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Forest health: context of forest pests and pathogen in Nepal

Forests form an integral part of life on Earth, and provide a range of benefits at local, national and global levels. In Nepal, forest is an important component of the livelihood of majority of people particularly living in rural areas. Moreover, forests provide several ecosystem services, including provisioning, regulating, supporting and cultural services. Considering such multiple roles of forests, the Government of Nepal has focused on the effective management of forest resources under its various programmes. Government realizes that the continuous supply of multiple goods and services largely depends on the health and conditions of the forests.

Forest health is a very important part of the sustainable forest management system. In the utilitarian approach, it is defined in terms of a forest's capacity to satisfy human needs, whereas the ecological approach considers resilience, recurrence and persistence of a forest and all biological processes involved in. Nevertheless, both approaches are not competing, but are complementary to each other. In essence, they emphasize on sustainable delivery of forest goods and services without deteriorating its quality. However, forests experience plenty of natural and anthropogenic disturbances, such as fire, extreme weather, harsh climate, illegal felling, grazing and encroachment as well as the rampant competition from weeds and invasive/alien species and infestation of various insect pests and pathogens. These disturbances lead to poor forest health, which can exert moderate to devastating negative impacts.

The forest resource assessment of Nepal (2010-2014) collected data related to the extent and severity of various forest disturbances, including grazing, forest fire and tree cutting. However, information related to forest pests and pathogens were not captured. There is a clear gap on comprehensive understanding on the various issues and status of forest pests and pathogens in the national scenario. General observations show that infestation of insect pests and pathogens is a serious problem in Nepal, particularly in plantation and forest nurseries.

A recent field survey by the then Department of Forest Research and Survey (DFRS) and FAO mission in some of the forest sites in the Terai and the mid-hills of Nepal found that both natural and plantation forests have been, in many cases, seriously affected by the infestation of insect pests and pathogens. Seedlings in forest nurseries were also found in feeble condition due to various fungal diseases. Diseased seedlings act as the vectors and are likely to carry pathogens from one place to another and may cause outbreak of diseases in plantation sites in future. Nepal has already witnessed a huge economic loss, though not precisely estimated, due to pathogenic attacks in commercial timber-yielding species like

Dalbergia sissso and Shorea robusta.

Controlling insect pests and pathogens in the forests is a critical task of forest managers; but it requires expertise in many disciplines; such as plant pathology, entomology, ecology, dendrology, mycology, taxonomy, silviculture, and forest management. It is more difficult in natural forests compared to plantation forests. Use of chemicals to control forest insects pests and pathogens is in practice; however, it is limited to forest nurseries or in small forest patches. It is extremely difficult to control them once they spread over a larger area. Therefore, producing insect and pathogen-free robust planting materials is important to keep a forest plantation healthy. The proper consideration on selecting healthy and robust genetic materials may limit the future infestation of insect pests and pathogens on forest crops; ultimately increasing the profits from plantations. In the case of natural forests, controlling insect pests and pathogens before they spread over a larger area is an efficient and effective way to keep them healthy besides implementing various tending and silvicultural operations.

A widely known Nepalese proverb "prevention is better than cure" can be a guiding principle in controlling forest insect pests and pathogens. It is the cheapest and most effective technique to maintain better forest health and conditions ensuring the regular and increased supply of forestry goods and services. Nevertheless, forest health has been one of the most neglected issues in the forestry discourse in Nepal for a long time.

In this context, Nepal requires upgrading the existing laboratory facilities, conducting training programmes for capacity development of the forest technicians, raising awareness among various forest stakeholders, and strengthening capacities of customs and quarantine offices. It is equally important to build strong functional networks of multiple stakeholders at multiple levels in order to stop several insect pests and pathogens entering into the country and conduct various control measures.

Moreover, application of remote sensing technology could be effective in monitoring of forest pests and pathogens. Integrating forest health monitoring as a component of national and local level forest resource assessments and collecting data related to forest insect pests and pathogens could be important. It helps us to know the trend of infestation of forest insects, pests and pathogens in time intervals and also to predict areas susceptible to be infested in the future. Similarly, the mapping and documentation of the extent and magnitude of the infestation followed by action research on prevention and control should be undertaken by the government and other sectors. The results of the action research can be implemented in wider areas at the time of needs

Forests of Nepal, undoubtedly, are infested by insect pests and pathogens. Prevention and control of forest insect pests and pathogens should be a priority program of the government in the forestry sector of Nepal.

Volume models for Sal (*Shorea robusta* Gaertn.) in far-western Terai of Nepal

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Sal (*Shorea robusta* Gaertn.) is one of the most important commercial tree species in Nepal and far-western Terai is renowned for its forest. This study was carried out in far-western Terai to develop volume models of Sal at tree level using destructive sampling. Out of 99 sample trees, 81 data were used to develop the models and 18 data for validation of the selected models. Over bark stem diameters were measured at an interval of 0.5 m in lowermost three sections, at an interval of 1 m for one section and at an interval of 2 m in upper part of the trunk from the ground level. Smalian's formula was used to compute tree volume. Seven regression models were tested using DBH as a predictor variable. Cross validation of the independent data set was used to validate the selected models. The graphical analysis and fit statistics of the models were evaluated to select the best fit model. The selected model for total over bark stem volume is ln V = - 8.04674 + 2.26641 ln DBH with R^2 of 92 % and standard error of 0.18. Similarly, the selected models for over bark volume up to 10 and 20 cm top diameter have R^2 of 82.41% and 79.97% and standard errors of 0.35 and 0.42, respectively. The prediction error of the selected model was found to be less than 6%. Forest managers can use the recommended model in estimation of timber volume of Sal in a particular forest area of this region for effective forest management.

Key words: Destructive sampling, far-western Terai, fit statistics, regression equation

Tree volume provides vital information in forest management for estimating current and future stock of forest. However, direct measurement of volume is a tedious and impractical in the field. Thus, models or mathematical functions are necessary to estimate the volume using some measurable variables such as height, diameter and form of the tree. Further, volume models have been used as one of the best means to estimate trees and stand volume and have played vital role in forest inventory, management and silvicultural research (Ozçelik *et al*., 2010).

In principle, height and diameter are measured in the routine forest measurement. However, height measurement is not always practical due to more time consuming and cost and possibility of being less accurate (Wagle and Sharma, 2011; Sharma and Pukkala, 1990b; Chaturvedi and Khanna, 1982). On one hand, the possibility of error increases more in the dense forest measuring tree height, on the other, DBH can be measured more easily and accurately with less time and cost. Further, volume table produced using a model with predictor variable DBH only is particularly useful for quick timber inventory. It can be tallied with species and only DBH (Sharma and Pukkala, 1990a; Chaturvedi and Khanna, 1982; Özçelik, 2008).

Department of Forest Research and Survey (DFRS) have been involved in producing various volume and biomass models (Sharma and Pukkala, 1990a; Laamanen *et al,* 1995, Tamrakar, 2000; Acharya *et al*., 2003) of tree species required for forest management for long time. The general volume tables of 21 tree species and two species groups were developed in 1990 using data collected in 1960s (Sharma and Pukkala, 1990a). During 1990s there were few studies on general volume and growth models of Sal, especially in central Bhabar forests of Nepal (Laamanen *et al.,*

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1995). In addition to this, DFRS has developed biomass and volume models of some trees and bamboo species and some forest types. However, the diameter used in developing the models was ≤ 35 cm and the data were collected from thinning operation applied in trial plots may not represent the natural forest and again, the data were from only central part of the country *(*Acharya and Acharya, 2004; Acharya *et al*., 2003; Tamrakar, 2000; Pukkala *et al*, nd.*)*.

S. robusta Gaertn.*,* only one species found in Nepal of tropical family Dipterocarpaceae, is a multipurpose tree species. Sal is a valuable and important timber species for construction, and fuel wood. Sal seeds are used as raw material in industries and leaf used for making plates and as fodder for livestock (Jackson,1994). It is still most predominant species in the terai of Nepal (DFRS, 2014). It is found from Terai region to 1500 m but common up to 1000 m. It occurs mostly in Terai, Siwalik and low land of hilly areas. In most areas, almost pure Sal forest can be found or in association with *Terminalia alata*. In some places, it grows along with broadleaved species. The Sal forests in the Terai (plain area) are mostly large and differ from hill Sal forest. In higher rainfall and moist areas, it is replaced by mixed forest. Dobremez (1976) listed nine types of *Shorea* forests, but Champion and Seth (1968) listed more than that, most of them are expected to be found in Nepal (cited by Jackson,1994).

The climate of far-western terai is drier than other parts of the country. Out of the total forest area of Kailali district, 32.16% is covered by Sal forest and 31.39% by Terai Mixed Hardwood (TMH) with Sal (DDC Kailali, 2015). The Sal forest in far-western Terai is similar with minor variations due to topographic and climatic similarity. Thus, DFRS, 2014 described as far-western forest clusters, which is different from those in other parts of the country because its climate is drier than other parts of the country. Therefore, the volume models based on one variable *viz*. DBH alone will be applicable.

In recent years, efforts have been made towards the scientific forest management in Nepal. However, there is lack of appropriate technical tool for volume and biomass estimation of timber. There is need for precise and site specific volume estimation equations using easily and accurately measurable independent variables of the trees. Realizing the situation, Department of Forests has called for preparing district wise local volume tables to estimate the timber quantity (DoF, 2014). Therefore, preparation of local volume equations of this species for the natural forest of far-western Terai is essential. The purpose of the study was to prepare local volume models of *S. robusta* for specific heights of tree trunk in far-western Terai.

Materials and methods

Study area

The study site is Balchaur area located at the eastern part of Kailali district and other sites such as Bani, Banka, Motipur, Gwalabari, Krishnapur, Basahan, Singapurur, etc. located at eastern and southern part of Kanchanpur district (Fig. 1).

