International Journal of Climate Change Strategies and Management

Farm households' perception on climate change and adaptation practices: a case from mountain district of Nepal

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1. Introduction

The global average surface temperature has increased by about 0.6ºC during the twentieth century. Many analyses show that the temperature increase in the twentieth century has been greater than in any other century during the past 1000 years (IPCC, 2001). Natural and human systems are expected to be exposed to direct effects of climatic variations such as changes in temperature and precipitation variability, as well as frequency and magnitude of extreme weather events. Adverse effects of climate change continue to be a major threat to rural livelihoods (IPCC, 2007a, 2007b; Nhemachena, 2009; Pouliotte et al., 2009). This poses a challenge of developing innovative technologies to improve rural livelihoods and environmental conservation and ensuring adoption of such innovative technologies (IPCC, 2007a).

Studies show that some low-lying developing countries and small island states are expected to face very high impacts that could have associated damage and huge adaptation costs. Climate change impacts are expected to exacerbate poverty in most developing countries and create new poverty pockets in countries with increasing inequality, in both developed and developing countries (IPCC, 2014). Because of high dependence on the agricultural sector, loss of agricultural productivity due to climate change significantly affects the economy of many developing countries (Gebreegziabher et al., 2011).

Nepal’s low level of development and complex topography renders it vulnerable to change. The ongoing climate change and changes projected to occur are likely to have impacts on different sectors of Nepal. Impacts on some sectors are likely to be more severe than others. The sensitive sectors are agriculture, forestry, water and energy, health, urban and infrastructures, tourism industry and overall livelihoods and economy (MoE 2010). Climate change is posing a threat to food security due to the loss of local landraces and crops (Regmi and Adhikari, 2007). The analysis shows that Nepal is highly vulnerable to climate change. It suggests that more than 1.9 million people are highly climate vulnerable and 10 million are increasingly at risk, with climate change likely to increase this number significantly in future (MoE, 2010).

In a humid climate like that of Nepal, there will be changes in the spatial and temporal distribution of temperature and precipitation due to climate change, which in turn will increase both the intensity and frequency of extreme events like droughts and floods (Mahtab, 1992). Increases in temperature result in a reduced growing season and a decline in productivity, particularly in South Asia (Pachauri, 1992). A warming climate would increase water demand as well as decrease river flows. The major rivers of Nepal are fed by over three thousand glaciers scattered throughout the Nepal Himalayas. These rivers feed irrigation systems, agro-processing mills and hydroelectric plants and supply drinking water for villages for thousands of kilometers downstream. Climate change will contribute to increased variability of river runoff due to changes in timing and intensity of precipitation as well as melting of glaciers. Runoff will initially increase as glaciers melt, then decrease later as deglaciation progresses (Agrawala et al., 2003).

Nepal is an agrarian country dominated by the subsistence type of production system. Agricultural sector contributes about one-third to the Gross Domestic Product and about two-thirds of the economically active population is engaged in agriculture. The cultivated area in Nepal is about 21 percent of the total land area. The average landholding is only 0.68 hectares and about 54 percent landholdings are less than 0.5 hectare (CBS, 2011a). Cropping patterns also vary by ecological regions. Rice and wheat are the major cereal crops in *Tarai*, i.e. southern plain area, while maize and finger millet are the main crops in the hills and the mountain region, especially grown on marginal lands. In addition to traditional and staple crops, there is also a trend of cultivating other non-staple crops such as legumes, seasonal vegetables, potatoes, and other cash crops. Due to inadequate irrigation facility, Nepalese agriculture heavily depends on monsoon rain and is likely to be affected adversely by climate change (Pant, 2009).

The climate change has already been noticed in Nepal. A study based on analysis of temperature trends in Nepal from 1977 to 1994 (collected from 49 stations), indicates a consistent and continuous warming during the period at an annual rate of 0.06^0C (MoE, 2010). A similar study conducted by Practical Action (2009), looking at data from 45 weather stations for the period 1976-2005, indicates a consistent and continuous warming of maximum temperatures at an annual rate of 0.04^0C. These studies also indicate that the observed warming trend in the country is spatially variable.

2. Literature Review

The relevant literatures on adoption of climate change adaptation technologies and practices focused on agricultural sector in Nepal and other countries and their determinants have been reviewed and presented below.

