TRADITIONAL CROPS FOR HOUSEHOLD FOOD SECURITY AND FACTORS ASSOCIATED WITH ON-FARM DIVERSITY IN THE MOUNTAINS OF NEPAL

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ABSTRACT

Traditional crops play an important role in household food security and livelihood needs of mountain communities, while at the same time safeguarding crop biodiversity for future generations. This study aims to analyse socioeconomic, farm-specificagro-ecological and market factors influencing cultivation and maintenance of crop diversity in Nepal. It used sample surveys of 328 households from mountains of Humla, Jumla, Lamjung and Dolakha districts in 2015. The sample survey was supplemented with participatory rural appraisals, field monitoring visits and local stakeholder consultations. Tobit regression model was used to assess factors driving household decisions to allocate area for production and maintenance ofon-farm diversity. Farm maintenance of crop diversity was related to household food sufficiency level of traditional crops. Factors influencing on-farm crop diversity and household food security varied with the crops, and mainly related with farmers' age, family size, farm size, agro-ecosystemand market factor. Future research and development interventions need to focus on diversity rich solutions and technologies tailored to specific crops, socioeconomic, market and farm-agroecology of the households enhancing household food security and management of mountain crop biodiversity.

Keywords: Crop biodiversity, food security, traditional crops, mountain agroecosystem

INTRODUCTION

The high mountain region of Nepal harbours globally important crop biodiversity of traditional crops such as buckwheat, naked barley, and different species of millet (finger, proso and foxtail), amaranth, bean and highland rice that have unique traits of cold and drought tolerance adapted to harsh risk prone marginal environments (UNEP GEF, 2013). These crops are cultivated over millennia by farmers and hence have helped to meet food security of marginalized communities even in the face of changing climate (Gauchan and Khanal, 2011; UNEP GEF, 2013). The intra-specific diversity of these crops is very high as most of these crops are either evolved or located

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at the center of diversity in Nepal Himalayas. Cold-tolerant rice is grown in Nepal (e.g. Chhumchaur, Jumla) at altitude 3030 masl, the highest in the world, with its very high cold tolerance ability. Buckwheat and naked barley are also grown at high altitudes near the snow line providing food and livelihood security to marginalized people living in harsh mountainous environments, where poverty incidence is the highest in Nepal (CBS, 2012; NPC, 2016). These traditional underutilized crops are intensively used by local mountain communities in many of the remote hills and mountainous regions, and contribute considerably to their site-specific food security, nutrition and adaptation (Joshi and Shrestha, 2018). They are nutrient dense and climate resilient crops, and provide food, fodder, nutrition, livelihood and ecologicalsecurities to smallholder farmers with potential for value chain development and income generation (Gauchanet al., 2019). Many of these crops (amaranth, finger millet, proso millet and foxtail millet) are gluten free; rich in micronutrients (calcium, iron), dietary fibers, rare amino acids, antioxidants and vitamins, and contain higher protein as compared to major food staples such as rice and wheat (DFTQC, 2012). Hence, they are considered Himalayan Superfoods[1] and also crops for the future. Furthermore, most of these crops (amaranth, finger millet, proso millet and foxtail millet) are C4 crops, thus resilient and fit on climate change adaptation as they are hardy and can be grown in harsh marginal lands with low inputs and water (Gauchanet al., 2019). These crops tolerate biotic and abiotic stresses; for example, escape drought and cold temperatureand ensure food availability in shorter period in lean seasons due to their short duration (e.g. buckwheat grown in 2-3 months) of production period. Considering their great value for nutrition, climate resilience and risk diversification, these traditional crops are considered “future smart foods” in the changing climate for site-specific food supply and adaptation (Li and Siddique, 2018; Joshi et al., 2019).

