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ORIGINAL ARTICLE

Determinants of adaptation practices to climate change by Chepang households in the rural Mid-Hills of Nepal

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Abstract This study analyzes the factors influencing the adoption of various adaptation practices by a highly marginalized indigenous community in the remote rural Mid-Hills of Nepal. The analysis is based on a household survey conducted among 221 Chepang households selected randomly. A multivariate probit model was used to analyze five categories of adaptation choices against a set of socio-economic, institutional, infrastructural, and perception variables. Perception of rainfall changes, size of landholding, status of land tenure, distance to motor road, access to productive credit, information, extension services, and skill development trainings are all influential to enable households to deviate away from traditional coping strategies and adopt suitable practices to adapt to climate vagaries. Policies and development activities should be geared to address these determinants in order to facilitate adaptation.

Keywords Adaptation choices · Climate change and extremes · Chepang · Multivariate probit

Introduction

As the challenges and opportunities arising from recent climate change become widely recognized, issues of adaptation to these changes are being placed higher on the international agenda, with emphasis on the rural and marginalized communities in developing countries (UNFCCC 2009; Jones and Boyd 2011). As pointed out by Smit and Wandel (2006), many earlier studies related to climate change adaptation were based on hypothetical adaptations presumed by the researchers in order to model climate change impacts or else to conduct comparative analyses among possible adaptations using tools like cost-benefit analysis. Until now, fewer studies were done considering the actual adaptation practices in a locality as well as the drivers of adaptive capacity or the process of translating capacity into actions (e.g., Adger 1999; Wall and Smit 2005). An important characteristic of these studies is that the assessment is based on direct interaction with the communities, thus termed as bottom-up approach, as opposed to the earlier top-down approaches. The fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) focusses on such ongoing adaptation practices and the underlying constraints in developing countries (Adger et al. 2007). The literature analyzing ongoing adaptation in rural communities in developing countries is increasing ever since (Barbier et al. 2009; Mertz et al. 2009a, b; Gbetibouo 2009; Deressa et al. 2011; Below et al. 2012). The local coping strategy database of the United Nations Framework Convention on Climate Change (UNFCCC) is an excellent collection of such ongoing adaptation practices, with a majority coming from rural farming communities in developing countries.

While the documentation of the adaptation practices is becoming more comprehensive, studies about the factors affecting the household adaptation choices are still comparatively rare. Understanding the determinants of a household decision to adopt a particular practice among the available choices may provide insights into the factors that enable or

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constrain adaptation. Policy recommendations can be drawn from these insights to facilitate suitable adaptations in the locality. Most researches on determinants of adaptation among the rural communities have been made in Africa (Maddison 2007; Hassan and Nhemachena 2008; Kurukulasuriya and Mendelsohn 2008; Gbetibouo 2009; Seo et al. 2009; Deressa et al. 2011; Below et al. 2012), and fewer are conducted elsewhere (Seo and Mendelsohn 2008a; Bouma et al. 2009; Jones and Boyd 2011). The studies shed light on the factors that enhance or limit the ability of households to adapt to climate-related vagaries. Household adaptation choices are found to be determined not only by the climate variables or geographic features, but also by household socio-economic characteristics; farm characteristics or infrastructures; social, institutional, and governance factors; and finally community perceptions.

This paper draws conclusions from several earlier studies and builds location-specific indicators to conduct analysis for a highly marginalized rural community in the Mid-Hills of Nepal. Few studies have been conducted to assess the factors influencing climate change adaptation among the rural communities in Nepal (Bouma et al. 2009; Jones and Boyd 2011; Onta and Resurreccion 2011). All of these studies are descriptive analyses focusing on the social and institutional factors. This paper conducts a quantitative analysis of the determinants of household adaptation decisions over a range of socio-economic variables, and perception of climate change, in addition to the social and institutional factors emphasized by the earlier studies.

The Chepangs and the study area

Marginalized communities in developing countries primarily depending on natural resources are more vulnerable to climate change, and the same communities are more constrained to adapt due to a multitude of barriers (Adger et al. 2007). Therefore, this paper focuses on the Chepang community, a highly marginalized community in Nepal, as the study population. Chepangs are one of the indigenous nationalities constituting 0.23 % of the total population. In Nepal, not only do the majority of indigenous people reside in remote areas, but also their socio-economic indicators lie below the national average. Based on the Nepal Living Standards Survey of 2003/04, hilly indigenous people have higher poverty incidence of 43 % compared to 33 % in the Tarai (the southern plains in the country) (NIRS 2006). The Chepang community is categorized by Nepal Federation of Indigenous Nationalities (NEFIN) as a highly marginalized indigenous nationality from the hills. Majority of the Chepangs live in the hilly villages of Chitwan, Makwanpur, Dhading, and Gorkha Districts. Although their native area is surrounded by major highways of the country (Fig. 1), feeder roads to their area are very few. The geographic remoteness is further compounded by poorly developed infrastructures like roads, communications, electrification, bridges, hospitals, and schools. Literacy rate among this community is very low, and this has hampered their representation in administration and politics. Despite living near Kathmandu (Fig. 1), they are marginalized from the national mainstream. Chepangs thus qualify as the representative of the marginalized group in Nepal.