Micro-level analysis of adaptation focuses on tactical decisions farmers and local communities make in response to seasonal variations in climatic, economic and other factors. These decisions are influenced by a number of socio-economic factors that include household characteristics, household resource endowments, access to information (seasonal and long-term climate changes and agricultural production) and availability of formal institutions (input and output markets) for smoothening consumption. Farm-level decision making occurs over a very short time period usually influenced by seasonal climatic variations, local agricultural cycle, and other socio-economic factors Tesso et al., 2012). Important adaptation options in the agricultural sector include: crop diversification, mixed crop livestock farming systems, using different crop varieties, changing planting and harvesting dates, and mixing less productive, drought-resistant varieties and high-yield water sensitive crops (Bradshaw et al.,2004).

Micro-level analysis of farmers' adaptation in Southern Africa using multivariate probit analysis confirm that access to credit, free extension services, farming experience, mixed crop and livestock farms, private property and perception of climate change are some of the important determinants of farm-level adaptation options (IFPRI, 2007).

In Ethiopia, Deressa et al (2009) analyzed the determinants of farmers' choice of adaptation methods in the Nile Basin. The study found that the adaptation methods currently in place in the study area were; changing planting dates, using different crop varieties, planting tree crops, irrigation, soil conservation. The farmers reported that the use of different crop varieties was the most common adaptation method while irrigation was the least common. The reasons for not adapting those practices were lack of information on climate change impacts and adaptation technologies, lack of financial resources, labor constraints and land shortages. The level of education, age, sex and household size of farmers were found to be significant determinants of adaptation to climate change.

A study carried out in Ghana by Acquah-de Graft and Onumah (2011) revealed that the main adaptation measures adopted by farmers include changing planting dates, using different crop varieties, planting tree crops, practicing irrigation, soil conservation and water harvesting. The farmers identified lack of information on climate change impacts and adaptation options, lack of access to credit, access to water, high cost of adaptation, insecure property rights and lack of access to sufficient farm inputs as the main barriers to the adoption of any adaptation measure. The significant determinants of adaptation to climate change were age, gender, years of education, years of farming experience, own farm land and other income generating activities

Different discrete choice models and other econometric models used in analyzing the socioeconomic determinants of adaptation to climate change in Sub-Saharan Africa showed that gender, age of farmers, years of farming experience, household size, years of education, access to credit facilities, access to extension services and off-farm income were among the significant determinants of adopting climate change adaptation measures (Juana et al., 2013).

A range of factors influenced the climate change adaptation practices in three ecological regions of Nepal. The result of the logistic regression analysis showed that adaptation practice is significantly influenced by farm size, number of family members available for farming, farm income, food sufficiency from own farm, and membership in the community level organizations and use of credit. In some cases, subsidies in the technology from the local organizations enhanced the adaptation technology on climate change (Tiwari et al., 2014).

A study conducted in remote rural hills of Nepal among marginalized indigenous Chepang community to analyze the factors influencing the adoption of various adaptation practices revealed that 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 were influential factors (Piya et al., 2013).

Adaptation to climate change is needed both in the short term and long term basis (Adger et al., 2003; Eriksen et al., 2011; Pittock & Jones, 2009). The adaptation theory posits that social, economic, ecological and institutional systems as well as individuals can and do adapt to changing environment (Smithers & Smit, 2009).

Appropriate adaptation to changing climatic conditions improves society's ability to cope with the impact of changes. In a rural community where agricultural activity is the dominant means of living, adaptive capacity enables farming system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. In community's life the ultimate goal of an adaptation measure is to increase the capacity of a farming system to survive external shocks or change (Tesso et al., 2012. The assessment of farm-level adaptation strategies is important to provide information that can be used to formulate policies and design programs that enhance effectiveness in reducing risks from climate change in agriculture.

There are several studies carried out on farm-level adaptation to climate change across different disciplines in different countries that have assessed farmers' perception on climate change and determinants of adaptation. Despite such extensive research work at international level on adaptation to climate change in agricultural sector, little work has been done so far in Nepal. Very few of those studies have considered farmers' perspectives of climate change adaptation. Hence, this study would help to fill the exiting gap to some extent. Furthermore, the study aims to assess the perception of farmers on important parameters of climate change, identify major technologies and practices adopted to mitigate the effects and their determinants in Rasuwa district of Nepal.