Even though the traditional mountain crops are considered minor crops at the national level, they happen to be the principal crops of high Mountain Himalayan districts of western and mid-western regions of Nepal and play important role in food and nutritional security of poor farmers and marginalized communities. For instance, present official statistics of Nepal (MoAD, 2016) show that millet is number one important crop in Humla and Mugu districts, while barley and millet are second important crops in Jumla. Buckwheat is number one crop in Mustang and Manang and second most important one in Dolpa district (MoAD, 2016).Therefore, despite the minor crops shared small proportion (6%) of area nationally (CBS, 2013), they are important for food security of farmers in high elevation areas of mid and

[1]www.himalayancrops.org

higher mountain regions of Nepal. However, very little research, development and investment have been done globally and nationally focusing on these crops from the perspective of breeding, processing, promotion and policies. Therefore, cropped area and varietal diversity of these crops are declining rapidly recently with climate change, migration, cultural change and commercialization. Previous studies in rice in middle mountainsof Nepal have shown various socioeconomic, market and agro- ecological determinants of farm maintenance of rice diversity (Gauchan et al., 2005). However, we have limited information about the factors influencing on-farm maintenance and management of the traditional crop diversities and their role in local and national food and nutrition security.

The main objectives of this study were (i) to document the status of traditional crop biodiversities and their relations with household food security and (ii) to analyse farm-household agro-ecological, socioeconomic and institutional factors influencing the crops' cultivationand diversity maintenance for food security and agrobiodiversity conservation in the mountains.

METHODOLOGY

The study used sample household survey combined with participatory rural appraisals and field trials to generate information on mountain agro-ecosystems of Jumla, Humla (western Nepal), Lamjung (central Nepal) and Dolakha (eastern Nepal) districts. A total of 328 farm households were surveyed in 2014-15 covering one village development committee (VDC) in each of the districts. The survey using proportionate random sampling covered 72 to 90 farm households from Chhippra, Hanku, Ghanpokhara and Jugu VDCs respectively in Humla, Jumla, Lamjung and Dolakha districts. The survey was supplemented with focus group discussions, field monitoring visits and consultation meetings with local communities and other stakeholders. The study focused on collection of farm household information regarding agricultural systems that mainly included household food sufficiency, and production, agronomy and market related features and diversity of traditional mountain crops. Data compilation, analysis and reporting were focused on important traditional crops grown by large number of farmers in the study sites. Food security is assessed from both secondary time series and survey data collected on household production and sufficiency level. Both qualitative and quantitative data were analyzed primarily with the use of descriptive statistics, such as mean, frequency and standard error of mean. Relationships among variables are tested using correlation analysis. Regression model (e.g. Tobit) is used to identify factors influencing farm choices and decisions maintaining intra-specific diversity of economically important traditional crops mainly cold tolerant rice, finger millet and bean. The data were analyzed using Microsoft Excel, Statistical Package for the Social Sciences (SPSS) 16 for descriptive analysis and STATA (10.0) for econometric analysis.

ANALYTICAL MODEL

There are various regression tools and techniques to analyse factors influencing farm maintenance of crop varieties. The Tobit (censored regression) model is used here to study the household specific socioeconomic and institutional factors influencing on-farm maintenance of traditional crop diversity as the data sets for on-farm diversity indicator (proportion of area allocation to specific crops) are continuous and censored at zero. Censored Tobit model is suitable when data are continuous and censored at zero (Maddala, 1983). Moreover, Tobit regression model is suitable here as it measures the extent of crop area allocation by specific households as a measure of on-farm diversity. It uses all observations, both growers and non-growers, that are at the limit, usually zero (e.g. non growers), and those above the limit (e.g. growers) to estimate a regression line (McDonald and Moffitt, 1980; Gauchanet al., 2005). Proportion of area allocated to specific crop is used as dependent variable. The general formulation for Tobit specification is usually given in terms of index function (Greene, 2000),

$$D_i^* = \beta' X + \varepsilon_i$$
$$D_i = 0 \text{ if } D_i^* \leq 0,$$
$$D_i = D_i^* \text{ if } D_i^* > 0.$$

where, D_i^* is a censored variable of the dependent variable, which is expressed as the share of traditional crop area (cold tolerant rice, finger millet, beans) under different varieties depending on the type of analysis. β' is a vector of parameters to be estimated and X, is a vector of explanatory variables which includes household variables (age, gender, family size, farm size, female involved in agriculture, agriculture income, working outside), farm agro-ecological variables (mountain agroecosystems western vs eastern) and institutional variables (market distance, access to training and tenancy) and ε is the disturbance term.

