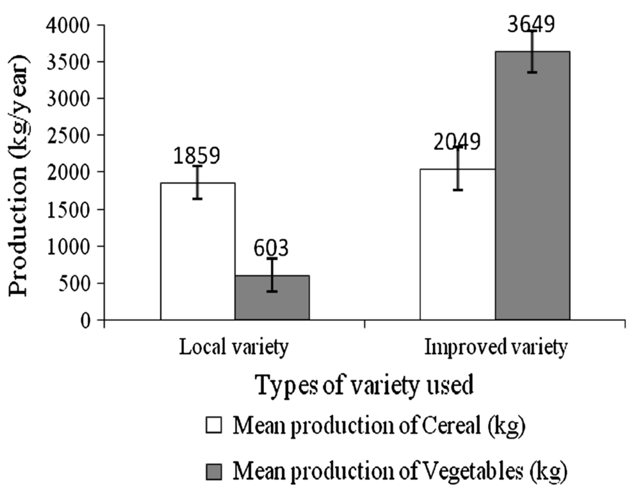

Fig. 7 Production of cereal and vegetables (kg/year) of local variety and improved variety users. *Bars* represent ±SE

scope to plant fodder trees. Hence, mainly high class ethnic groups *Brahmin* and *Chettri* under large and medium farm categories were likely to rear larger livestock (Fig. 5).

Production and Income Performance: Cropping Pattern Change, Variety Change

Farmers who adapted the new cropping pattern had both significantly ($p \leq 0.005$, 0.005) higher production and income from cereal and vegetables than who did not change. The income from cereal and vegetables sale was not considered as a production value for crops. This income represented after meeting their home consumption from cereal and vegetables crops. The adaptation of changed or new cropping pattern has increased the production 584 and 3,328 kg/year for cereal and vegetables, respectively. Nevertheless, within farms under unchanged pattern there had been higher production of cereal than that of vegetables which was opposite to farms under changed pattern. The significant difference of production and income generation after home consumption was likely an indication of using new or changed cropping pattern as effective technique. Farmers who cropped IVs of vegetables had higher significant ($p \leq 0.001$) production and income than who

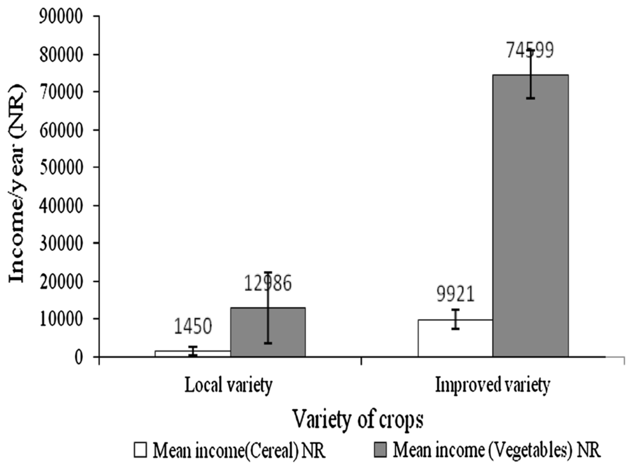

Fig. 9 Income (after home consumption) from cereal and vegetables (NR) under IV and LV users. *Bars* represent ±SE * 72 NR = 1 $, Date of relevance: 30 July 2010

cropped LV, however no significance difference ($p = 0.001$) was found for income from cereal between LV and IV users (Figs. 6, 7, 8, 9). The using IV could also be considered as adapted good technique that coincide with delineating the significant production increase using IV rather local bean crops in Columbia [17]. Therefore, introduction of new such techniques of conserving both species and genetic diversity was considered to signify their role in their livelihoods (Fig. 10).

There was no significant (Spearman's rho = 0.556, $n = 148$, $p \leq 0.01$) relation found between the size of farm and introduction of new cropping pattern and IV use. This indicated the practices of two techniques (new cropping pattern, IV) were not regulated by farm size. This agreed with study conducted by Mahesh (2000) [22] in Kerala revealing the choice of cropping pattern was not regulated by the size of the farm [22]. However, it could not but mention the one important thing that the application of these two techniques was interrelated which showed the significant relationship (Spearman's rho = 0.556, $n = 148, p \leq 0.01$) between them, meaning the changing cropping pattern had influence on the use of IV of seeds. This might be due to the case that improved seeds had time flexibility to grow any season; subsequently, cropping season and sequence of crops had ultimately changed.