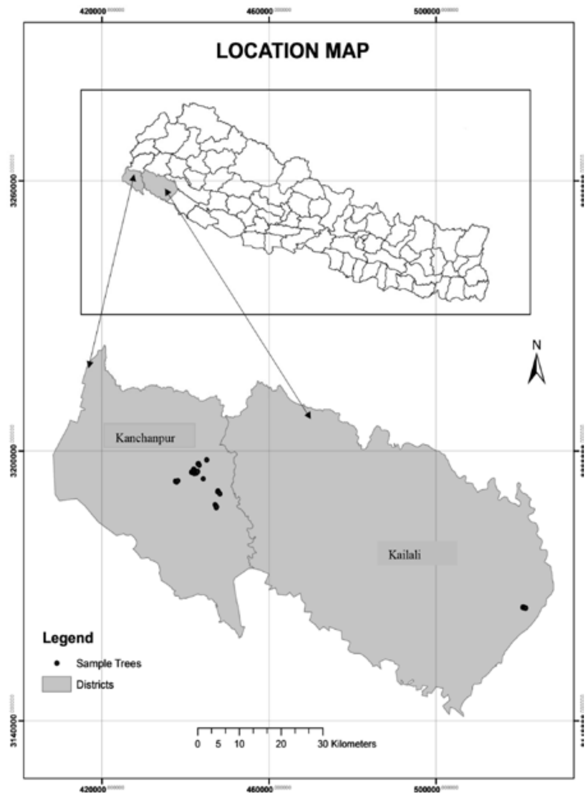

Fig 1: Map of the study area

These sites are in an altitudinal range of 109 m to 200 m above the mean sea level. Kailali district has an area of 3,235 sq. km, in which 40 per cent is covered by Terai (flat land) and 60 per cent by Chure hills. The total area of Kanchanpur district is 1610 sq. km in which 11.7 percent covered by Chure region, 55 percent is covered by forest and streams and 548.5 sq. km. of wildlife reserves and its buffer zone area. The far-western Terai forest extends from the Karnali River in the east to the western border of Nepal. It covers 97,622 ha forest outside the protected area (DFRS, 2014). Sal forest, Terai Mixed Hardwood forest, Sal with Terai Mixed Hardwood forest and Khair-Sissoo forest are the dominant types of forest in this area (DFRS, 2014).

The southern parts of the districts consist of plain area with deep fine sandy loamy soil. The climate is generally sub-tropical. The precipitation and temperature from Dhangadhi and Mahendranagar stations represent eastern and western study sites, respectively. The data of precipitation and temperature in Dhangadhi are average figures of 25-years and 6-years, respectively. The data of precipitation and temperature in Mahendranagar are average figures of 10-years and 4-years, respectively. Average annual precipitation ranges from 1547 mm in Mahendranagar to 1725 mm in Dhangadhi. Average monthly temperature ranges from 23.7^{o} C in Dhangadhi to 23.6^{o} C in Mahendranagar. Absolute maximum temperature is 43.5^{o} C whereas absolute minimum temperature is 2.0^{o} C in Dhangadhi. Absolute maximum temperature is 43.0^{o} C whereas absolute minimum temperature is 2.6^{o} C in Mahendranagar. Dhangadhi annual autumn temperature is maximum 43^{o} C to minimum 24^{o} C and winter temperature is maximum 19^{o} C to minimum 2^{o} C. In this way, average temperature is found as 30.5^{o} C. These climatic data taken from Department of Hydrology and Meteorology/Department of Irrigation, Hydrology and Meteorology are stated by Jackson (1994).

Data collection

According to the Forest Act (1993), plants above 30 cm diameter are regarded as tree and selected as samples for the study. The data of selected sample trees were collected above 30 cm DBH to develop models particularly for estimation of Sal timber. The data were collected from the forests of far-western Terai. The trees above 30 cm diameter were divided into 10 cm diameter class up to 90 cm and one class above this. For each diameter class, at least 10 trees were selected for developing a model. The data were collected from different forest types, quality class, crown class and density to represent all the possible local minor variations of natural forest. The forest type, quality class, crown class and density were measured as in FRA (2010). The representative sample trees with respect to size (diameter) were chosen randomly among the available trees from all parts of the selected area. Twenty-one sample trees were selected from pure Sal forest, 23 from Sal-Asna mixed forest and 37 from Terai Mixed Hardwood forest to develop the model . The crown cover of these forests ranged from 30 to 85% having median of 60% crown cover. Similarly, the selected sample trees to develop the model were 67 from predominant, 12 from co-dominant and two from suppressed trees. In this way, 81 (32 from Kailali and 49 from Kanchanpur) sample trees were selected to develop the model. Similarly, 18 sample trees were selected from representative study area for validation of the models.

The basic characteristics of the site and sampled trees were recorded before felling the sample trees. After measuring DBH, trees were felled and over bark diameters were measured at an interval of 0.5 m in lowermost three sections, at an interval of 1 m for one section and at an interval of 2 m in upper part of the trunk (Sharma and Pukkala, 1990a; Eerikainen, 2001). Further the height of the sampled tree up to 10 cm and 20 cm over bark top diameters were recorded. The over bark diameters were measured by a diameter tape with an accuracy of 0.1 cm. Sectional volume was calculated using Smalian's formula and then total volume and volume up to top 10 and 20 cm diameters were obtained by summing up sectional volumes (Laamanen *et al*.,1995, Segura and Kanninen, 2005 Özçelik, 2008, Ozçelik *et al*., 2010).

Data structure and model development

The average DBH and height of the sample trees were approximately 59 cm and 30 m (Table 1). The detailed descriptive statistics of 81 sample trees is given in table 1.

Table 1: Descriptive statistics of data of sample trees

Variables	Number of sample trees	Minimum	Median	Mean	Maximum	Standard deviation
Total height (m)	81	19.00	30.05	29.91	41.20	5.05
DBH (cm)	81	30.10	57.50	59.21	108.50	16.86
Height diameter ratio	81	0.38	0.50	0.53	0.76	0.10
Crown height (m)	72	3.40	12.20	12.39	23.30	5.28
Total volume (m^3)	81	0.58	2.90	3.69	11.20	2.35
Volume up to 20 cm (m^3)	81	0.38	2.80	3.59	11.14	2.36
Volume up to 10 cm (m^3)	81	0.56	2.89	3.67	11.18	2.35

The following different models were tested using R statistical software (R core Team, 2012).

$V = a + b * D$ ....(i)
$\ln V = a + b * \ln D$........................(ii)
$V = a + b * \ln D$............................(iii)
$\ln V = a + b * D$............................(iv)
$V = a + b * D_2$...............................(v)
$V = a + b*D+c*D_2$.......................(vi)
$V = aDb$..(vii)

Moreover, the following models were tested for predicting the volume of the proportion of sample tree in top 10 cm and top 20 cm over bark diameter (Sharma and Pukkala, 1990a; Laamanen *et al*., 1995).

$\ln V_1 / V = a + b* \ln D$ ....(viii)
$\ln V_2 / Vt = a + b*\ln D$ ....(ix)

where,
a, b and c are parameters to be estimated,
V is total volume of tree,
V_1 is volume beyond 10 cm top diameter,
V_2 is volume between top 10 and 20 cm diameter,
Vt is volume up to 10 cm top diameter,
DBH is diameter at breast height and ln is the natural logarithm.

Model selection and validation

T-test and F-test were used for testing the significance of the parameters and whole equation, respectively. The best fit model was selected based on residual analysis (whether the model fulfilled regression assumption or not), and fit statistics (standard error, bias and coefficient of determination). The back transformation was done with bias correction by adding exp ($SE^2/2$) to the intercept (Sprugel, 1983).

The method of cross validation technique was used (Hawkins, 1987; Kozak and Kozak, 2003). The models were evaluated by testing cross validation of separate data sets of 18 trees. The prediction statistics was estimated using following equation and percentage error were plotted against the explained variable (Hawkins,1987; Acharya *et al.,* 2003; Ducey and Williams, 2011).

$(bias = \sum_{n}^{i}(yi - y\hat{}) / n$ ....(x)

$RMSE = \sqrt{\sum_{n}^{i}(yi - y\hat{}) / (n-1)}$ ……(xi)

Prediction error = (∑ actual volume − ∑ predicted volume)/ ∑ actual volume ∗ 100)………(xii)

Results and discussion

Relationship between total volume and tree variables

The relation of volume with both the height and DBH was found to be strong and positive (Fig. 2). The Pearson Correlation between total volume and DBH was found to be 0.9897. Similarly, the correlation between volume and height was found to be 0.8610 whereas it was

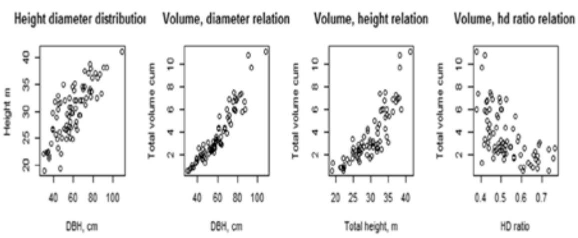

Fig 2: Relationship among different variables

0.8011 between DBH and total height. Since, the total height has strong and positive relation with DBH, the height adds very little effect on volume than that of the DBH alone.

Total stem volume model

Above mentioned models were fitted and checked both by graphically and numerically in order to identify the best predicted model. The fitted models were overlaid on the observed data (Fig. 3). In second graph, the observations are better distributed around the model throughout the DBH range. However, in all other figure, the models better capture the observation only in some part of the DBH range.

The seven different regression models as given above were fitted and checked both by graphically and numerically to test the best predicted model. The fitted models were overlaid on the observed data (Fig. 3).

Except the fifth and sixth models, the parameters of other five models are significant at 5% level of significance or even less. In general, all models fitted to the data well, as their good statistical fits in terms of R^2 explained greater than 80% of variability (Table 2). There were variations in standard error of estimate (SEE) in different models and equation 2 has the lowest SEE which is less than 0.2.