RESULT AND DISCUSSION

HOUSEHOLD SOCIO-DEMOGRAPHY

The socio-demographic information of the sample households is presented in Table 1. Sample households are dominated by middle age farmers (44 years) with average family size of 6 persons and average farm size of 10 ropani (0.5 ha). This indicates predominance of smallholder farmers with smaller farm size as compared to national average of 0.68 ha. Over half of the sample households have nuclear families and about one-fifth of them are female decision makers. About 50% of the sample households fall under disadvantaged groups (Dalit and Janajati), which is the highest in the study site of Lamjung (96%).

Table 1: Household socio-demographic information in study sites in 2014-15 (n=328)

Socio-Demography	Humla (n=72)	Jumla (n=83)	Lamjung (n=83)	Dolakha (n=90)	All(n 328)
Age of the respondents (years)	37.9	39.5	51.9	47.0	44.0
Farm size (Ropani)*	4.4	8.00	18.2	10.4	10.4
Family size (No)	5.3	6.0	6.4	5.8	5.9
Nuclear households (%)	68	61	42	60	58
Female members in the households (%)	28	46	37	59	46
Female decision makers (%)	6	24	28	38	23
Disadvantaged groups (Dalit &Janjati) (%)	15	45	96	31	48

Note: One Ropani =500 sq meter

ON-FARM DIVERSITY OF TRADITIONAL CROPS

On-farm diversity of traditional mountain crops is measured in terms of (i) proportion of farm households cultivating these crops, (ii) farm area allocation to these crops and (iii) number of varieties (varietal richness) grown by farmers at the households and community levels in the mountain agro-ecosystems. These are briefly discussed focusing on high altitude cold tolerant rice, fingermillet and common bean in following outlines.

Proportion of households growing crops

Finger millet, cold tolerant rice and bean are grown by large proportion (>50%)of the households in mountain agro-ecosystems of Jumla (2300-2700 msl), Humla (2200-2900 msl), Lamjung (1500-1800 msl) and Dolakha (1700-2000 msl) (Figure 1). Proso millet, foxtail millet, amaranth, naked barley and buckwheat are not common to Lamjung and Dolakha, but they are grown by larger proportion of the households in Humla. In Jumla, foxtail millet, proso millet, buckwheat and amaranth are grown by smaller proportion of the households, but barley in larger area by many households.

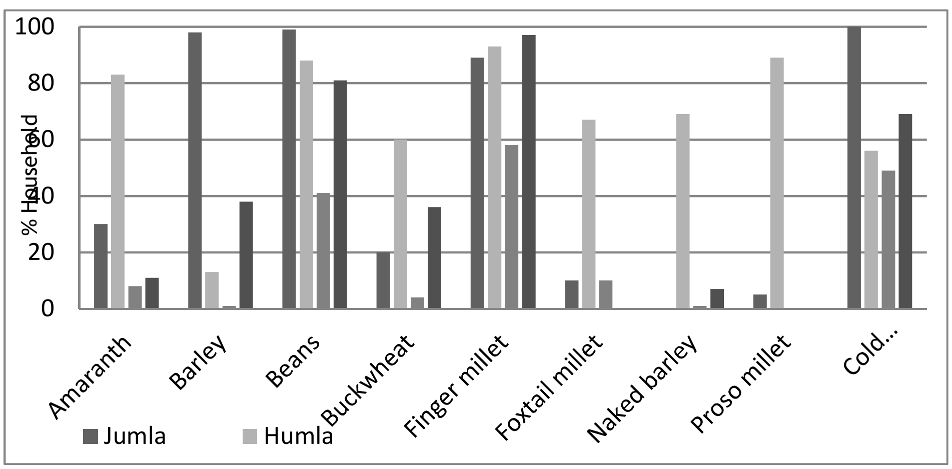

Figure 1: Percent households growing traditional mountain crops in study sites

Farm area allocation to traditional mountain crops

Since, farm households in mountain areas have small farm sizes (< 0.5 ha), they grow traditional crops in relatively smaller area. High altitude cold tolerant rice is grown in the largest area (33%) followed by finger millet (17%) in all the mountain study sites (Table 2).