3. Methods and Analysis

3.1 Description of the area of study

Rasuwa district is one of the mountain districts of Nepal. The district, situated at 120 km north of Kathmandu. It has a total area of 1544 sq.km. The altitude ranges from 845 m to 7245 m from mean sea level. The majority of the groups is dominated by Tamangs (68.8%) followed by Brahmins (15.1%), Gurungs (3.1%), Chhetri (2.5%) and others (10.5%) (CBS,2014). Rasuwa is rich equally in natural and cultural resources. Tourism is the second most viable economic sector after agriculture (DDC-R, 2002). The Dhunche and Syaphru Village Development Committees (VDCs) are inhabited mostly by Tamangs (75%) and Brahmins is a dominant ethnic group (46%) in Daibung and Laharepauwa VDCs. The number of people living below the poverty line[1] in this district reaches 31.6% of the population which is higher than the national average of 25.2% (CBS, 2011b). The climatic conditions are characterized by warm and moist summer, coinciding with the monsoon season (June-September); relatively warm and sunny autumn and spring seasons; and cold winter with occasional snowfalls (coldest months being January

[1] The poverty line income is NRs. 19261 (or USD 178 at the current price) per-capita per year

and February). Altitudinal and topographic variation, however, produces considerable local variations in climatic conditions in this district.

3.2 Data source and sampling procedure

The study used cross-sectional survey data from 120 households during 2009. Data were collected through questionnaire survey focus group discussions (FGDs) to elicit information. Both structured questionnaire and interviews were held with local government officials, buffer zone communities and all other stakeholders on climate change knowledge and adaptation. In addition, the study also used Focus Group Discussions to assess perception on different climate related parameters and strategies adapted to cope with the impact of climate change.

Being an exploratory type of research, the purposive sampling technique was used while selecting the VDCs situated in the buffer zone of Langtang National Park. In order to meet the study objective, four VDCs namely Syaphru, Dhunche, Daibung and Laharepauwa were purposively selected representing paddy, wheat, maize and potato production area of the district. A two stage sampling technique was adopted to select the respondent households. In the first stage, a ward was[2] randomly selected from among the nine wards of a VDC. In the second and final stage, 30 households were randomly selected from a list of households within a ward cultivating the crop in question with a total sample size of 120. These selected households were interviewed by using the structured questionnaire and the socio-economic and climatic information were collected.

The cropping pattern is different in these VDCs. In Syaphru and Dhunche area, the potato, maize, millet and oat are main crops in the upland while wheat in the lowland. In case of Daibung and Laharepauwa, paddy, maize, wheat and mustard are main crops in lowland while maize, millet, vegetables and potato are main crops in the upland.

For analyzing the climatic trend, the data on temperature and precipitation were obtained from Department of Hydrology and Meteorology for the year 1989 to 2012.

3.3 Empirical model and variables

The adoption of agricultural technologies and climte change adaptation practices involve decisions on whether to adopt or not to adopt such technologies or practices. Previous studies have observed that agricultural technology adoption models are based on farmers' utility or profit maximizing behaviors (Norris and Batie, 1987). Binary logit or probit models are employed when the number of choices available are limited only at two cases. In this study, a binary logistic model has been used to examine the factors influencing the adoption of adaptation technologies and practices applied by the farm households in the study area. The decision to adopt requires that farm households recognize local changes in the long term climate such as temperature and rainfall patterns (Bryan et al., 2013).
In this case the logit model has been used as the dependent variable is dichotomous and the distribution functions are bounded between 0 and 1. The model is based on the

[2] A VDC consists of nine wards and a ward is the smallest administrative unit.

cumulative logistic probability function. It uses logistic CDF and is specified as (Pyndick and Rubinfeld, 1991):

$$P_{1/i} = F(\alpha + \beta X_i) = \frac{1}{1 + e^{-(\alpha + \beta X i)}} = \frac{e^{(\alpha + \beta X i)}}{1 + e^{(\alpha + \beta X i)}} \quad (1)$$

Where F = cumulative logistic probability function,
e = base of natural logarithm,
$P_{1/i}$ = probability that the individual makes a certain choice.