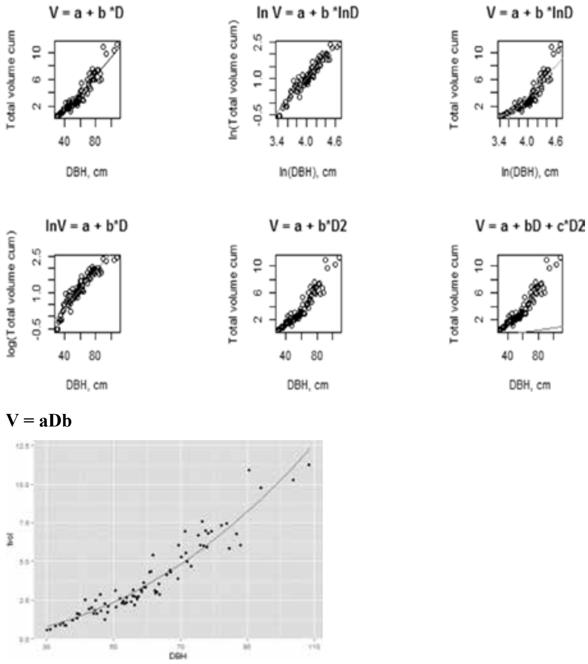

Fig. 3: Visualization of seven models

Table 2: Values of regression constants, std.error, R^2 with t and p-values of tested models

Model no.	Parameter	Estimate	Standard Error	t value	Pr(>|t|)	Sd. Error of Estimate	R^2	p-value
1	a	-4.3588	0.3291	-13.2500	<2e-16***	0.8053	0.8915	<2.2e-16
	b	0.1360	0.0053	25.6600	<2e-16 ***			
2	a	-8.0640	0.2930	-27.5300	<2e-16 ***	0.1859	0.9249	<2.2e-16
	b	2.2664	0.0722	31.4100	<2e-16 ***			
3	a	-27.2900	1.6610	-16.4300	<2e-16 ***	1.054	0.8142	<2.2e-16
	b	7.6680	0.4090	-18.7500	<2e-16 ***			
4	a	-1.1329	0.0937	-12.1000	<2e-16 ***	0.2292	0.8873	<2.2e-16
	b	0.0376	0.0015	24.9400	<2e-16 ***			
5	a	-0.3144	0.1626	-1.9330	0.568	0.724	0.9135	<2.2e-16
	b	0.0011	0.0000	28.8680	<2e-16 ***			
6	a	-0.7848	0.8744	-0.8970	0.372	0.7272	0.9137	<2.2e-16
	b	0.0154	0.0281	0.5480	0.586			
	c	0.0009	0.0002	4.3460	4.14e-05***			
7	a	0.0006	0.0002	2.9250	0.00449**	0.7306	0.8928	6.11e-06
	b	2.1144	0.0786	26.8970	<2e-16***			(convergence tolerance)

Note: ** shows significant at 95% and *** shows significant at 99% confidence level

In the past, similar models were tested for different species (Hawkins, 1987; DFRS, 2006). Laamanen *et al.* (1995) developed a general volume model with R^2 of 97.1% and standard error of estimate of 0.13 for Adabhar, Bara district. The model developed for Sal by Sharma and Pukkala (1990) for producing general volume table has R^2 of 98.3% and standard error of estimate of 0.13 and it is widely used. In both cases, DBH and height were used as predictor variables but in this study only DBH was used as a predictor variable, which alone explained 92.5% variation of the observed tree volume. Lower R^2 value in this study may be due to the use of single predictor variable, DBH. SEE is greater in one explained variable than two variables (Pukkala *et al.* n.d.). Other similar models were also developed in the past but their statistics of fit was not mentioned (Acharya *et al.,* 2003).

The residuals of all models were analyzed. Due to the brevity of space, only graphs of the most suitable model (M2) were presented in figure 4. It is important to note that only model 2 showed homoscadascity and normality of residual distribution. The curve of the residuals was not seen sharply decrease or increase in the selected model. Similar trend was found for standardized residuals. Three outliers were found in which two outliers had underestimated and one outlier had overestimated values. The outlier samples were identified and analyzed. Though, removal of outliers improves the model reliability but they were not removed so as to represent the data from all parts of the study area.

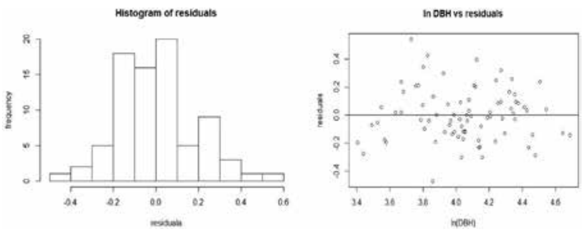

Fig. 4: Histogram of residuals and residuals versus Ln (DBH)

Over bark stem volume up to top 10 cm and top 20 cm top diameter

The distribution of ratios (M8 and M9) against its predictor variable clearly indicates that the data were distributed negative exponentially (Fig. 5). Hence the models with both side logarithms were used as in the past in similar cases (Sharma and Pukkala, 1990a; Laamanen *et al.*, 1995).

In this case, only logarithmic model was tested as used in similar past studies (Sharma and Pukkala, 1990a ; Laamanen *et al.,* 1995). All the parameters of both models were significant (Table 3).

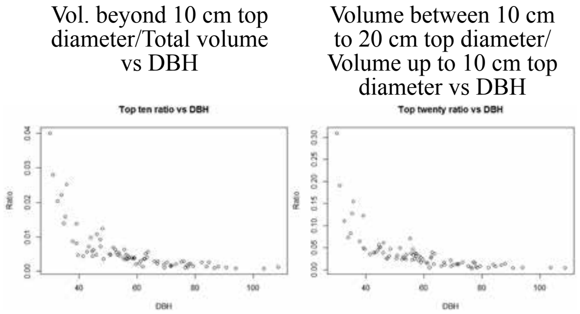

Fig. 5: Volume ratio of top 10 and 20 cm diameter vs. DBH

In comparison to total stem volume equation, the R^2 values of both equations were lower, while standard error of estimates was higher. It may be due to error accumulation from total volume model. Sharma and Pukkala (1990a) reported 78.9 and 74.1 R^2 values for the ratio of top 10 and 20 cm over bark diameter, respectively. Similarly their standard error of estimates was 0.51 for both the equations. These two models were better than Sharma and Pukkala (1990a) in terms of R^2 and SEE (Table 3). However, the fit statistics reported by Laamanen *et al*. (1995) was better than that of the study.

Table 3: Values of regression constants, R^2 and standard error of the models

Model no.	Model	a	b	R^2	SEE	n
8	$\ln(V_1/V) = a + b*\ln D$	5.0445	-2.6094	0.8241	0.3469	81
9	$\ln(V_2/Vt) = a + b*\ln D$	8.221	-2.954	0.7997	0.4253	81

Table 4: Prediction statistics of the models

Model	RMSE	Bias	Prediction error (%)
Total volume over bark	0.3958158	0.1836834	5.812
Volume up to 10 cm over bark	0.395469	0.1827535	5.809
Volume up to 20 cm over bark	0.4009819	0.1759837	5.769

The residuals of both models (M8 and M9) were found to be satisfactory and they were distributed evenly without any trend, so these models can be recommended. The residuals against DBH are shown in figure 6.

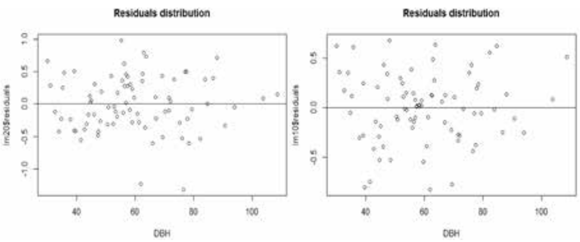

Fig. 6: Residuals *vs*. DBH in two models

Model validation

The definition and method of validation among the researchers were not found uniform (Kozak and Kozak, 2003; Bellocchi *et al*., 2010). Most of them considered components of fit statistics and graphical inspection for validation (Kozak and Kozak, 2003; Bellocchi *et al*., 2010). In addition to the analysis of fit statistics, Meehl *et al*. (2005) compared different models, which are used for similar purposes. Vanclay (1994) calculated the prediction statistics of independent data sets for model validation. Iles (2003) strongly recommended for checking few independent trees to measure accuracy of the volume table (cited by Ducey and Williams, 2011). Therefore, for validation of these equations, in addition to compare different equations, fit statistics and graphical inspection, the prediction statistics of 18 trees were analyzed.

The bias, RMSE and prediction error of models for total volume, and volume up to 10 and 20 cm diameter are almost similar (Table 4). The equation for total volume over bark was biased to 0.1 8 m^3 with RMSE of nearly 0.4 m^3, which is acceptable since validation data sets were fewer than modeled data, resulting losses of the information (Kozak and Kozak, 2003). Moreover, Hawkins (1987) recommended that the overall prediction error should be within 10 to 15 % of the actual value. In this study, the prediction errors of selected model was found to be within 6% and were lower than that of Acharya *et al.* (2003). But some statisticians argue that due to fewer validations data sets rather than modeled data validation losses the information (Kozak and Kozak, 2003).

The predicted values of all suggested models were plotted against the actual values of test data sets (Fig. 7). There is slightly underestimation of volume mainly in large-sized trees (Fig. 7).

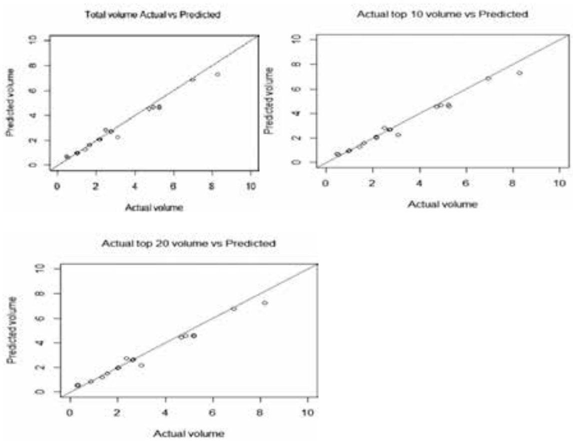

Fig. 7: Predicted versus actual volume

The individual error of test data set was evaluated by plotting against the diameter (Fig. 8). The overall prediction errors of all models were within limit but the error percentage of individual trees was a bit high in some cases. The models consistently underestimated volume of trees over the range of DBH (Fig. 8).