Table 2: Average area allocations (Ropani) to different mountain crops in 2014-15

Crop	Jumla	Humla	Lamjung	Dolakha	Overall Average	Area share (%)*
Amaranth	0.027	0.12	-	-	0.06	0.57
Barley	2.20	0.39	-	1.1	0.80	7.70
Bean	1.88	0.48	0.38	0.026	0.35	3.4
Buckwheat	0.69	0.88	-	2.46	1.10	10.5
Finger millet	1.03	1.17	2.52	3.5	1.77	16.9
Foxtail millet	0.07	0.49	1.27	-	0.03	0.30
Naked barley	-	0.88	-	0.7	0.80	7.65
Proso millet	0.95	0.79	-	-	0.85	8.12
Rice	2.57	0.86	11.12	4.9	3.43	32.7
Farm size	8.06	4.29	18.22	10.44	10.46	100

Note: Area share includes percent share of specific crop area to total crop cultivated area by farmers*

The area share of different traditional crops to total cultivated farm area in the study sites ranges from less than 1% to 33% with the highest share for rice (33%) and the lowest share for foxtail millet (0.30%). Some of them are location specific such as proso millet, foxtail millet, buckwheat and amaranth in Humla and Jumla. Barley is grown mainly in Jumla and naked barley mainly in Humla. Buckwheat in Dolakha and foxtail millet in Lamjung are also grown in small area by few households.

Diversity of traditional crop varieties at community level

A high intra-specific diversity of traditional crops (rice, finger millet and bean) was found maintained at all four mountain agro-ecosystems. The varietal richness or number of varieties grown by farm households, an indicator of crop diversity, was found highest for rice in Dolakha, finger millet in Lamjung and bean in Dolakha and Jumla (Figure 2). Community level richness (number of crop varieties grown at the community level) is relatively high for rice, bean and finger millet. The level of varietal richness at the community level varied by specific crops in specific sites. For instance, the varietal richness (number of varieties) is relatively high for bean in Jumla and Dolakha, and finger and foxtail millet in Lamjung.