The Chepangs were described by anthropologist Brian Hodgson in 1874 as a nomadic group “living entirely upon wild fruit and the produce of the chase” (Hodgson 1874, p. 45). Over time, their livelihoods have gone through transition from hunting–gathering to shifting cultivation (Rai 1985) and further to sedentary farming (FORWARD 2001). Subsistence rain-fed agriculture forms the mainstay of the Chepang livelihoods. However, due to low agricultural productivity, only few households are food self-sufficient (Piya et al. 2011a). Thus, most of the Chepang households depend on wild edibles during the dry months when storage is depleted and new harvests are not yet available (Maharjan et al. 2010).

More than 95 % of the Chepang population reside in Chitwan, Makwanpur, Dhading, and Gorkha Districts. To ensure representativeness, all the four districts are covered in this study (Fig. 1). The majority of their settlements are found at altitudes higher than 1,000 m above sea level (masl), ranging up to 1,920 masl. The Chepang settlements are highly scattered, connected by narrow foot trails. One village development committee (VDC—the lowest administrative division) from each district was selected based on the dominance of Chepang population, viz Kaule VDC from Chitwan, Kankada VDC from Makwanpur, Mahadevsthan VDC from Dhading, and Bhumlichowk VDC from Gorkha. The Chepangs form the largest population in Kaule and Kankada VDC and second largest population in Mahadevsthan VDC. Bhumlichowk VDC accommodates the largest Chepang population within Gorkha District.

There are no meteorological stations in the Chepang areas, and this limits the description of climate at the research sites. Based on the records for 1975–2008 from the nine nearest meteorological stations located at similar elevations within the four districts, the mean summer temperature (May–August) in the area ranges from 24.8 to 27.4 °C, the mean winter temperature (December–February) from 13.4 to 16.3 °C, and the total annual rainfall from 1,200 to 2,540 mm. Over the last decade, the summer temperature shows a rising trend, while the winter temperature and annual rainfall show a declining trend in the area (Piya et al. 2012a). The commonly reported climatic hazards in the study area are landslides, droughts, and hailstorms. The communities in the area opine that droughts have become more frequent. They also reported that short-duration droughts during the maize-growing season

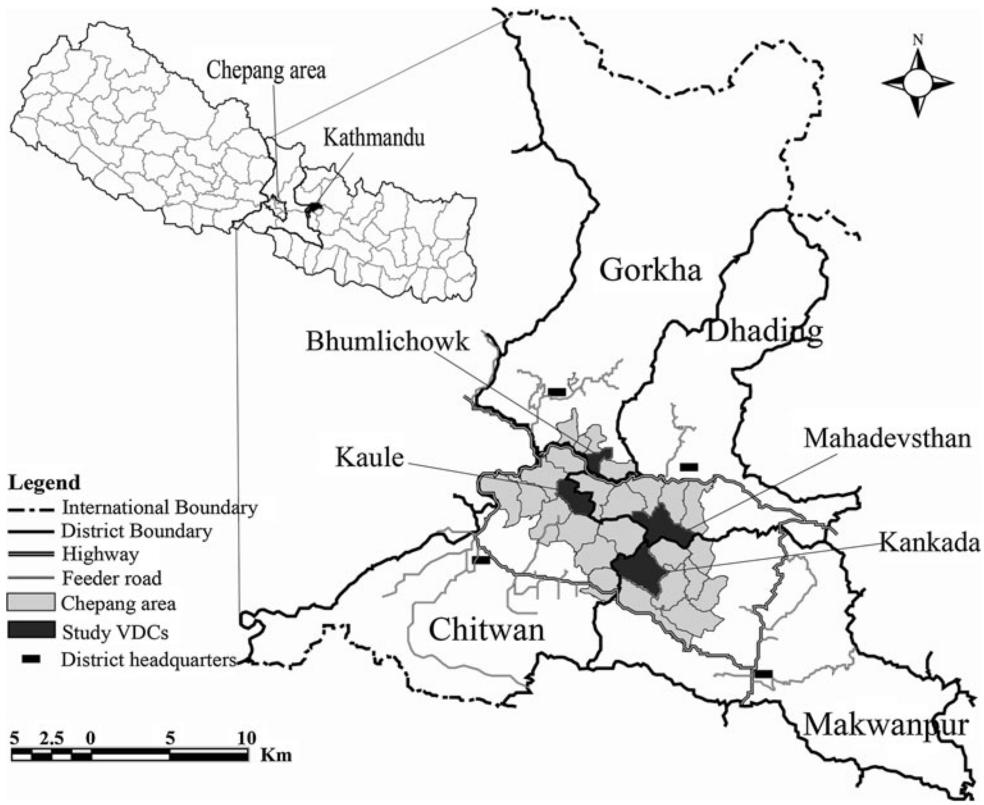

Fig. 1 Map of the study area. The *map* on the *left* shows the study area in the map of Nepal and relative position of the area from the capital Kathmandu. The *map* on the *right* shows the VDCs within the four districts where the majority of Chepang population resides (*lightly shaded areas*) and the study VDCs (*dark shaded areas*)