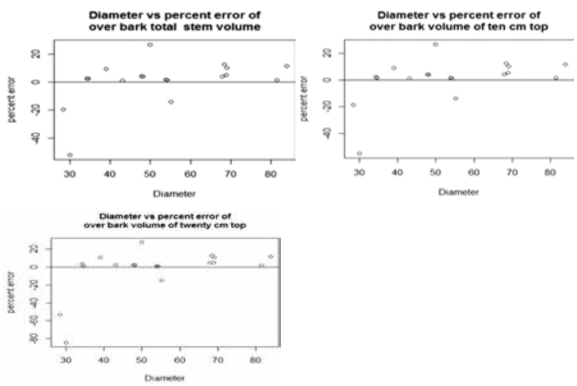

Fig. 8: Percent error vs. DBH of individual tested tree

Conclusion

Among the tested seven models, the recommended logarithmic model has the smallest RMSE and bias, and higher R^2. The model for total stem volume is ln V = 8.04674 + 2.26641 ln DBH. The models for ratio of volume beyond 10 cm top diameter to total stem volume is ln (V_1/V) = 5.0618 - 2.6094*ln DBH and ratio of volume between 10 cm and 20 cm diameter to volume up to 10 cm top diameter is ln (V_2/Vt) = 8.31144 - 2.954*ln (DBH). This study recommends for application of the equations within the range of sample data. Since, the samples are site specific, the models should be used cautiously in other places of Nepal after validating the models.

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Identification and mapping of risk areas of rhino poaching; a geospatial approach: A case study from eastern sector of Chitwan National Park, Nepal

M. Subedi[1]*, R. Subedi[2]

Nepal has an appreciative history on conservation of rhino with remarkable proportions of Asian rhino population protected and managed within the protected areas. Poaching risk map promises early warning and a way to target preventive action, which can safeguard both human and ecosystem. This study was designed to identify and map risk areas of rhino (*Rhinoceros unicornis*) poaching within and around eastern sector of Chitwan National Park (CNP). A multi criterion GIS method was used to analyze and derive the risky zone. A binary logistic regression and expert consultation were done to finalize variables and risk rating, then weighted sum index model was performed in ArcGIS to derive risk zonation map. Presence/poaching and pseudo absence data were dependent variables and distance to guard post, settlement and road network from poaching events, land cover, slope and elevation were predictor variables for logistic regression model. Poaching events were observed to be spatially distributed around the park except in the south part. Among the seven predictable variables, five variables except terrain (slope and elevation) were statistically significant at 10% level of test ($p<0.1$). The poaching risk map indicates that areas near to roads, far from the guard post, and densely populated area of grasslands are high risk zone areas for rhino poaching. The GIS based maps will be practical and strategical to wildlife managers in CNP to facilitate decision making on intervention programmes and how best to direct law enforcement patrol within and around the park.

Key words: Pseudo absence data, *Rhinoceros unicornis,* weighted sum index model

Among the natural resource management programme in Nepal wildlife conservation has been steadily budgeted since the late 1970s (Poudyal *et al.,* 2012). Primarily this is true for greater one-horned Indian rhinoceros, which is protected within the protected areas in the low-lying Terai region (Poudyal and Knowler, 2005). Chitawan National Park (CNP) provides prime habitat for the most of the rhinoceros in Nepal, and the preservation of rhinos in this park is impressive conservation success stories (Poudyal, 2005). Due to the high value on illegal markets, endangered species are often targeted species of poachers.

The Greater one horned rhinoceros, also known as Indian rhinoceros is an odd-toed ungulates of the family Rhinocerotidae. The greater one-horned rhinoceros is the largest of three types of Asian rhinos and, together with African white rhino, is the largest of all rhino species (WWF, 2017). It is listed in appendix I of CITES (Bhattarai and Rupakheti, 2015), globally vulnerable (IUCN, 2017) and nationally endangered (Jnawali *et al*., 2011) and protected by National Park and Wildlife Conservation Act 1973. Rhino population has been increasing in Nepal for few years (WWW, 2017).

Poaching and illegal trade in endangered species and products made from them are considered foremost serious problem in biodiversity conservation, hence poaching is the biggest challenge in the biodiversity conservation (Aryal, 2002). According to the NBSAP (2014) illegal hunting and trade of important wildlife

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species is a major threat in the management of protected area's biodiversity which has affected more severely to those vertebrates whose demand of products in international market is very high. Poaching is one of most challenge faced by the management in CNP (Acharya, 2006). As long as there is demand for oriental medicine-prepared from wildlife products like rhinoceros's horns, there is always risk of poaching (Aryal *et al*., 2009). Despite the success in preserving the rhinos in Nepal, substantial number have been poached within and outside these protected areas since the establishment of national park.

According to Treves *et al*. (2011), identification of the spatial distribution (e.g., extent, location) of poaching activities is utmost for managers to mobilize limited resources appropriately to the concentrated areas where poaching severity is high. Monitoring, enforcement and deterrence are difficult for poaching due to its illegal nature. To control poaching significant human and financial resources are needed (Keane *et al*., 2008) and manager most prioritize the monitoring and assessment activities relative to the other natural resources based on economic analysis (Sheil, 2001). Thus, it is necessary to investigate the relationship between accessibility, habitat and control factors with poaching events to identify high poaching risk zone.

During the last three decades, Remote Sensing (RS) and Geographical Information System (GIS) technologies are emerging as new tools assisting in resolving land use conflict and management of natural resources (Brown *et al*., 1994) and also have made significant contributions in the management of natural resource and also for environmental monitoring (Zaman, 2012). GIS technology is a powerful tool for managing, analyzing, and visualizing wildlife data to intended areas where interventional management practices are required to monitor their effectiveness (ESRI, 2010). This study was carried out with an integrated approach using RS and GIS techniques together with ancillary data for poaching risk mapping of rhino.

Population density and catch per unit effort of poachers is inversely proportionate which means if rhino population density increases, the effort required to find a rhino to poach will decreases (Metzger *et al*., 2010). In the study area, population density of rhinoceros is very high in comparison to other protected areas of Nepal which has created more favorable environment for poachers. Regular monitoring of population is therefore essential to guide protection efforts and management decisions (Subedi *et al*., 2013). Mapping can be used to prioritize conservation efforts and to minimize wildlife poaching risk which is helpful to manage wildlife and to delineate the most vulnerable area of poaching risk for a specific species (Sanches *et al*., 2008). This study had two main objectives: (i) to establish the relationship between accessibility habitat and control factors with spatial and temporal pattern of poaching events of rhino and (ii) to derive a poaching risk map. The results of this study will be useful for concerned stakeholders to conserve rhino in and around the CNP.

Materials and methods

Study area

The study was confined to the eastern sector of world heritage listed Chitwan National Park (Fig. 1). Geographically, the study area extends from 27° 25' 30'' N to 27° 39' 30'' N latitude and from 84° 23' 30'' E to 84° 45' 03'' E longitude. The eastern sector covers around 407 sq. km of core area and 138 sq. km of buffer zone and spreads into the Parsa, Makawanpur and Chitwan districts. The eastern sector consists of very good habitat for rhinoceros and has good population density. Since the last 12 years 30 % of total poaching incidents were found in this sector (CNP, 2015).

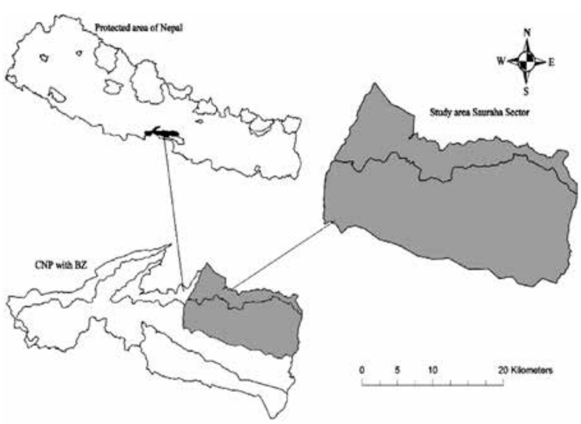

Fig 1: Map showing the location of study area

Methodology

The overall methodology used in this study is given in figure 2.

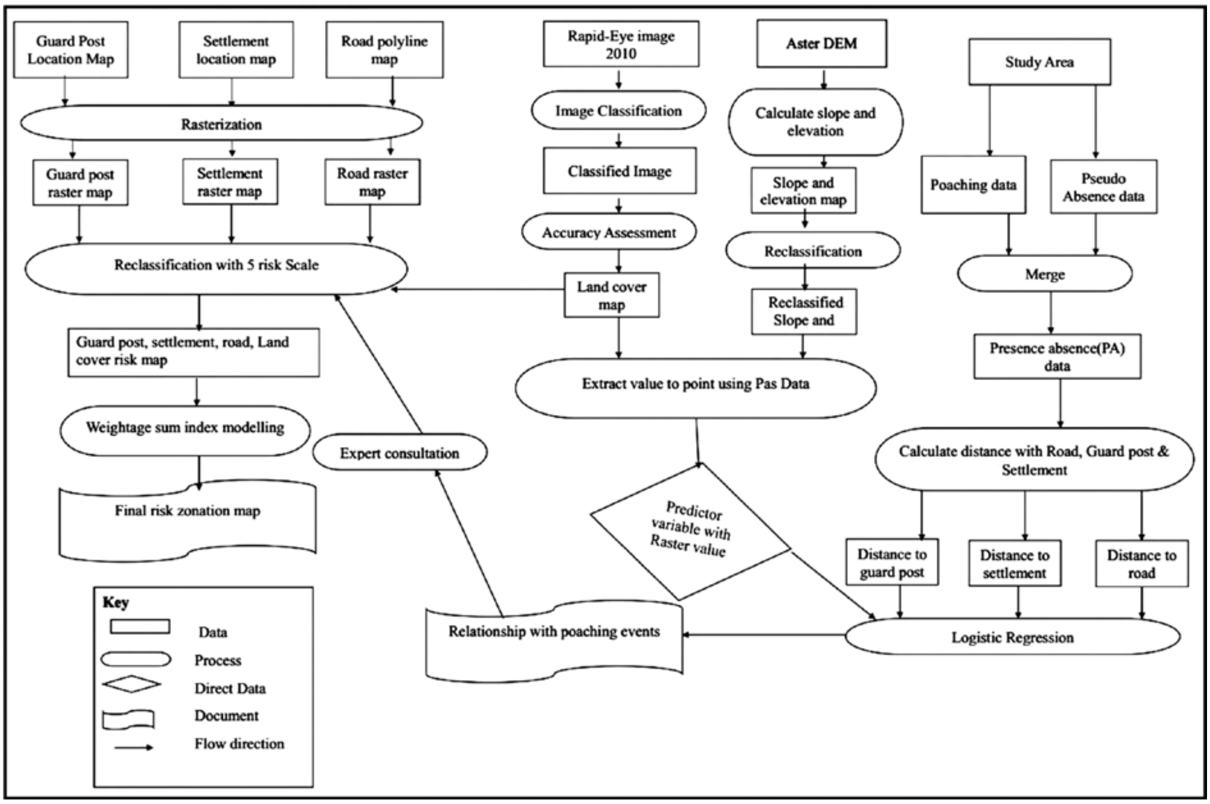

Fig. 2: Overall methodology for the risk mapping

Data use

The Rapid Eye image dated February 2010, having 5 m spatial resolution of the study area was used for the land use land cover map preparation. ASTER Digital Elevation Model (DEM) of the 30-m spatial resolution dated October 2011 was also downloaded from USGS (https://earthexplorer.usgs.gov) and used for the slope and elevation map preparation. Digital topographic maps of the study area were purchased from Department of Survey, Kathmandu Nepal and used for the road network and settlement map preparation. The location of the guard/security post, poaching and population information, habitat distribution from 2003 to 2015 were used and the data were supplied by the CNP.