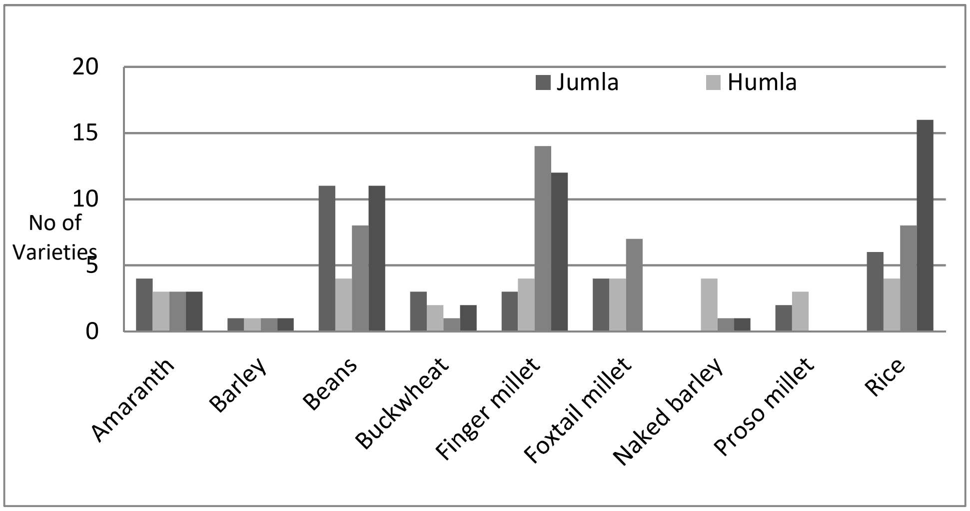

Figure 2. Crop varietal richness of traditional crops at community level

FOOD SECURITY STATUS

Food sufficiency in terms of cereals, pulses and vegetables production at farm level in aggregate was low and inadequate, which is not even adequate forabout six months (Figure 3). Farmers' annual production of food staples meet 7 months in Lamjung and Dolakha and only for 4-5 months in Humla and Jumla. The pulse sufficiency was relatively higher in Jumla for about 6 months, 5 months in Lamjung and only 4 months in Humla and Dolakha. The level of vegetable sufficiency was 5 months in Lamjung and Dolakha but less than 4 months in Humla and Jumla. The finding shows that study sites in far western high mountain (Jumla and Humla) have very low food sufficiency level, though this was also not adequate (not more than six months) in central mountain (Lamjung) and eastern mountain (Dolakha).

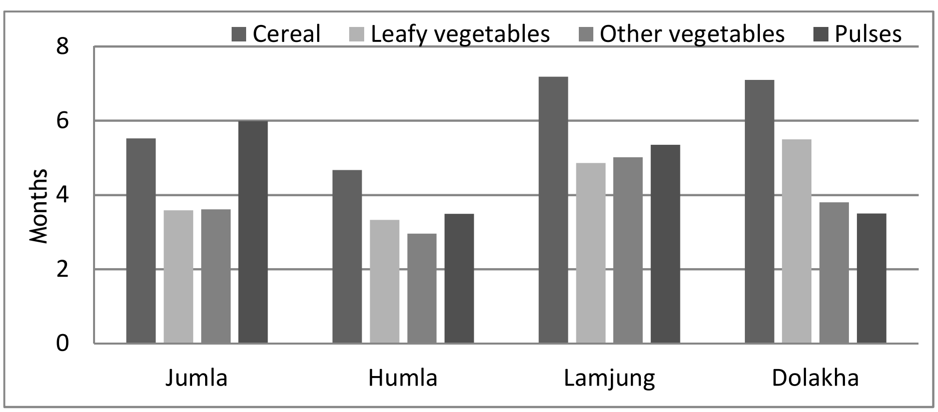

Figure 3: Status of household food and vegetable self-sufficiency (months) in study sites

Relationship between food security and crop diversity

Analysis on average period of food sufficiency (number of months) from farm production and its relationship with on-farm crop diversity (as measured by varietal richness or number of varieties grown by the households) is essential to get an idea about whether crop diversity had positive contribution on food security and livelihood of smallholder mountain farmers. The analysis was carried out for rice, finger millet and bean that are predominantly grown in all the high-altitude study sites (Table 3). Correlation analysis was carried out for key household socioeconomic variables with proportion of area allocated with traditional mountain crops and varietal richness. There is a positive and significant relationship between rice richness (rice varietal diversity of the households) and household food sufficiency in Humla, Jumla, Lamjung, and Dolakha and at the aggregate level. Similarly, there is positive relationship between finger millet richness and food sufficiency indicating finger millet is critical food staple in this high mountain district. Secondary data also indicate that finger millet is number one crop in term of its area coverage in Humla district (MoAD, 2016) contributing important role in food sufficiency. However, this relationship was not significant in bean in Humla, Jumla and Dolakha, probably due to production of this crop in small area in all the sites. The finding clearly indicates that on-farm diversity of high-altitude rice cultivars has positive role in food security of the households in all the mountain agro-ecosystems, while that of finger millet diversity has only in Humla contributing positive role in food security of the mountain households.

Table 3. Relationship between food security and on-farm traditional crop diversity

Crop Diversity	Jumla	Humla	Lamjung	Dolakha	All Sites
Rice richness	1.49 *	0.61**	0.572**	0.311**	0.4**
Finger millet richness	0.91ns	0.237*	-.017	0.161	0.066
Bean richness	1.78ns	0.85ns	-0.230*	0.029	-0.027

Note. ** Significance at P<0.01, and *significance at P<0.05 level.