coupled with uncertain timing of rainfall have hampered maize cultivation. Another change in the climatic variables significantly noted by the communities is the late onset of post-winter rain (March–April), which delays the sowing of maize from March to mid-April. This further delays the millet transplantation afterward (Piya 2012). The adaptation options reported and analyzed in this study are undertaken in response to these extreme events and rainfall changes.

Method of data collection

This study is based on household survey conducted in two phases. The first phase was conducted from February to March 2010 and the second phase from May to June 2011. Sixty randomly selected households from each VDC, that is, a total of 240 households, formed the sample for the first survey. Due to the lack of official list of Chepang households, the list was obtained by consulting the local people, and households were randomly selected from this list. The survey was conducted using semi-structured interview schedule in Nepali. A handful of university students studying related subjects were hired as research assistants. They were oriented about the study sites and the questionnaire before going to the field. The main researchers led the research assistants during the surveys. All the households covered in the survey were not yet connected to motorable roads and the central electricity grid at the time of the survey. The first household survey focused on demographics, livelihood activities, assets, income, and expenditures. Focus group discussions were carried out, one in each VDC, comprising of 8–10 people, varying in age from 40 to 60 years. The purpose of the focus group discussions was to assess local changes in climate and obtain a timeline of climate-related extreme events over the last 30 years. Based on the climate-related information obtained from the group discussions, the interview schedule for the second phase was designed, and a follow-up field visit that revisited the same households for gathering supplementary data was made in 2011. Out of the total 240 households, 58 in Chitwan, 56 in Makwanpur, 54 in Dhading, and 53 in Gorkha could be revisited in 2011; thus, our final sample constitutes 221 households. The second phase focused on information related to the perceptions of climate change; the livelihood impacts of climate change including the extreme climate events; and the households' adaptation or coping strategies in response to these events.

Empirical model and selection of variables

Empirical model

Maddison (2007) and Deressa et al. (2011) analyzed the decision of the household to adapt or not using Heckman sample selection probit model. However, these studies do not differentiate the different adaptation practices, which are affected differently by various factors. When all the adaptation practices are lumped into a single category, this difference is not accounted for. The simplest option to analyze different adaptation practices is to estimate univariate models for each choice. However, independent estimations fail to account for the relationships between different choices (Golob and Regan 2002), which may be complementary or competing. For example, constructing a water storage structure will complement the choice to grow cash crops, while diversification of livelihoods to skilled jobs will reduce dependence on traditional wage laboring.

A better alternative to univariate estimation is the multinomial discrete choice model, which assumes independence across outcomes and requires that the choice variables be mutually exclusive (Seo and Mendelsohn 2006). Many studies differentiate between the various adaptation practices undertaken by the households and analyze the determinants influencing the adoption of those practices using the multinomial logit (MNL) model (Kurukulasuriya and Mendelsohn 2008; Seo and Mendelsohn 2008a; Hassan and Nhemachena 2008; Seo et al. 2009; Deressa et al. 2009; Gbetibouo 2009). The major limitation of the MNL model is the assumption of the practices to be mutually exclusive, which is not true in reality because a single household can simultaneously adopt more than one strategy. Seo and Mendelsohn (2008b) and Kurukulasuriya and Mendelsohn (2008) first identify the possible combinations of livestock and crop choices and employ the MNL to study the determinants of these combinations. However, as already explained, using combinations as the choice variables makes it difficult to interpret the influence of explanatory variables on each of the options individually.

Nhemachena and Hassan (2007) and Seo and Mendelsohn (2006) address this problem by running a multivariate probit (MVP) model where the probability of choosing more than one option is simultaneously modeled against the explanatory variables. MVP models are suitable when it is important to take into account the correlation structure among the choice variables. An advantage of the MVP model over the MNL model is the relaxation of assumption of independence of the irrelevant alternatives (IIA), which, in many cases, is unrealistic. Furthermore, Young et al. (2009) demonstrated that the MNL is a poor approximation of outcome probabilities relative to the MVP model. This paper uses the MVP model to analyze the determinants of adaptation choices among the Chepang households in the Mid-Hills in Nepal.