Data analysis

Generation of spatial layer and land cover map

Spatial layers of Land Use Lan Cover (LULC), settlement, slope, elevation, guard post, road, habitat distribution and poaching events of rhino were generated using ArcGIS. Object based image analysis (OBIA) techniques were used for the land cover map using Classification and Regression Tree (CART) approach (Fig. 3) and eCognition Developer version 8 was used to produce the LULC map. First of all, images were divided into object segments and then using the test sample, image objects were classified into samples. Finally, the tuning parameters of different classifiers were adjusted to generate high classification accuracy. Altogether, 206 sample points were used for the training sample and 60 sample points were used for the accuracy assessment. The mean values, standard deviation, brightness, max. diff. (max. intensity difference), NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) were also chosen for classifications.

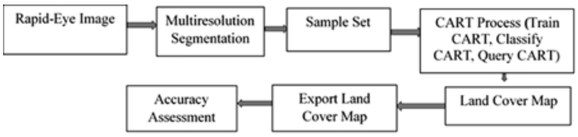

Fig. 3: Flow chart of image classification using CART Pre-processing of poaching events data

Poaching data and poaching absence data were combined and processed in logistic regression analysis. Poaching data were given name to presence data and poaching absence data were generated from the study area where poaching events were absent assuming there is no poaching and gave name to pseudo absence data. Fifty pseudo absence data were generated using QGIS and merged with presence data and got the presence- absence dataset which were later used as a dependent variable in regression analysis. Presence data were labelled 1 and pseudo absence data were labelled 0 during the logistic regression analysis.

Logistic regression model

Logistic regression is one of the Generalized Linear Model (GLM) which is distinguish with other statistical model since it is not influenced by the supposition of variance inequalities across the groups, and is appropriate to use whenever the dependent variable is binary in nature (Hosmer *et al.*, 2000). In the logistic regression model presence absence data as a dependent variable and distance to road network, distance to settlement, distance to guard post, land cover and slope as predictor variables, were used to explain the relationship with poaching events.

Distance to road, settlement, guard post as descriptive variables were determined from presence absence dataset using the near distance function in ArcGIS. The attributes and raster value of LULC map, slope and elevation were analyzed and extracted using ArcGIS and used in regression model. Statistical Package for Social Science (SPSS) were used for the logistic regression analysis.

The poaching risk mapping

After establishing the relationship between the bio-physical factors and poaching events, the results were discussed with the concerned expert and their weightage was fixed. Only significant variables in logistic regression analysis were discussed with expert. This method was done because poaching spatial factor and field scenario may be different so only statistical test is not sufficient. After finalizing criteria all maps according to the risk rating were prepared and finally used to derive poaching risk zonation map of the study area by using multi-criterion weightage sum index modelling in raster GIS environment.

Results and discussion

Relationship of poaching events with variables

The logistic regression model perfectly predicted 34 pseudo absence (non-poaching) events out of 50 sample points and 25 presence (poaching) events out of 29 poaching events. 85.5 % overall accuracy was provided by the full model.

To explain the rhino poaching within and around the eastern sector of CNP, six predicted variables were examined for their significance using stepwise logistic regression. Out of six predictor variables, only four variables such as distance to guard post ($p=0.030$), distance to road ($p=0.010$), distance from settlement ($p=0.021$) and land cover ($p= 0.074$) were remained in the model with significant negative relationship of distance to road network and distance from settlement and positive relationship of distance to guard post and land cover with poaching events ($p<0.1$). Logistic regression analysis table is given annex 1.

In the scenario of natural resource management, roads make easier to people's movement in formerly unreachable areas. If the area is easier to reach; then poacher can go in the area at short time for poaching (Toxopeus,1996). Similarly, in this study most of the poaching events were found to be occurred in areas within one to two kilometers.

Security guard post plays the most important role in bio-monitoring of illegal activities. The wildlife conservation history showed that more the guard posts less the poaching. This study showed negative relationship between security guard posts and illegal activities, as the increase in distance from guard post enhanced the likelihood of poaching.

Some local inhabitant adjoining to the protected areas, illegal hunting comprises the part of their livelihood. Ouko (2013) found the direct relationship between the incident of poaching and level of income of local people. In this study, the relationship between distance from the settlement and poaching incident was found negative which means nearer the area from settlement, higher the risk of poaching.

Rhinoceros preferred the alluvial plain grasslands and swampy area. They have definite spots for dropping their excreta (Thakur *et al.*, 2014). Grasslands and water bodies are the potential area for rhino poaching. Most of the poaching incidents were in grassland area, it could be because of habitat limitation in other areas.

Spatial distribution of poaching events

The results showed that during a period of 12-years from 2003 to 2015, 72 % of the poaching events occurred in the grasslands, 7 % in forestlands, 14 % in water bodies, 4 % in cultivated area and remaining 4 % were in the sandy/river cutting area (Fig. 4). About 35 % poaching events were found at a distance of 3000 m to 4500 m away from the guard post and very less at a distance of less than 1000 m (Fig. 5).

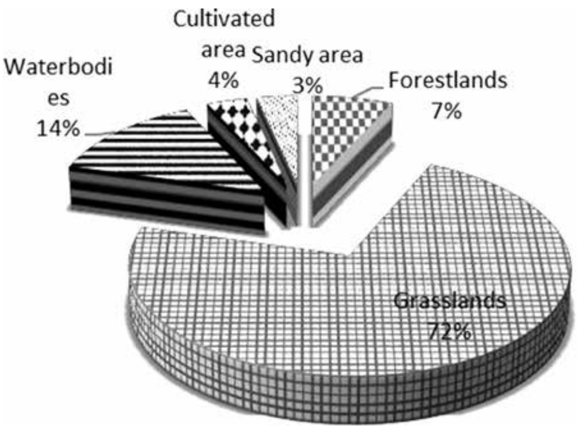

Fig. 4: Distribution of poaching events with LULC

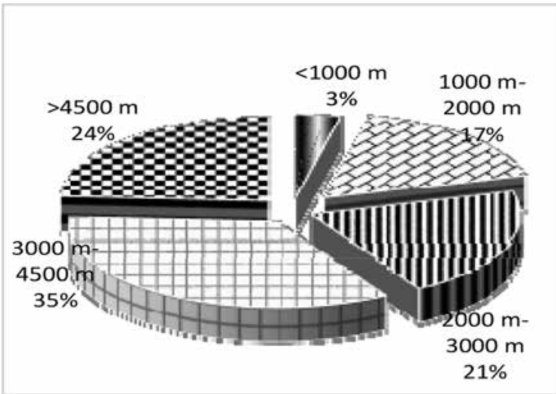

Fig. 5: Poaching incident and distance from guard post

Most of the poaching events were occurred at a distance of less than 1000 m from the road (Fig. 6) and 2 – 4 km away from the settlement. No poaching events were found at a distance of 3000 m away from road and 8 km away from settlement (Fig.7)

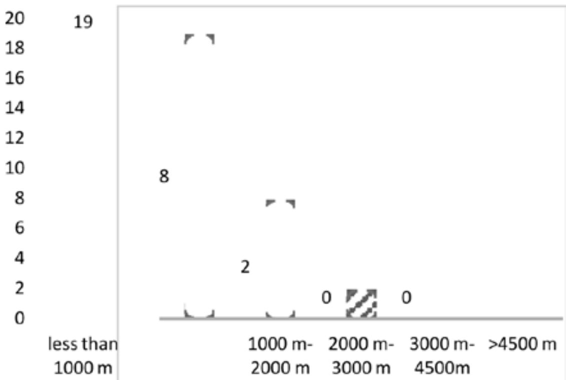

Fig. 6: Poaching events with distance from road

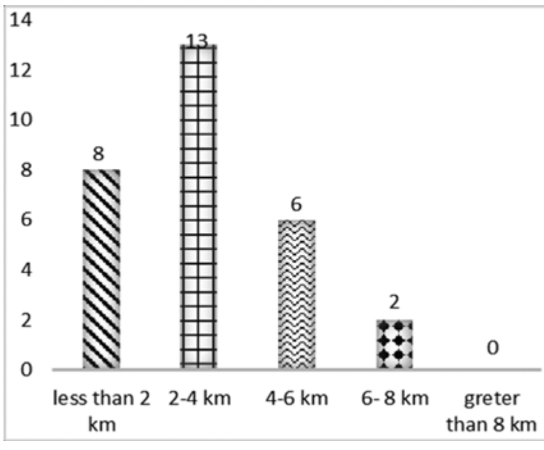

Fig. 7: Poaching events with distance from settlement

Finalized criteria for risk mapping

The variables were classified into five classes. The very high-risk area, high risk area, medium risk area, low risk area and very low risk area were rated as 5 to 1, respectively. Finalized variables and their weightage is given in annex 2.

Risk zonation map

Figure 8 depicts the risk zone areas of rhino poaching within and around eastern sector of the CNP. The high-risk zone areas for rhino poaching are those areas close to roads, far from guard post and higher populated area of grasslands with red to green tones. This map is a result of combining the guard post distance risk map, road distance risk map, settlement distance risk map and land cover risk map.