$$P_{1/i}(1 + e^{\alpha + \beta X i}) = e^{\alpha + \beta X i}$$

$$P_{1/i} = (1 - P_{1/i}) * e^{\alpha + \beta X i}$$

$$P_{1/i} / (1 - P_{1/i}) = e^{\alpha + \beta X i}$$

$$\log_e (P_{1/i} / P_{2/i}) = \log_e P1/i / (1 - P_{1/i}) = \alpha + \beta X_i = Z_i \quad (2)$$

The left-hand side of equation (2) is known as the log odds or the logit transformation and the model is known as the linear logit model. Wigley (1985) pinpointed the importance of logit transformation: it increases from $-\infty$ to $+\infty$ as $P_{1/i}$ increases from 0 to 1. Thus, while the probability is bounded, the logit is unbounded with respect to the values of X. According to Wigly, the predicted Logit values

$$\hat{L}_{1;2/i} = \log e \left\{ \frac{\hat{P}_{1/i}}{\hat{P}_{2/i}} \right\} = \hat{\alpha} + \hat{\beta} X_i \quad (3)$$

are likewise unbounded but the predicted probability (which can be found by substituting $\hat{\alpha}$ and $\hat{\beta}$ into equation 3 are confined to the 0-1 range. In this study, $P_{1/i}$ represents the probability that individual 'i' practices climate change adaptation (technologies and practices) and, $1 - P_{1/i} = P_{2/i} = 1/(1 + e^{(\alpha + \beta X i)})$ represents the probability that individual 'i' does not.

The estimation of marginal effects is also considered important. Marginal effects refer to the partial derivatives of the expected value with respect to the vector of characteristics. They are computed at the means of the Xs. Marginal effects show the change in probability when the predictor or independent variable increases by one unit.

Since $P_{1/i} = \frac{1}{1 + e^{-(\alpha + \beta X i)}}$ as per equation (1)

Taking partial derivative of the above equation with respect to X_i, the following formula is derived to estimate the marginal effect of X_i:

$\delta P(1/i)/\delta X_i = P1/i \times (1 - P1/i) \times \beta_i$

3.4 Dependent and explanatory variables

As the agricultural production system is rainfed in nature and farmers have perceived decreasing amount of rainfall during both rainy and winter season and also perceiving the increased incidence of droughts even during rainy season, they have adopted strategies to cope up with these situations. They have adopted water conservation practices, rain water harvesting techniques and mulching to conserve soil moisture. If a household has adopted at least one of the above technology or practices, it is regarded as an adopter and assigned a value of one, zero otherwise.

The studies have shown that socio-economic, cultural, political, geographical, ecological, environmental, and institutional factors all influence the decision making of a household on whether to adopt climate change adaptation technologies. Therefore, the explanatory variables are chosen based on previous studies in Nepal and elsewhere on climate change adaptation on agriculture and data availability. These variables include age, gender, and education of the interviewee, household size, landholding size, non-farm sources of income, perceived threat due to climate change, perception of increased incidences of droughts during rainy season, and location of villages (north or south). The data was analyzed using SPSS.

4. Result and Discussion

4.1 Analysis of hydrological and meteorological information

The analysis of climate data showed that the increase in annual average, maximum and minimum temperature for 1989-2012 period was 0.02^0C, 0.06^0C and -0.01^0C, respectively. The maximum temperature increase was 0.03^0C in January and 0.08^0C in July. The increase of average minimum temperature was 0.06^0C in January and 0.04^0C in July. The average rainfall increase per year for the period was 42 mm. Disaggregating by crop season, there was negative growth (-0.12 mm) between January to April, an increase of 9.25 mm during April to June and 37 mm during June to September for the period from 1989-2012.

4.2 Socio-demographic information

The average age of the interviewee was 51.5 years and 24% interviewees were female. The average household size in the study area was 5.7 people, the dependency ratio, which is defined as the ratio of the dependent population (less than 15 years and more than 60 years) to the working age population was 0.67. It means a single working age population has to support 0.67 number of other population with regard to supporting livelihood. Other socio-demographic information is presented in Table 1.

Table 1. Socio-demographic information of the survey VDCs

S.No.	Characteristics	Average
1	Age of the household head (yrs.)	51.5
2	Household size (number of members)	5.7
3	Dependency ratio	0.67
4	Land holding size (ha)	0.64
5	Households perceiving food security threat (%)	90.0
6	Female headed households (%)	24.0

7	Education level of household head (category)	Primary level
8	Households also deriving income from non-agricultural sources (%)	59.1
9	Sufficient to feed from own production (no. of months)	6.3

4.3 Perception about Climate Change and Crop Production

A variation in the perception of the households with regard to various climatic and weather parameters was observed. Majority of the households perceived the changes in those variables which ranged from 28 percent in case of increase incidences of droughts during the rainy season to 78 percent in case of perception regarding decreasing amount of rainfall every year during winter season (Table 2).