The MVP model assumes that given a set of explanatory variables, the multivariate response is an indicator of the event that some unobserved latent variable (Z), assumed to arise from a multivariate normal (Gaussian) distribution, falls within a certain interval. Following Tabet (2007), the MVP model assumes that each subject has J distinct binary responses. Let $i = 1,\ldots,n$ be the independent observations, $j = 1,\ldots,J$ be the available options of binary responses, and X_i be a matrix of covariates composed of any discrete or continuous variables. Let $Y_{ij} = (Y_{i1},\ldots,Y_{iJ})$ denote the J-dimensional vector of observed binary responses taking values {0,1} on the ith household and $Z_{ij} = (Z_{i1},\ldots,Z_{iJ})'$ denote a J-variate normal vector of latent variables such that

$$Z_{ij} = X_i\beta + \varepsilon_i, \quad i = 1,\ldots,n \tag{1}$$

where $\beta = (\vec{\beta}_1^{'},\ldots,\vec{\beta}_J^{'})$ is a matrix of unknown regression coefficient, ε_i is a vector of residual error distributed as multivariate normal distribution with zero means and unitary variance; $\varepsilon_i \sim N(0, \Sigma)$, where Σ is the variance–covariance matrix. The off-diagonal elements in the correlation matrix $\rho_{kj} = \rho_{jk}$ represents the unobserved correlation between the stochastic component of the kth and jth options (Cappellari and Jenkins, 2003). The relationship between Z_{ij} and Y_{ij} is

$$Y_{ij} = \begin{Bmatrix} 1 & \text{if } Z_{ij} > 0; \\ 0 & \text{otherwise} \end{Bmatrix} \quad i = 1,\ldots,n \text{ and } j = 1,\ldots,J. \tag{2}$$

The likelihood of the observed discrete data is then obtained by integrating over the latent variables Z:

$$P(Y_{ij} = 1|X_i,\beta,\Sigma) \int A_{i1}\Phi_T(Z_{ij}|X_i,\beta,\Sigma)\mathrm{d}Z_{ij} \tag{3}$$

where A_{ij} is the interval $(0,\infty)$ if $Y_{ij} = 1$ and the interval $(-\infty,0]$ otherwise and $\Phi_T(Z_{ij}|X_i,\beta,\Sigma)\mathrm{d}Z_{ij}$ is the probability density function of the standard normal distribution.

This study uses the simulated maximum likelihood (SML) using Geweke–Hajivassiliou–Keane (GHK) simulator in STATA developed by Cappellari and Jenkins (2003) to estimate the MVP model. The SML estimator is consistent as the number of observation and number of draws tend to infinity. For large sample size, the number of draws equal to the square root of the sample size would suffice. However, for smaller sample size, the number of draws should be sufficiently large. The number of draws (R) in this paper was set to 100 (default $R = 5$) to ensure consistent estimates. To run the diagnostic tests, individual ordinary least squares (OLS) estimates were run for each individual choice variable against the same set of explanatory variables. The variation inflation factor (VIF) test was run to check multicollinearity. The VIF value for all the independent variables was below 10, with mean VIF value of 1.21 suggesting no problems of multicollinearity. The null hypothesis of homoscedasticity was significant for Breusch–Pagan/Cook–Weisberg test in four out of the total five choices. White's test of heteroscedasticity, however, yielded insignificant *P* values for all the choices, failing to reject the null hypothesis of homoscedasticity. To correct heteroscedasticity of any kind, following Nhemachena and Hassan (2007), model estimation was conducted using robust standard errors. The use of robust standard errors does not change the significance of the model and the coefficients, but gives relatively accurate *P* values, and is an effective way of dealing with heteroscedasticity (Wooldridge 2006, p. 274).

Model variables

The choices of adaptation practices are the dependent variables for the MVP model used in this paper. The description of ongoing adaptation practices and the grouping of these practices for the purpose of analysis will be elaborated in the next section of the paper.

Thirteen independent variables were selected based on the literature review and location-specific characteristics (Table 1). The ability to notice changes in climate is found to facilitate adaptation (Nhemachena and Hassan 2007). The meteorological records show decreasing annual rainfall, increasing mean summer temperature, and decreasing mean winter temperature in the study area over the last decade (Piya et al. 2012a). It is thus hypothesized that the households that are able to perceive these changes are more likely to adopt livelihood diversification strategies, varietal selection, construction of water collection tanks, and adjusting sowing time.

The impact of the age of the household head on adaptation decisions is not uniform, with literatures showing both positive and negative propensity to adapt with age (Nhemachena and Hassan 2007; Seo and Mendelsohn 2008a; Hassan and Nhemachena 2008; Deressa et al. 2009). The findings are similar for education of the household head, depending on the nature of adaptation practices (Maddison 2007; Seo and Mendelsohn 2008a; Gbetibouo 2009; Deressa et al. 2009, 2011; Below et al. 2012). Literatures also show varying relations between household size and adaptations (Hassan and Nhemachena 2008; Kurukulasuriya and Mendelsohn 2008; Seo and Mendelsohn 2008a; Deressa et al. 2009; Gbetibouo 2009; Deressa et al. 2011; Below et al. 2012). For this study, it is hypothesized that the households headed by older and educated heads are less likely to depend on traditional coping strategies but more likely to adopt the remaining adaptation practices. Same relationship is hypothesized for households with higher number of economically active members.