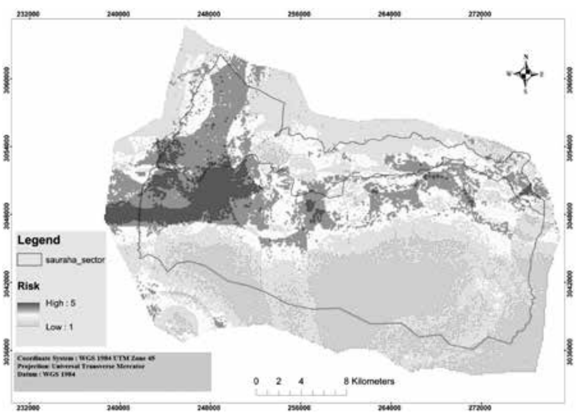

Fig. 8: Rhino poaching risk zonation map

About 34. 6 km^2 area was found as very higher risk area, 106.23 km^2 as high risk, 132.92 km^2 as medium, 161.88 km^2 as low and 109.66 km^2 as very low risk area of poaching (Fig. 9).

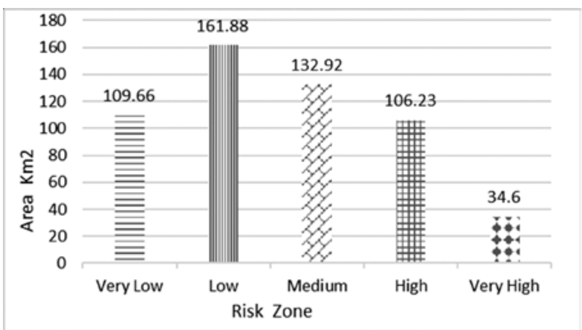

Fig. 9: Area covered by different risk zone

Conclusion

The findings from this study indicate that the multi-criterion GIS based weightage sum index model presented in this research identified and mapped risk areas of rhino poaching within and around eastern sector of the CNP. Poaching events occurred all, except in the southern part of eastern sector of CNP. Frequency of poaching was concentrated more in western site of the sector. The average rhino poaching location was found to be 792 m away from road, 3106 m away from settlement and 3424 m from guard post. Grasslands and water bodies were more likely to exhibit poaching events. The increase in distance from the guard post increased the likelihood of poaching, but the increase in distance from road and settlement reduced the likelihood of poaching. Most poachers avoid long distance travelling inside the park boundary. Nearby village of the CNP has also created the proxy environment for the poaching. About 45 % incidences were found at the distance between 4—6 km from settlements.

Hence for the effective control of rhinoceros poaching, more security guard posts should be established and the area of responsibility (AoR) of existing guard posts should be increased (maximized). This study recommends to prepare the similar risk map to other sectors of the CNP taking into account social factor in addition to the habitat, control and accessibility factors and the park should be arranged the anti-poaching activities according to risk zonation map.

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Annex 1: Logistic regression analysis table

Variable	β	df	Sig.	Exp (B)
Distance to guard post	.068	1	.030*	1.001
Distance from settlement	-.001	1	.021*	.999
Distance to road	-.053	1	.010*	.997
Land cover	3.054	1	.074**	21.195
Slope	2.984	1	.598	7.25
Elevation	6.34	1	.895	15.43
Constant	-2.882	1	.293	.056
* significant at 0.05 and ** significant at 0.10				

Annex 2: Variables in forest poaching risk area modeling, their ratings and poaching Occurrence and β coefficient in regression analysis

Variable	Class	Poaching Occurrence	Risk Rating	β	Statistically significant
Land cover	Forestland	3	3	3.054	(p=0.074) Significant at α=10%
	Grassland	21	5		
	Water bodies	3	4		
	Sandy areas	1	2		
	Cultivated area	1	1		
Distance from guard post (m)	<1000	1	1	0.680	(P=0.030) Significant at α=5%
	1000 — 2000	5	2		
	2000 — 3000	6	3		
	3000 — 4500	10	5		
	>4500	7	4		
Distance from road (m)	<1000	19	5	-0.053	(P=0.010) Significant at α=5%
	1000— 2000	8	4		
	2000—3000	2	3		
	3000— 4500	0	2		
	>4500	0	1		
Distance from Settlement (m)	<2000	8	2	-0.001	(P=0.021) Significant at α=5%
	2000— 4000	13	5		
	4000—6000	6	4		
	6000— 8000	2	3		
	>8000	0	1		

Integrating forests and biodiversity in Nepal's National Adaptation Plan: A review and synthesis of knowledge stock on opportunities and way forward

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Climate change brings lasting changes in forests and biodiversity together with the ecosystem services altering its ability to support present and future economic activities. Current forest utilization and preservation is based on how forests developed under past climatic conditions. Policy-makers and forest managers must accept that climate change is inevitable and from which forests and forest communities are significantly impacted globally and in Nepal also, sustainable forest management (SFM) is already based on many measures to adapt to climate change as planned adaptation will reduce vulnerability at intervened sites and will have long term impacts. However, many forest species will be adapting autonomously and society will have to adjust to the result. Adaptation requires planning for change so that a suite of options for the future but based on the present practice and knowledge is to be available whenever needed. On the foundation of concurrent learning, knowledge and experiences of National Adaption Program of Action (NAPA) process, the National Adaptation Plan (NAP) process for forests and biodiversity will build medium and long-term adaptation strategies and plans with widely accepted objectives of future forests and biodiversity management.

Key words*:* Adaptation, biodiversity, climate change, forest, NAP

Climate change is one of the pronounced global challenges for our civilisation which is calling for immediate responses to tackle its impacts for the sake of current as well as future generations. The changing climate has been affecting all economic sectors and complicatedly intertwined with multiple environmental pressures such as loss of biodiversity, deforestation, forest and land degradation, desertification, water and air pollution, etc. Including other sectors, forests and biodiversity in Nepal is highly vulnerable to climate change due to climate variability and associated risks of the natural disasters (MoE/NAPA, 2010). The effective response to climate change requires urgent formulation and implementation of comprehensive strategic plans and programmes that could halt the damages posed by climate change and prepare the economic sectors and population to adapt with. Nepal commenced systematic adaptation planning based on the vulnerabilities after the National Adaptation Programme of Action (NAPA) process in 2010. Understanding that NAPA is intended to reduce climate change vulnerabilities through urgent and immediate actions, the National Adaptation Plan (NAP) process has been put forward to address medium and long-term climate change adaptation needs.

Nepal, a least developed Himalayan country, characterized by high levels of poverty, dense population, exposure to climate-related events, and their reliance on flood and drought-prone agricultural land (NCVST, 2009; IDS *et al*., 2014), is one of the most vulnerable countries to the impacts of climate change. The ongoing climatic change and changes projected to occur are likely to have impacts on forests and biodiversity which urge for comprehensive adaptation actions.

Climate change adaptation considerations in forest and biodiversity management plans

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articulating specific goals and objectives for climate change will help to create better avenues for adaptation in forestry sector. A clear statement of goals and objectives based on current trend and future scenario of climate change can lead to an achievement of stated goal that addresses long- term concerns within short-term decisions (Gregory *et al.*, 2001).

This paper collates information on major climate change impacts on forests and biodiversity and the response to address impacts of climate change through policy and programmes. It envisions to review the policy measures and the programmes undertaken to address impacts of climate change in the sector. As Nepal is formulating NAP, which is aimed at reducing vulnerability and integrating adaptation into the development planning process (LEG, 2012), it is imperative to assess the key gaps and needs in the forestry sector which accounts for 15% of GDP of the country (MoPE, 2017) with a potential to generate employment for about 100,000 man- days per year (MSFP, 2015). Moreover, forests in Nepal have a total carbon stock of 1,054.97 million tonnes (DFRS, 2015), the trading of which could further offer additional economic contributions for adaptation actions. Hence the idea of this paper emphasizes on creating an enabling policy environment for the NAP formulation process by understanding the existing situation and future requirements.

Materials and methods

This study is a synthesis of the knowledge stock and is based on the review of published reports, journal articles and research papers. Information was drawn from national repositories. The policy provisions were reviewed from Nepal's policies, strategies, plans, and gaps and needs were identified accordingly. In addition, national experiences, consultations with key experts and their judgment also flourished the discussions.

Results and discussion

Global warming and climate change are the biggest concerns since they affect the whole ecosystem and human population. Its impact on forests and biodiversity is more pronounced and easily understood as this sector is more dependent on climate sensitive natural nurture. In Nepal, early symptoms of climate change due to alarmingly increased temperature have been observed. Forests and biodiversity was considered one of the most climate sensitive and highly affected thematic areas in NAPA (MoE/NAPA, 2010) and the same proposition was adopted in NAP formulation process too where forests and biodiversity is a distinct thematic area.

Climate change poses a new dimension to forest and biodiversity management and planning because forests are not only affected by climate change but also by the climate change affected community and political economy as the mountain forest is expected to be most affected by a changing climate (Gitay *et al*., 2001, Houghton *et al.*, 2001, IPCC, 2007). In Nepal, forests cover about 45% of the area (DFRS, 2015), and play a critical role in regulating global and local climate, global carbon and water cycles, and in national economy (Bhatti *et al.,*2003, Karki, 2013). On contrary, forests are also highly affected by changing climate, with their distribution and characters being largely determined directly or indirectly by climate (Kuusela. 1990, McGuire and Chapin, 2006). By 2100, global climate is expected to warm by 1.4 to 5.8°C, but the temperature increase in Nepal is projected to be double than this (IPCC, 2001 and 2007), with major implications for mountain biodiversity and forests. A study by Organisation for Economic Cooperation and Development (OECD) using Global Circulation Model (GCM) at Special Report on Emissions Scenarios (SRES) B2 scenario shows increment of mean annual temperature by an average of 1.3°C, 1.7°C and 3°C by 2030, 2050 and 2100 respectively, in comparison to the 2000 baseline (MoE/NAPA, 2010). In this situation, the NAP process and its outcomes could be a point of departure for further adaptation medium and long-term planning in forests and biodiversity thematic area.