Table 2. Perception of households on the climatic parameters

S.N.	Parameters	Percentage of Households
1	Rainfall is decreasing every year during rainy season.	40.8
2	Rainfall is decreasing every year during winter season.	78.3
3	The weather is becoming dry every year	60.0
4	The yearly rains are not supporting crop production as before	68.3
5	Climate change has led to crop infestation and diseases	51.7
6	The cost of food crops are increasing because of climate change.	41.7
7	Increased incidences of droughts during the rainy season	28.3

The households' also perceived the changes in harvesting time of the crops. In Syaphru, the harvesting time was delayed by 1 month in maize and potato while it was 1 month early in case of wheat. In Dhunche, the harvesting time was delayed by 1.5 months for potato and wheat and one month for maize. In Daibung, the harvesting time of wheat was 1 month early while 1 month late for maize. In Laharepauwa, the harvesting time of maize, wheat and paddy was delayed by one and half months.

4.4 Quantitative Analysis of Adaptation

The result of the strategies for adapting moisture conservation technologies by the farm households using logit model is presented in Table 3. The model had a 73.3 % correct prediction value. The Likelihood Ratio Chi square value was 32.16 implying that the model fits very well to the data, that is, the likelihood of the null hypothesis which states that the coefficients are equal to zero being correct is extremely low.

Most of the variables tested had the expected hypothesized signs. The results indicate that farmers' decisions to adopt climate change adaptation technologies are driven by a number of factors. It shows that landholding size, perceived threat of food security, education level of the interviewee appeared to be significant at 10 percent level while the gender of the interviewee, perception on the increased incidence of droughts during rainy season and households also deriving income from non-agricultural sources appeared to be significant at 5 percent level. Only the village dummy variable was significant at 1 percent level.

Table 3. Logit model on Adaptation of Water conservation technologies/practices

Explanatory Variables	**Marginal effects[3] coefficients**
Constant	- -0.392
Age of the household head	0.0003
Household size	0.008
Land holding size	0.008*
Perceived threat of food security (dummy)	0.368*
Gender of the household head (dummy)	-0.260**
Education of the household head (scale)	0.130*
Perception on increased occurrence of drought during rainy season	0.241**
Households having income also from non-agricultural sources (dummy)	0.240**
Village location (dummy)	-0.325***
Pseudo R Square	0.236
Log likelihood	126.50
LR Chi-square	32.16
Prob > Chi-square	0.0002
Overall Percentage correctly predicted	73.3

Note: ***, ** and * denotes 1 percent, 5 percent and 10 percent significant level respectively.

The positive and significant coefficient of the education of the household head implies that the probability of adaptation to climate change is greater for those household head having higher educational attainment compared to less-educated or illiterate heads. It is obvious that educated farmers have more knowledge, a greater ability to understand and respond to anticipated changes, are better able to forecast future scenarios and overall have greater access to information and opportunities than others, which might encourage

[3] Marginal effects refer to the partial derivatives of the expected value with respect to the vector of characteristics. They are computed at the means of the Xs.

adaptation to climate change. With a unit increase in the level of schooling, the probability of the t the farmers adopting a climate change adaptation technologies would increase by 13 percent. Several studies found that education positively and significantly affects the adoption of technology (Quayum and Ali, 2012; Vijayasarathi and Ashok, 2015).

The female headed household (dummy for gender) appeared to be a significant factor and had the negative relationship with the probability to adopt climate change adaptation practices. This implies that the male-headed households are often considered to be more likely to get information about new technologies and take risky businesses than female headed households (Asfaw and Admassie, 2004). The female headship reduced the likelihood of adaptation to climate change by 26 percent compared with male headship.

The size of the landholding positively and significantly influenced adaptation decision. For a unit increase in land holding size, the probability of adoption of climate change adaptation practices would rise by 0.80 percent. This implies that the bigger the size of landholding, the higher the probability of adapting to climate change. Considering that some of the adaptation strategies such as rain water harvesting need capital for purchasing materials, households with bigger land holding size are able to take up such practice compared to the smaller ones.