The total landholding per capita is taken as an indicator of farm size, while the area of unregistered land per capita is taken as an indicator of tenure status. Landholding or farm size is found to influence adaptation positively (Maddison 2007; Seo and Mendelsohn 2008b; Hassan and Nhemachena 2008; Gbetibouo 2009; Below et al. 2012) with few exceptions (Nhemachena and Hassan 2007; Deressa et al. 2011). In this paper, it is hypothesized that larger farms are more likely to adopt all the adaptation practices except traditional strategies. Studies show that land tenure is important in determining adaptation, especially if it involves long-term investments. In the case of Chepangs, due to unfavorable government policies and difficult administrative procedures, many land plots that they cultivate are unregistered (Piya et al. 2011b). In this study, it was found that 44.3 % of the households cultivate unregistered plots. Gbetibouo (2009) and Maddison (2007) found that farmers cultivating borrowed land are less likely to adopt adaptation practices compared with those cultivating own lands. For this study, it is expected that the households with higher area of unregistered land are less likely to invest in the construction of water tanks as it is intended for the long-term use.

The households located further away from markets are found to adopt lesser adaptation practices (Maddison 2007;

Table 1 Explanatory variables selected for the model

Variables	Unit	Mean[a]	Standard deviation
Perceived decreasing rainfall	Dummy; 1 = yes, 0 = otherwise	0.36	0.48
Perceived temperature change (hot summer and/or cold winter)	Dummy; 1 = yes, 0 = otherwise	0.32	0.47
Age of the HHH	Years	49.21	16.27
Education of the HHH	Years of schooling	1.23	2.31
Number of economically active members (EAM) in the household (HH)	Number	3.27	1.62
Total landholding per capita	Area in local unit (*Kattha*; 1 *Kattha* = 0.033 ha)	2.36	1.85
Unregistered land per capita	*Kattha*	0.45	0.85
Walking distance to nearest road	Hours	2.12	2.62
Access to credit	Dummy; 1 = yes, 0 = otherwise	0.94	0.24
Listen to related information in the radio	Dummy; 1 = yes, 0 = otherwise	0.47	0.50
HH membership in organizations	Number	1.11	1.15
Trainings received by HH members	Number	0.52	0.78
Site	Dummy; 1 = Kaule, 0 = otherwise	0.26	0.44

[a] *Source* Field survey 2010/2011

Hassan and Nhemachena 2008; Bouma et al. 2009; Deressa et al. 2011; Below et al. 2012). In this study, all the sample households are untouched by motor roads. The walking distance to the nearest road represents the nearest market where extension institutions and service centers are also located. Further distance from the roads symbolizes poor access to inputs and information as the marketplace acts as a center for information dissemination. It is expected that the households located further away from the road are less likely to adopt livelihood diversification strategies, varietal selection, and the construction of tanks, but more likely to depend on traditional coping strategies.

It is reported that access to credit facilitates adaptation by enabling investments in machineries and infrastructures (Hassan and Nhemachena 2008; Deressa et al. 2009, 2011; Gbetibouo 2009; Below et al. 2012). It is expected that households' access to credit would facilitate adaptation options and reduce dependence on traditional coping strategies. The next three variables, viz listening to climate-/agriculture-related information on the radio, membership in community-based organizations, and participation in trainings represent the households' access to information and extension. Households' adaptation is facilitated by access to information through radio or extension agents (Hassan and Nhemachena 2008; Deressa et al. 2009, 2011; Gbetibouo 2009) and through institutions (Bouma et al. 2009; Below et al. 2012). In the study area, the provision of village-level extension services by the government agencies is absent. However, there are many non-governmental organizations (NGOs) working in the field of agriculture, livestock, forestry, health, and renewable energy. Such organizations work with the community by forming household groups and provide trainings (like construction of poly-tunnels for off-season vegetable production) to the group members. Thus, membership in such groups and participation in trainings are the major sources of information and extension services for the community. It is hypothesized that radio information, membership in the NGOs, and participation in trainings will enable the households to deviate from the traditional strategies and adopt other adaptation choices. Finally, to capture the site specificities, Kaule VDC is included as dummy. Among the four sites, Kaule VDC is reported to have the least adaptive capacity in terms of indicators based on livelihood assets (Piya et al. 2012b). Thus, it is hypothesized that households in Kaule are less likely to adapt.