Climate change concerns of forestry sector

Forest's contributions to the well-being of humankind is enormous and wide-ranging including its input in fostering agriculture and assisting in combating rural poverty and providing decent livelihoods, as about 76% of Nepal's population depends on forests for their livelihoods (Amatya, 2013), where some 64% still using fuelwood as a major source of domestic energy (CBS, 2014). In addition to addressing climate change impacts, forests also offer green growth opportunities and provide vital environmental services such as conserving biodiversity and watersheds. With providing essential goods and services, sustainably managed forests ultimately contribute to sustainable development. Therefore, forests and their roles have also been strongly recognized in the sustainable development goals (NPC, 2015). Forests are not only the livelihoods base of rural community, but they are also one of the key economic sectors of Nepal (Subedi *et al.,* 2014), it contributes to the national economy by providing an average annual revenue of NPR 550 million (USD 5.4 million). Moreover, the sale of different forest products and services, including timber, non-timber forest products (NTFPs) and nature-based tourism, has become a significant source of national revenue (Subedi *et al*., 2014).

Nepal houses 118 ecosystems, 75 vegetation types and 35 forest types (BPP, 1995; Jackson, 1994; MoFSC, 2014) and is characterized by a high number of floral and faunal diversity (Table 1). Majority of the ecosystem are reported to be found in the Mid Mountain (52 ecosystems) and in the High Mountain (38 ecosystems) (MoFSC, 2014). Out of these ecosystems, 80 ecosystems are in the existing protected areas that cover 23.23% of the country's area (DNPWC, 2016). Xu *et al.* (2009) have projected that a 1^{O}C increase in mean annual temperature will result in a shift in isotherms about 160 m in elevation or 150 km northward in mountain ecosystems. Nepal is experiencing intense rainfall and/or drought with increased frequencies of landslides, floods, droughts, and forest fires and with accelerated damage to life and property but no clear and significant trend has been noticed in rainfall pattern (MoE/NAPA, 2010). There is an increase at an average annual precipitation of 3.6 mm from 1976 to 2005. However, observed precipitation has reached over 40 mm/year in some small pocket areas while decreased annual rainfall has been observed in most parts of mid-western development region (Baidya *et al*., 2007 and JVS/GWP, 2015). These statements indicate that a small change in the temperature will have dramatic change in the precipitation which is the major attribute of sustainable forest and biodiversity management.

Table 1: Floral and faunal diversity in Nepal

Floral diversity		**Faunal diversity**	
Group	**# of species**	**Group**	**# of species**
Angiosperm	6973	Mammals	208
Gymnosperm	26	Birds	867
Bryophyte	1150	Reptiles	123
Pteridophyte	534	Amphibians	117
Fungi	1822	Fish	230
Lichens	465	Butterflies	651
Algae	1001	Moths	3958
		Spider	175
		Others	5642
Total	**11971**	**11861**	

Source: MoE, 2010; MoFSC, 2014

Another climate change concern of forestry sector is vulnerability to forest fires in Nepal. Forest fires occur annually in all physiographic/ climatic regions of Nepal. Rimal *et al.* (2015) analysed The International Centre for Integrated Mountain Development- Moderate Resolution Imaging Spectroradiometer (ICIMOD-MODIS) based forest fire detection and monitoring system data until 2013 and found that Terai region is the most vulnerable to forest fires. Forest fire is a serious driver of forest degradation with increased incidents in Nepal and is one of the toughest threats to forest conservation in Nepal (Karki *et al*., 2013 and Karki, 2015a, 2015b) which has two fold implication *i.e.* it's a source of Greenhouse Gas (GHG) emission and the accelerated climate change due to GHG emission triggers more forest fires. Both preparedness and combating forest fires is further compounded in the hills and mountains due to remoteness, and this is accelerated by prolonged droughts in recent years. Furthermore, introduction of alien invasive species is another concern but very few data available on the magnitude and impacts and infestation of alien invasion. Invasive species invade degraded forests and then colonize the site gradually. The central and eastern parts of Nepal seem to have high infestation by invasive species in comparison to the western parts (Rai *et al*., 2012)

Like for other biological systems, both temperature and precipitation are critical to forests. In general, warmer and wetter will enhance forest growth, while warmer and drier will likely be detrimental. If drying is significant, grasses will often replace forests in natural systems (Bowes and Sedjo, 1993) where for the 2xCO2 climate, a poleward shift of vegetation by 500 km or more is assumed (Solomon and Kirilenko, 1997). In general, climate change is likely to shift natural forests toward the poles (to high altitude also). Thus, for forests, the changes will be the greatest in the temperate climate. For forests growth and composition, perhaps changes in precipitation and moisture is more important than change in temperature because limits on moisture could result in forestlands being converted to grasses. Although climate models are not generally regarded as good predictors of regional precipitation changes, the interiors of continents tend to be dry, and this tendency should be exacerbated under climate change and warming (Sedjo, 2010).

Some impacts of climate change on forests are likely to be beneficial also. Increased temperature could have direct effects on plant growth by enhancing photosynthesis and respiration rates, and plants can tolerate even extremely high temperatures, if sufficient water is available (Kirschbaum, 1998). Sensitivity of natural systems like forests is linked to the projected climate change-induced impacts, the degree to which natural systems have been degraded and the unsustainable utilization of resources. Among forest species, NTFPs are directly exposed and more sensitive to climate change. Declined productivity of economically viable NTFPs, such as panch aunle *(Dactylorhiza hatageria*), silajit (Rock exudates), amala (*Phyllanthus emblica*), ritha (*Sapindus mukurosii*), timur (*Zanthoxylum armatum*), and bel (*Aegle marmelos*) have been observed as a result of climate change (MoFSC, 2011). A decrease in the availability of NTFPs will impact the communities dependent on these resources for their livelihoods (MoPE, 2017). Increase in population often result in the conversion of forest lands to cultivation and more intensive farming that result to accelerated forest fires and land degradation. There are also expected impacts on soil erosion, fertility in the soils, and depletion of water resources and genetic variability of crops (Sinha *et al*., 1998; IPCC, 2001).

Impacts of climate change on biodiversity

Our understanding of the impacts of climate change on Nepal's biodiversity is inadequate (MoPE, 2017). The Millennium Ecosystem Assessment showed that over the past 50 years human activities have changed ecosystems more rapidly and extensively than at any comparable period in our history (MA, 2005). These changes have bagged many net development gains but at growing environmental costs: biodiversity loss, land degradation, and reduced access to adequate water and natural resources for many of the world's poorest people. Biodiversity loss matters because species and habitats are the building blocks on which human livelihoods depend, the foundation for production forests, fisheries and agricultural crops. Enhanced protection and management of biological resources will also contribute to solutions as nations and communities strive to adapt to climate change (World Bank, 2008). The risk of climate change to human systems is increased by the loss of ecosystem services that are supported by biodiversity (e.g., water purification, protection from extreme weather events, preservation of soils, recycling of nutrients, and pollination of crops). Studies since the Fourth Assessment Report (AR4) broadly confirm that a large proportion of species are at increased risk of extinction (Oppenheimer *et al*., 2014).

Nepal houses about 12000 faunal species (MoFSC, 2014). A smaller change in temperature significantly affects the rich biodiversity of Nepal making it more vulnerable. Natural disasters, such as landslides, glacial lake outburst floods and drought which have been triggered by climate change pose considerable threat to ecosystems and the people (MoFSC, 2014). Further, global warming may cause forest damage through migration of forests towards the polar region, change in their composition, and extinction of species. Tropical forest and warm temperate forest would disappear, and cool temperate vegetation would turn to warm temperate vegetation. Vegetation pattern would be different under the incremental scenario (at $2^{O}C$ rise of temperature and 20% rise of rainfall) than the existing types (Sedjo, 2010; Bazzaz, 1998). In this situation, species with narrow tolerances may vanish by virtue of the extinction of their habitat.

Detail impacts of climate change on Nepal's biodiversity are inadequate as less research have been conducted in this sector. Some of the known impacts are: (i) shifts in agro-ecological zones, prolonged dry spells, and higher incidences of pests and diseases, (ii) increased temperature and rainfall variability, (iii) increased emergence and quickened spread of invasive alien plant species, (iv) increased incidence of forest fire in recent years, (v) changes in phenological cycles of tree species, (vi) shifting of tree line in the Himalaya, and (vii) depletion of wetlands (MoE/NAPA, 2010). The following are some of the likely impacts of climate change on biodiversity:

a. The climatic range of many species will move upward in elevation from their current locations. Having differential effects, some species will migrate through fragmented landscapes whilst others may not be able to do so. Many species that are already vulnerable are likely to become extinct. Species with limited climatic ranges and/ or with limited geographical opportunities (e.g., mountain top species), species with restricted habitat requirements, and/or small populations are typically the most vulnerable (Xu *et al*., 2009).

b. Changes in the frequency, intensity, extent, and locations of climatically and non-climatically induced disturbances will affect how and at what rate the existing ecosystems will be replaced by new plant and animal assemblages. The High Himal and High Mountain ecosystems are likely to be worst affected by climate change. Among the natural habitats, remnant native grasslands are highly vulnerable to the impacts of climate change (BCN and DNPWC, 2011). The impacts of climate change are likely to increase in future, which will not only affect biodiversity but also livelihoods of millions of local and indigenous people who depend on biodiversity. Disruption of ecological services on which they depend due to climate change is expected to especially affect the poorest and most vulnerable communities (UNEP, 2010).

National adaptation plan formulation process and forestry sector

Nepal's NAP is aimed at building on the experiences of the MoE/NAPA (2010) and Local Adaptation Plan for Action (LAPA) implementation. NAPA provides a process for the Least Developed Countries (LDCs) to identify priority activities that respond to their *urgent and immediate needs* to adapt to climate change – those for which further delay would increase vulnerability and/or costs at a later stage (UNFCCC, 2016). Since vulnerability to climate change, particularly in the LDCs, is increasing over the years, 16th Conference of the Parties (COP) to the UNFCCC in 2010, realized the need for the medium and long-term adaptation together with addressing the most urgent and immediate adaptation needs. Under the Cancun Adaptation Framework (CAF), the COP16 established a process to enable LDC Parties to formulate and implement NAP, and established Adaptation Committee to promote implementation of enhanced action on adaptation.

The NAP aims to reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience. The objective is to facilitate integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programme and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate. Having climate change adaptation (CCA) a high priority at national development discourse, Nepal has been amplifying its efforts on raising awareness and building capacities in climate change along with creating enabling policy environment in addressing climate change in Nepal.