Factors influencing on-farm crop diversity

Tobit (censored) regression model was carried out to analyse household specific socioeconomic, agroecological and institutional factors influencing on-farm diversity of rice, finger millet and bean. The results of the model for the selected crops with their significance level are presented in Table 4.

Table 4: Factors influencing on-farm diversity of selected traditional mountain crops

Socioeconomic groups	Rice Coefficient	Finger millet Coefficient	Bean Coefficient
Age (number of years)	0.0025**	0.003**	-0.003
Gender of decision makers (Female=1; Otherwise=2)	-0.0067	-0.007	-0.0153

Family size (Number)	0.026**	0.018**	0.0141**
Female involved in agriculture (Number)	0.066**	-0.0401	0.0121
Agri as main income source (Yes=1; Otherwise 0)	0.065*	-0.0431	0.0086
Farm size (Ropani)	0.013***	0.007**	-0.0002
Working outside (Yes=1; Otherwise= 2)	-0.056	0.003	-0.0673**
Mountain agro-ecosystem (Western=1; Otherwise=0)	-0.188***	-0.0215***	0.318***
Access to training (Yes=1; Otherwise=0)	0.0368	-0.0104	-0.0619
Tenancy (Share out/in =1 Otherwise= 2)	0.003	-0.007	-0.0159**
Market access (Distance to market, Km)	-0.0215***	0.004	-0.0174***
Constant	0.614	0.5800**	0.4652***
Number of observations	309	309	309
Likelihood ratio(LR chi2(11) and Prob (> Chi2)	99.70 ***	52.48***	199***

*Note ***, ** and * significant at p<0.01; 0.05 and 0.1 respectively.*

Dependent variable used in this analysis was proportion of area allocation to each crop. The independent variables were household specific socioeconomic, agro-ecological and institutional factors. The household socioeconomic factors included are age and gender of decision makers, female involved in agriculture, family type, family size, farm size, agriculture as main source of income and family members working outside. Mountain agro-ecosystem whether located in the eastern mountains (Lamjung and Dolakha) or western mountains (Jumla and Humla) was considered as a farm-specific agro-ecological factor. Institutional factors mainly include access to training, type of tenancy situation and market factors. The significant variables in explaining area allocation to rice include age of farmers, female members involved in agriculture, farm size, family size, market factors such as market distance in kilometer and agro-ecology (mountain agro-ecosystem). For finger millet, household specific factors such as family size, farm size, age and agro-ecological location were significant whilst market factor was not significant. For bean, family size, family members working outside village, tenancy, agro-ecological location, and market access are significant. Agro-ecological factors were significant in all the three crops due to important roles that agro-ecology (climatic and natural conditions) play in the study mountain locations. The factors such as access to training to production of these crops and gender of the decision makers did not have significant effect on the maintenance of on-farm diversity of all the important crops.

RESULT AND DISCUSSION

The findings showed that various socioeconomic status of the households such as farm size (proxy for wealth status), age (proxy for experience and knowledge), family size (proxy for farm labour availability), market distance (proxy for market access and demand) and agro-ecology (mountain locations and its environment) are the key factors that influence the farmers' decision and shapes the diversity of a crop. Age of the farmers and farm size are influencing factors for rice and finger millet but they are not important for bean. Age was found significantindiversified cultivation of rice and finger millet that requires specific knowledge on seedbed preparation, cultivation and crop management. Family size was important for all of these crops as these are labour intensive crops grown under traditional family farming system. Larger farm size provides spaces for growing different varieties of the crops in larger area resulting in more on-farm diversity of these crops. For bean, only family size was important but not the farm size and farmers' age as this crop is labor intensive for cultivation, threshing and handling where larger family size provides more labour sources for this. Since bean is grown in small area by all the farm households older or younger in similar proportion of the area, farm size and age were not important. Farmers' sources of agricultural income and female members working in agriculture are important factors for area allocation to rice but not for finger millet and bean, because rice tends to be preferred crop and area allocation to this crop increases with more income sources of the farmers. Female members in the households are important in rice production, post-harvest handling, processing and food preparation as their engagement and knowledge is higher in rice farming in Nepal.