The income received from non-agricultural sources (dummy) was positive and significant variable with the probability to adoption. This implies that the likelihood of adoption of climate change adaptation practices would be higher by 24 percent for households having some level of income from non-agricultural sources (in addition to agricultural sources) compared with the farmers deriving income only from agricultural sources. Non-farm income and farm size are considered to represent wealth. It is regularly hypothesized that the adoption of agricultural technologies requires sufficient financial well- being (Knowler and Bradshaw, 2007). Farmers with bigger land holding size and income from non-agricultural sources have ability to purchase improved technologies and the capacity to bear risks.

The dummy variable for households who have perceived threat to food security was positive and significant with probability of adoption. This implies that the probability of adoption of climate adaptation practices would be higher by 24 percent for those households that perceive food security threat compared to the households that do not perceive. This finding is consistent with the findings of Kurukulasuriya and Mendelsohn (2006); Deressa et al.,(2009) and Apata et al.,(2011) which mentions that the adaptation to climate change increases with increasing temperature in anticipation of damages to farmers thereby responding to this through the adoption of different adaptation methods.

The village location (dummy) variable appeared to be negative and significant which implies that the households located in northern areas (Syaphru and Dhunche) tend to do less adaptation (lower by 32 percent) compared to those located in the south (Daibung and Laharepauwa). The variables such as age of the household head (for experience) and size of the household were not significant.

5. Conclusion and Policy Implication

The study area is mountainous with rugged topography. About 32 percent of the people are living below poverty line. The main occupation of the interviewees is agriculture. The size of land holding is 0.64 ha which is considered to be the principal asset in the rural areas. There is little irrigation systems developed in this area and the agriculture production relies on monsoon rain.

The households derive income from both agricultural and non-agricultural sources. The average food self sufficiency, the number of months sustained by their own farm production is 6.3 months. Majority of the households perceived increased incidence of drought during rainy season and decreased amount of rainfall during winter season. Moreover, they have also perceived that the weather is becoming dry every year and the yearly rainfall is not supporting crop production as before. These changes indicate that the households have perceived threat on food security due to climate change.

Households were aware of climate change but not all of them responded by adapting to the changed climate in order to reduce the negative impact and increases resilience of the agricultural systems. The households have adopted different water conservation practices, rainwater harvesting techniques and mulching. The size of landholding, perceived threat on food security, education and gender of interviewee, perception on the increased incidence of droughts during rainy season and off-farm income sources of the household all influenced significantly on whether to adopt adaptation technologies and practices to mitigate the impact of climate change.

The results show that climate change will bring about substantial welfare losses especially for smallholders who derive their livelihood from agriculture. There is a need to neutralize the potential adverse effects of climate change if welfare losses to this vulnerable segment of the society are to be avoided. Adaptation seems to be the most efficient and friendly way for farmers to reduce the negative impacts of climate change. A household perceiving the climate change and its impacts increases the probability of uptake of adaptation measures. Households who are aware of changes in climatic conditions have higher chances of taking adaptive measures in response to observed changes. Size of land holding and households also deriving income from non-agricultural sources increases uptake of adaptation measures as these types of households have higher propensity to invest in adaptation options compared to the smaller ones.

The government policies aimed at enhancing the adaptive capacity of the farmers in the study area should thus be formulated. Massive awareness campaign on climate change and adaptation methods should be created and also mainstream climate change issues into various training programs. Government and local level development actors should encourage adult education, as majority of interviewees were limited to adapt to climate change technologies and practices because of illiteracy among them.

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Journal, Series, Serial or Book Title	Farm Households' Perception on Climate Change and Adaptation Practices: A Case from Mountain District of Nepal		
Journal or Series Editor/s	Leal-Filho, Walter		
Volume Title and Number (if applicable)			
Article/Chapter Title			
Author/s	Binaya Joshi, Weihong Ji, Narayan Babu Joshi		
Publication Date (approx)	February 2017		
Page Count	17	Print Run	
Format (print/electronic)	electronic	Price	
Publisher	EMERALD GROUP PUBLISHING LIMITED		

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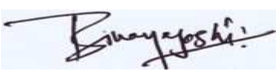
Signature (either hand-written or insert a scanned signature)	
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