Results and discussion

Ongoing adaptation practices in the study area

Table 2 summarizes the adaptation practices adopted by the Chepang households in the study area. A detailed description of these adaptation practices can be found in Piya et al. (2012b). While some of the adaptation practices like adjustment in sowing time are specific to changing rainfall, others are not specific to climate change only. Soil conservation practices like terracing, constructing walls, and planting hedgerows are adopted widely by the Chepang households (98.6 %). Soil conservation practices are a must because the geographically fragile Mid-Hills are prone to landslides. Diversification from subsistence farming to cash crops (tomatoes, vegetables, and pulses) helps to adapt by increasing cash income. However, cash crops are usually more vulnerable to droughts compared with the cereals. Therefore, this adaptation practice requires access to irrigation and market. Livestock is less affected by climate compared with cereals. For this reason, households rear small livestock that is sold during emergencies like droughts. Non-farm jobs include salaried jobs (clerks, office-guards); skilled non-farm jobs (carpenter, driver); and laboring in foreign countries. Since these income sources are not based on natural resources, income flow is less affected by climate. However, only 16.3 % households pursue this option due to the lack of financial and human resources (Piya et al. 2011b). Varietal selection, adopted by 19.0 % of the households, includes the adoption of short-duration improved maize varieties in response to the delayed onset of post-winter rains and mixing of improved and local maize varieties in the same plot or different plots as a risk management strategy in response to rainfall uncertainties. Small cement or plastic tanks have been constructed to store freely flowing water from natural sources. Such tanks are usually constructed with the partial support from development agencies working in the area and are managed commonly by 5–7 households. During drought, this water is used for irrigation on a turn basis. In the study area, 19.5 % of the households benefit from such small-scale water tanks. Practices like borrowing food or money from the community, wage laboring, and collecting wild edibles are common coping strategies in case of any emergencies including climate extremes.

Soil conservation and seeking assistance from the community are practiced by almost all the households (98.6 and 96.8 %, respectively). The analysis of the determinants on the households' choices is not meaningful when the practice is adopted by all the households. Therefore, these two practices were dropped from the analysis. The remaining eight practices were run as the dependent variables against common explanatory variables. However, the model could not calculate numerical derivatives due to the failure to achieve convergence. Therefore, cash crops, livestock, and non-farm jobs were merged as livelihood portfolio diversification because all these three options involve diversifying away from the subsistence agriculture. These activities are separated from wage laboring because

Table 2 Adaptation practices adopted by Chepang households in the study site

Adaptation practices	Percentage of households adopting the practice ($n = 221$)
Soil conservation practices	98.6
Livelihood portfolio diversification	
Cash crops	57.0
Livestock	69.7
Non-farm jobs	16.3
Varietal selection	19.0
Construction of water collection tank	19.5
Adjusting sowing time	53.4
Traditional coping strategies	
Seeking assistance from relatives and neighbors	96.8
Wage laboring	81.9
Collecting wild edibles	74.7

Source Field survey, 2010/2011

n = number of households covered by the study

these are comparatively newer practices in this community, require development of specific skills and access to specialized market, and give comparatively higher cash returns compared with wage laboring. On the other hand, wage laboring and collecting wild edibles were merged as traditional coping strategies because these two activities are integrated components in Chepangs' livelihoods, are practiced since a long time in response to any kind of emergencies, and are thus commonly adopted by most of the households. Our final model comprises five categories of adaptation practices as the binary choice variables, viz livelihood portfolio diversification, varietal selection, construction of water collection tank, adjusting sowing time, and traditional coping strategies. It is hypothesized that households will depend on traditional strategies only if they are unable to adopt other practices.

Results from the MVP model

The direction of influence for most of the explanatory variables is as expected with few exceptions (Table 3). The likelihood ratio statistics (Wald χ^2) is highly significant ($P = 0.0000$), showing that the variables sufficiently explain the model. Also, the likelihood ratio test for the null hypothesis of the absence of correlation between the individual equations is strongly rejected ($P = 0.0005$), thus validating the estimation of all equations simultaneously by the MVP instead of individual equations.

Livelihood portfolio diversification is significantly more likely to be adopted by households who can correctly perceive the decreasing trend of rainfall and listen to information on the radio, but it is significantly less likely to be adopted by households further away from road. Contrary to our hypothesis, the direction of influence of credit access, temperature perceptions, and age of the household head is negative. Land tenancy does not limit the households from diversifying to cash crops. While training facilitates livelihoods portfolio diversification, memberships in community-based organizations do not necessarily do so.

Households with larger landholding per capita are significantly more likely to make varietal selection. Similarly, households with access to information and extension services via radio and memberships in groups are significantly more likely to practice varietal selection, whereas households in Kaule are significantly less likely to adopt this practice. Once again, the influence of perception of temperature change and age of the household head is not in the direction as hypothesized. Also unexpected is the negative influence of the education of the household head in varietal selection. Households with unregistered land are also adopting varietal selection as it does not involve any long-term investments.

The construction of water collection tank is significantly facilitated by the perception of decreasing rainfall and larger landholding. Households with more unregistered land are significantly less likely to invest in water tanks as it is a long-term investment. As with the earlier two adaptation choices, the influence of temperature perceptions, age of the household head, and credit is not as hypothesized. Although the influence of training is also not as hypothesized, households with membership in organizations are more likely to construct water collection tanks. As stated before, the water tanks are constructed with partial financial support from these organizations.