Agroecological conditions and locations of mid-western mountain environments are positively driving allocation of area for bean but negatively on rice and finger millet production. This may be due to less suitability of lands for rice and finger millet cultivation under high altitude cold and harsh extreme environment of Karnali Mountains as compared to relatively mid altitude and better environment of central and eastern mountain agro-ecosystem such as Lamjung and Dolakha. In contrast, Karnali Mountain shows positive and significant effect on diversified cultivation of bean, because the crop is well adapted and suited to the high altitude environments, and Karnali high altitude bean fetches high demand in urban markets of Nepal. Market access (distance) factor was significant with negative sign for rice and bean but non-significant for finger millet. This indicates farm households located farther away from market are less likely to maintain rice and bean diversity, because recently rice and bean are cultivated nearby market are becoming more cash crops requiring inputs from markets and products to be sold in nearby market for generating cash income. Farmers working outside the village seasonally for non-farm works showed negative effect for bean, but not for rice and finger millet. This is because family labour used in non-farm outside the village does not affect much for rice and finger millet cultivation prebaby because, they work seasonally outside during off-season and tend to come to village during peak cultivation and harvesting season of rice and fingermillet.Focus group discussion and field observations in the study sites also support this finding. However, for beans, this has some negative effect as its main planting and harvesting period contradicts with outside non-farm work and this crop is not much important for many of the farm households as compared to rice and finger millet.Tenancy situation (share cropping) variable is only significant for bean regression but with negative sign indicating that share croppers are less likely to maintain bean diversity than owner cultivators since bean is becoming more cash crops and owner cultivators tend to grow bean in their own area including in kitchen gardens than that of share cropping and those cultivators renting the land. For traditional mountain crops, factors such as access to training and gender of the decision makers in the households did not have significant effect on the maintenance of on-farm diversity, probably due to both men and women farmers' pre-existing good experiences and traditional knowledge on cultivation of these crops.

CONCLUSIONS

On-farm diversity maintenance of traditional crops namely finger millet, high altitude cold tolerant rice and bean is fair in the study sites, while that of barley, naked barley, prosomillet, foxtail millet and amaranth are specific to some mountain regions (mainly Humla and Jumla districts). Among the traditional crops, the diversity particularly of cold tolerant rice in all the mountain sites and that of finger millet in Humla play important role in farm production and food security of the mountain households despite current food sufficiency level of these crops is low in these marginal mountain environments. Factors influencing on-farm diversity of the three economically important crops namely finger millet, cold tolerant rice and bean varied by agro-ecological, farming system and socioeconomic conditions of the mountain locations. Agro-ecology of the mountain farming system has been a critical factor in influencing area allocation and diversity maintenance of rice, finger millet and bean in all the mountain agro-ecosystems. Farmers' socioeconomic factors such as farmers' age, family size and farm size play important role in on-farm maintenance of rice and finger millet diversity. Similarly, family size, tenancy and family members working outside are important for on-farm diversity of bean. Market factors play important role for rice and bean, since market demand for nutritious high altitude local organic *marshi* rice and bean is increasing in urban markets of Nepal. Therefore, market development in the mountain regions needs to consider promoting on-farm diversity of high-altitude rice and bean.While other interventions on household-specific socioeconomic characteristics promoting on-farm crop diversities and farm household food security are essential for all the major traditional crops. Furthermore, crop-specific agro-ecological factors and the crops diversities should also be considered in such promotions. Future research and development interventions need to focus on diversity rich solutions and technologies tailored to specific crops and farm socioeconomic, agro-ecological conditions and institutional settings of the mountain households to enhance household food security and management of crop biodiversity of the mountain agro-ecosystems.

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