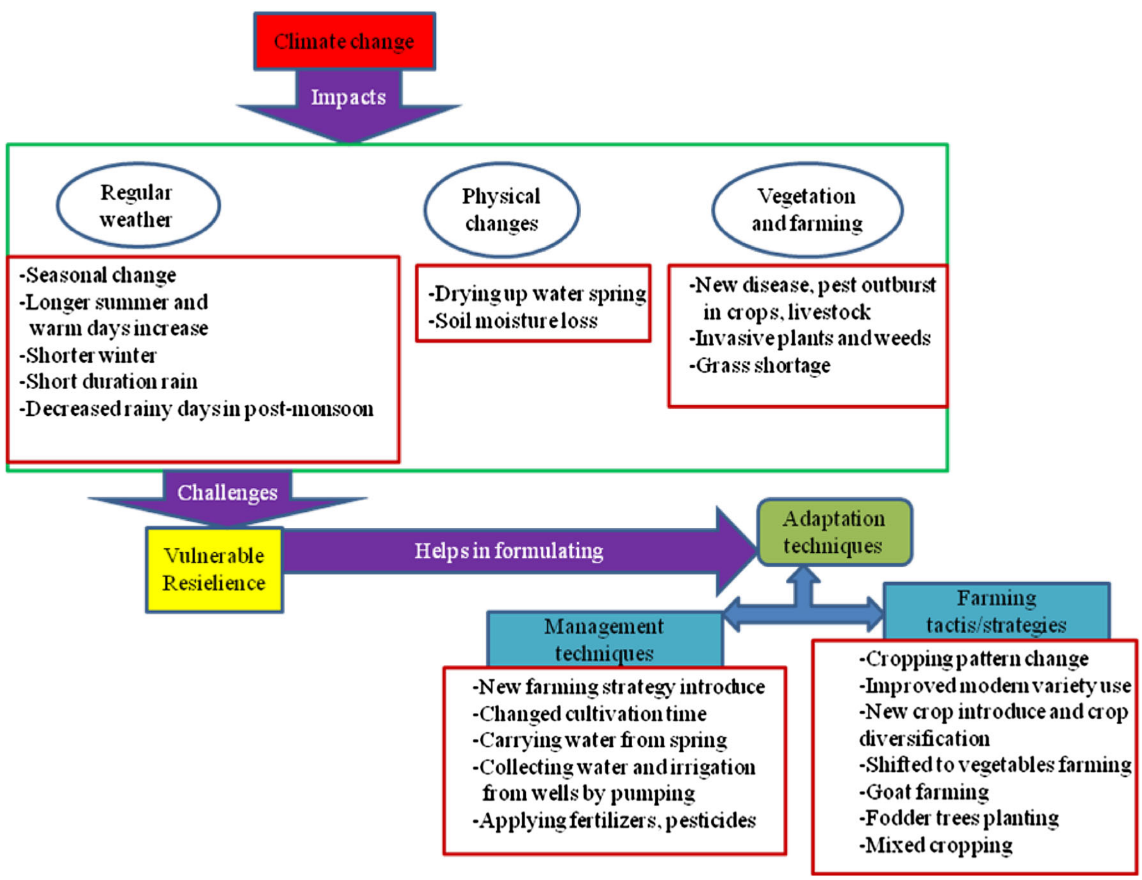

Fig. 10 Summarized presentation of climatic impacts and agro-biodiversity based adaptation in the study site

Conclusions

Local communities can understand the signal of changes in seasons over the period of years owing to their proximity to natural resources. Peoples were experienced with increased summer intensity, short and warm winter, short monsoon with unpredictable and erratic rainfall (short but heavy downpour), and seasonal changes in rainfall patterns. The peoples realized that drying up of water sources, pests, diseases, and weeds are major threats to their survival. The reduced grazing resources due to declined local grass species induced the reduction of big livestock. To adapt with this adverse phenomenon, they used to carry water from natural spring, collect and irrigate water from wells by pumping in dry period, adjusted cropping season, applied fertilizers and pesticides, and practiced new farming strategies. In coping with risk of seasonal change of rainfall, drought, and crop failure, people introduced diversified cropping and shifted to massive vegetables cultivation to make them more resilient. The interchanged and new introduced cropping patterns (paddy–vegetables–paddy, paddy–vegetables–fallow in *khet*; maize–vegetables in *bari*) since 2002 reduced wheat and millet production due to short winter and insufficient post monsoon and annual rainfall. The adaptation of use of drought resistant, high and fast yield IV of seeds, goat keeping instead of big livestock, and planting fodder trees on *bari* were also perceived as coping strategy. But local variety of seeds should be cultivated to preserve the land races and genetic diversity and trigger the land productivity discouraging chemical fertilization which opened up the new window for future research. Therefore, understanding of climate change and agro-biodiversity based adaptation must combine the objectives, empirical information and people's observations, and indigenous knowledge. On the other hand, non-indigenous knowledge is considered as alien, undervalued if these are communicated in unfamiliar ways in the communities or vulnerable groups [20]. Thus, the success of the use of indigenous knowledge in coping with climate change depends on a healthy relationship between scientific knowledge and traditional knowledge base system—which both have their limitations, especially in developing countries where technology for prediction and modeling is least developed, expensive, and time consuming. This is why policy makers and scientists should come forward to incorporation of people's traditional knowledge and wisdom into scientific explanation for efficient utilization and management of agro-biodiversity developing more effective strategies to cope with the risks of adverse climate.

Conflict of interest The authors declare that they have no conflict of interest.

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