Only the site variable is significant in adjusting the sowing time. The households in Kaule have the higher propensity to adopt this practice. As noted before, perception of decreasing rainfall facilitates the time adjustment, while the perception of temperature change does not. The direction of influence of landholding shows that smaller farms are more likely to stick to this practice. Surprisingly, both radio information and memberships in organizations influence the time adjustment in the opposite direction than hypothesized.

The adoption of traditional coping strategies is significantly influenced by the size of landholding, with smaller farms relying more on such strategies. The relationship between access to credit and adoption of traditional strategies is also negatively significant. The direction of influence of remaining explanatory variables on the adoption of traditional coping strategies is as hypothesized.

Table 3 Parameter estimates of the multivariate probit model

Explanatory variables	Livelihood portfolio diversification		Varietal selection		Water collection tank		Adjusting sowing time		Traditional coping strategies	
	Coeff.	*P* value	Coeff.	*P* value	Coeff.	*P* value	Coeff.	*P* value	Coeff.	*P* value
Perceived rainfall	0.434	0.027**	0.134	0.558	0.385	0.078*	0.283	0.131	−0.249	0.275
Perceived temperature	−0.150	0.456	−0.456	0.039**	−0.169	0.475	−0.019	0.919	−0.212	0.427
Age	−0.004	0.527	−0.013	0.109*	−0.009	0.221	0.000	0.893	−0.011	0.272
Education	0.036	0.478	−0.072	0.181	0.039	0.422	0.004	0.925	−0.030	0.649
EAM	0.095	0.136	0.048	0.502	0.008	0.902	−0.015	0.798	0.098	0.347
Total land	0.004	0.932	0.107	0.077*	0.107	0.074*	−0.045	0.401	−0.117	0.057*
Unregistered land	0.153	0.211	0.032	0.811	−0.286	0.012**	0.074	0.504	−0.130	0.325
Distance to road	−0.052	0.092*	−0.009	0.791	−0.130	0.134	−0.031	0.293	0.098	0.411
Credit	−1.197	0.002***	−0.119	0.800	−0.412	0.312	0.233	0.517	−3.651	0.000***
Information in radio	0.482	0.010***	0.476	0.023**	0.127	0.544	−0.030	0.862	−0.323	0.198
Membership	−0.082	0.340	0.219	0.016**	0.117	0.190	−0.024	0.773	−0.067	0.567
Training	0.065	0.643	0.028	0.839	−0.048	0.758	0.058	0.641	−0.010	0.940
Site	−0.342	0.125	−0.997	0.002***	−0.043	0.880	0.471	0.030**	−0.094	0.809
Constant	1.131	0.028**	−0.749	0.197	−0.297	0.607	−0.208	0.669	5.969	0.000***

Correlation coefficients	Coefficient	*P* value
$\hat{\rho}_{21}$	0.359	0.003***
$\hat{\rho}_{31}$	0.151	0.221
$\hat{\rho}_{41}$	0.298	0.004***
$\hat{\rho}_{51}$	−0.002	0.990
$\hat{\rho}_{32}$	−0.019	0.905
$\hat{\rho}_{42}$	0.382	0.002***
$\hat{\rho}_{52}$	0.357	0.034**
$\hat{\rho}_{43}$	−0.303	0.008***
$\hat{\rho}_{53}$	−0.162	0.402
$\hat{\rho}_{54}$	0.069	0.648
Draws	100	
Number of observations	221	
Wald $\chi^2(65)$	980.16	
P value	0.0000***	
Log pseudo likelihood	−511.48526	

Likelihood ratio test H$_0$: $\hat{\rho}_{21} = \hat{\rho}_{31} = \hat{\rho}_{41} = \hat{\rho}_{51} = \hat{\rho}_{32} = \hat{\rho}_{42} = \hat{\rho}_{52} = \hat{\rho}_{43} = \hat{\rho}_{53} = \hat{\rho}_{54} = 0$, $\chi^2(10) = 31.475$, *P* value = 0.0005***

***, **, and * significant at 1 %, 5 %, and 10 % levels, respectively

The estimated correlation coefficients ($\hat{\rho}_{kj}$) among the various adaptation options are significant for five out of ten combinations. Livelihoods diversification is positively correlated with varietal selection, water tank construction, and adjustment of sowing time, but negatively correlated with traditional coping strategies. This means livelihood diversification to alternative income sources reduces the dependence on wage laboring and wild foods. Varietal adjustment is complemented by adjustment in sowing time and negatively correlated with the construction of water tanks. Surprisingly, varietal selection is positively correlated with traditional coping strategies. The construction of water tanks is negatively correlated with the adjustment of sowing time which means that households with access to irrigation are lesser dependent on rainfall. Construction of water tanks is also negatively correlated with traditional coping strategies, and lastly, the adjustment of sowing time is complemented by the latter.

Discussion

The results provide some important location-specific insights into the determinants of adaptation choices. While the ability to perceive rainfall changes facilitates adaptation practices, the influence of the perception of temperature changes was not as expected. It might be because the adaptation practices covered by this model are more valid for rainfall changes and the practices undertaken in response to temperature changes are not covered by this research. It is also possible that compared with rainfall changes, farmers do not perceive the temperature changes as directly threatening their livelihoods and are thus not prompted to take adaptation measures against the changing temperatures. Previous literatures analyzing the determinants of adaptation have not considered the perception factors in their analysis except for Nhemachena and Hassan (2007), who also do not differentiate between perception of rainfall and temperature. Future analysis focusing on adaptation to changing temperatures is recommended.

The direction of influence for the age of the household head is also not as hypothesized except for adjusting the sowing time according to rainfall timings, revealing that aged households are reluctant to diversify away from subsistence agriculture or adopt new practices as also reported in southern African countries (Nhemachena and Hassan 2007). Households with larger landholding are more likely to adapt as they can afford to make the necessary investments (Maddison 2007; Gbetibouo 2009; Below et al. 2012). However, households with higher area of unregistered land are reluctant to make investments in infrastructures like water tanks that are intended to be utilized over a long time (Maddison 2007; Gbetibouo 2009).

Households further away from road rely more on traditional strategies and adopt other adaptation practices lesser. Similar findings are also reported by Below et al. (2012) and Bouma et al. (2009). This is because households in remote areas are constrained by the lack of information and lack of access to market to dispose their products, have less off-farm employment opportunities, and are less served by development agencies, leading to lesser dissemination of information and no support for construction of water tanks.

The direction of influence is surprisingly negative for households with access to credit. This is because the Chepangs borrow credit to fulfill their subsistence needs rather than for productive investment. Credit has a negative influence even in the adoption of traditional coping strategies, implying that households rely on subsistence credit only when they are constrained to adopt any other alternative coping measures. The Chepangs borrow small amount of money from relatives, neighbors, or the local moneylenders in order to fulfill their immediate needs. Their access to productive credit is limited because there are no formal lending institutions in the remote areas. In addition, the Chepangs often lack fixed assets needed as collateral in order to obtain loan from formal lending institutions. This necessitates the need of provision of collateral-free credits for productive investments in the area. There are few NGOs recently lending collateral-free credit based on group liability to facilitate commercial farming or livestock in the study area. However, such cases are still very few.

Households listening to related information on the radio are significantly more likely to adopt livelihoods diversification and varietal selection, but less likely to adjust sowing time according to the rains. Membership in organizations is also not influencing the adjustments in sowing time in the hypothesized direction. This means that the households are receiving agriculture-related information like techniques of cash crop cultivation and the suitable varieties, but the information related to weather forecasts is not circulated effectively by the radio or by the development agencies. Although the information of daily weather forecast is broadcasted in the radio, such forecast is limited to major cities and not available to remote areas in Nepal. Seasonal weather forecasts, however, are not at all available from any information sources for the farmers in Nepal. Furthermore, weekly radio programs broadcasting agricultural services do not combine such information with seasonal weather information that would have been helpful for the rural households in designing crop calendar according to the forecasts. The direction of influences of membership in organizations and training on various adaptation choices suggests that while membership in organizations is important to receive services like seeds of improved maize varieties and support for water tanks, simply membership is not sufficient for skill-oriented livelihood diversification options like cash crops or off-farm jobs but needs to be supplemented by trainings for capacity development.

Conclusion, policy implications, and recommendations

The ability of households to perceive rainfall changes is an important determinant of adaptation. Thus, creating awareness of climate change through information dissemination among the community members is an effective way to promote adaptation. The information related to agricultural practices needs to be complemented with seasonal weather forecasts. The extension agents working in the community can be trained to provide advice to the households combining both weather- and agriculture-related information in order to formulate cropping calendar to suit the changing climate. Small landholders are more likely to depend on traditional coping strategies. The provision of collateral-free micro-credit aimed at the small holders will facilitate investment in other adaptation options besides the traditional ones. In order to encourage investment on infrastructure, policies must recognize the traditional land ownership system among the indigenous people and facilitate the registration of their plots. The Chepangs seek credit from informal sources for subsistence purposes. The lack of access to formal credit hinders the productive investment among the Chepangs. Skill development trainings complemented with the provision of micro-credit can help the households to diversify their livelihoods to cash crops, livestock, and skilled off-farm works. Such development assistance and extension services by development agencies need to be extended in areas far from the roads. Future analysis needs to focus on the adaptation practices in response to the changing temperatures. Furthermore, the analysis in this paper is limited to livelihoods diversification as on-farm and off-farm diversification is merged. A further separate analysis of the determinants of these two categories is recommended.

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