In the context where impacts of climate change are likely to couple up in the decade or so, forestry sector's challenge is to conserve pristine biodiversity values together with fulfilling the need of growing population and infrastructure development. Taking into account of the experience and outcomes of the NAPA process, the Thematic Working Group (TWG) on Forests and Biodiversity has been led by the MoFSC. As the lead, MoFSC is expected to coordinate with all stakeholders, facilitate the process of vulnerability and risk assessment (VRA), propose medium and long-term adaptation options, *inter alia*, develop effective financial mechanism and institutional framework in line with the new governance system.

Key gaps and challenges

Nepal has formulated many plans and policies in Forests and Biodiversity sector. However, there are critical gaps that need to be addressed to effectively address the increasing threats of climate change. Impacts of climate change cannot be and must not be denied while addressing other conservation and forests management and economic development issues in policy discourse. Broadly, the gaps include, a) Inadequacy of policy to identify the poor and for providing special facilities on the basis of the identity, b) effectively addressing the emerging global challenges including climate change, c) the mechanism of benefit sharing between the state, developer and local communities on the use of local natural resources and d) the occasional conflicts between policies and acts that tend to take a long time to resolve.

The institutional gap, at first, points to the organizational structure of MoFSC. Except creating REDD Implementation Centre (which is basically not for adaptation), There is neither in the ministry nor in the departments, a designated desk to deal with climate change adaptation exist. Both Forest Policy 2015 (MoFSC, 2015) and Forestry Sector Strategy 2014 (MoFSC, 2014b) have clearly articulated the action points on climate change adaptation and mitigation including institutional reform, which urges forestry sector to lead the local adaptation planning and implementation process through existing forest user groups. But, a true translation of those strategic points into action is yet to be observed. Other issues are the focus on a top-down approach in implementation, lack of effective monitoring mechanisms, and weak inter-sectoral and interagency coordination. The projects implemented in forestry sector have multiple significance on climate change but institutional synthesis, memory and collection and replication of good practice are still missing. These gaps have delayed decision making, leading to poor implementation, lack of an enabling environment, poor compliance and social safeguards, inadequate devolution to local bodies as envisaged by decentralization policy, and inadequate resources (human and financial) and technology for effectively designing and implementing the adaptation actions.

Data gap and limitation is another challenge. While preparing the vulnerability assessment report for the MoE/NAPA (2010), use of expert judgement particularly in assigning weights to the various climate indicators was necessarily subjective. This has somehow missed the real vulnerability and hence further work is required on the sensitivity, risk/exposure, and adaptation capability indices and consequently the outputs on the basis of these indices, which hopefully need to be considered and the problems should be rectified in the NAP process. Moreover, there is limited research on assessing vulnerability, exposure and climate change impact on forests and biodiversity since it demands long-term engagement (MoFSC, 2010).

Setting the goal of future forests and biodiversity is next pertinent challenge. The policy and strategic documents have stated broader forest management goals that anticipate a desired outcome, and objectives describe the range of conditions that are necessary to achieve management goals. Within the context of climate change, the determination of the potential range of future conditions that could occur under different climate scenarios is expected together with its relation to the desired future conditions. Second, while the influence of climate change on forest ecosystems poses new questions as to how sustainable forest and biodiversity management can be achieved (Spittlehouse and Stewart, 2003), in Nepal also, the existing principles and practice of SFM within all forest management regimes embody many of the activities that will be required to respond to the effects of climate change on forests.

Nepal is comparatively new in systematic forest management although significant achievements are in place within a course of half century practice. Nepal has rejuvenated the denuded forest lands and equally conserved the globally endangered and rare ecosystems including flora and fauna. However, at the interface of climate change, there are several challenges including (i) enhancing knowledge of the impact of climate change on ecosystems and species, (ii) mitigating the negative impacts of climate change, (iii) promoting ecosystem-based adaptation methods and (iv) keeping people's involvement intact in managing forest and conserving biodiversity Additional issues include how to strengthen the process for translating the policy into implementation; mitigation of dependence on foreign technology for climate change adaptation due to inability to develop domestic technology; strategic enhancement; evaluation of the contributions of local genetic resources in climate change adaptation; and need to strengthen monitoring mechanism and system (NPC, 2015).

Opportunities in the NAP process for Forests and Biodiversity sector

NAP process is an opportunity to integrate adaptation into the forests and biodiversity policies, strategies, plans and programme. As NAP is expected to develop adaptation measures for medium and long-term, it is imperative to consider the major objective of the forests and biodiversity such as conservation of biological diversity, maintenance of productive capacity, forest health and vitality and contribution to global carbon cycles. Further it is important to rationalize on how to adapt forestry policies and actions to achieve these objectives in changing climate to meet the needs of societies and adoption of present legal, institutional, and economic framework for forest conservation and sustainable management. As for the NAP process, vulnerability and risk assessment framework put forth by AR5 of IPCC has been considered, the gaps that was encountered during the NAPA vulnerability assessment could be addressed where holistic science (data based) approach could be used in assessing the vulnerability. It is also an opportunity to refine and validate the data that are available in forestry and biodiversity sector.

Although generic adaptation options for forestry are available in the literature (e. g., Spittlehouse and Stewart, 2003; Ogden and Innes, 2008), little research outcomes are available to evaluate their applicability in a local or applied context of forestry. In relation to climate change adaptation, structured decision making is required that involves: (1) establishing management objectives for the future forest, which are considered to be synonymous with the internationally agreed upon criteria for SFM; (2) determining the vulnerability of forest ecosystems, forest communities, local economies, and human populations; (3) developing alternative adaptation options; (4) evaluating alternative options against management objectives; (5) implementing desired adaptation policies and measures; (6) monitoring the effectiveness of climate change adaptation efforts in achieving management objectives; and (7) modifying management practices when adaptation efforts are not successful in meeting management objectives (e.g., adaptive management) (Ohlson *et al*. 2005; Ogden and Innes, 2008).

Current forest utilization and preservation is based on how forests developed under past climatic conditions. Policy makers and forest managers must accept that climate change is probable and that forests and forest communities face significant impacts. Adaptation requires planning for change so that a suite of options for the future but based on the present practice and knowledge is to be available whenever needed. For a smooth facilitation of this process, a number of questions of forest management must be addressed (Spitlehouse *et al.*, 2003), such as, current research needs to aid development of strategies for climate change adaptation; capacity needs of the forestry community to enhance awareness and to facilitate adaptation at all levels; forest management actions implemented now that reduce compromise in future responses; policy and strategies need to be in place to facilitate adaptation in forests and biodiversity; current knowledge base and monitoring systems adequate to spot problems tempted by climate change soon enough to allow implementation of an acceptable response, which forest ecosystems and species will have to adapt autonomously and where we can intervene a planned adaptation, etc.

Nepal is now to formulate a clear vision that can lead the country to undergo rapid socioeconomic transformation to become a prosperous middle-income country (NPC, 2015). In this connection the NAP process is going to be instrumental to envision the climate change risks to sustainable development and propose and implement adaptation measures to halt the damages posed by climate change. On top, the new local governance system has transferred more responsibilities to the local level, where if the NAP process could give a clearer current picture with future scenario, could facilitate the local authorities to better plan for adaptation for not only forests and biodiversity but for all resource and service sectors.

Conclusions and recommendations

The impacts of climate change on forests and biodiversity are very complex compared to other sectors. Climate change induced risks projected in the Greater Himalayas, however, cannot only be addressed by a natural process of gradual adaptation. Consolidated and coordinated adaptation interventions have to be in place considering the local knowledge, tools and practices. Climate change, no action to tackle it, is the greatest threat to growth. The longer we wait, the harder and more expensive it will be and the costs will be the greatest for the developing world (Freer-Smith *et al*., 2007). In this backdrop, as forests and biodiversity sector is more exposed to climate change, it is one of the highly sensitive and thus highly vulnerable sector.

Forests are not only impacted by the climate change itself, they are also facing surmounted pressure from the people and communities affected by climate change as well. Forests and climate change are fundamentally linked, in ways that range beyond carbon. The uncertainties associated with projections of climate change and associated impacts emphasize the need to identify robust but flexible management strategies that are likely to achieve the SFM goals and are likely to implement well across a wide range of potential future climate conditions (Ogden and Innes, 2008). Flexible and responsive strategies to new information is sought (Lempert *et al*., 2003), specifically to incorporate the principles of adaptive management as climate change scenarios are associated with irreducible uncertainties originating from a variety of factors, including a lack of information, long time scales, complexity of the climate system, measurement error and disagreement about structural models (Moss and Schneider, 2000; Kalindikar *et al*.. 2005). Climate change brings lasting changes in the ecosystem services altering its ability to support present and future economic activities which have already been observed in the mountains of Nepal. Unlike environmental problems, which are local and can be solved by relatively short-term interventions, climate change requires lasting solutions with coordinated and harmonised interventions in the long term.

For Nepal, which is more vulnerable and has fragile geography and socio-economy, climate change adaptation strategy should be viewed as part of the risk management component of a sustainable forest and biodiversity management plan under future climate change where adaptation should be facilitated by successful traditional technologies and practices used over the centuries. It should also be coupled by incorporation of climate change concerns into resource use and development decisions and plans for regularly scheduled investments. The NAP process, need to recognise the key area of interventions for future adaptation planning within the national strategic thrust. With these all considerations in the light of the NAP Guidelines, Nepal has developed a 'NAP Approach' and framework for VRA. An inclusive and wider representative thematic working group (TWG) is in place. The immediate next step is to capacitate the TWG and involve in this iterative process to produce a functional NAP document that could address the anticipated climate risk and vulnerability of thematic area including all sectors and support in climate resilient development pathway.

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Participatory market chain appraisal for the full range of agroforestry products including market trends and growing markets

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This paper focuses on the participatory market chain analysis of agroforestry products in six sites of two districts (Kavre and Lamjung) of Nepal. In total, 93 market actors were involved in the study, in which 80 persons were purposively selected from Local Resource Person (LRP) and Local Resource Group (LRG) members and 13 persons were randomly selected from the local, district and national level traders. Primary data on agroforestry products was collected through Participatory Rural Appraisal (PRA) tools following several field visits. Fourteen agroforestry products in Lamjung and 20 agroforestry products in Kavrepalanchok district were selected for analysis. The findings showed that small-scale production and insufficient service to farmers from the village level agriculture collection centers and cooperatives are the major constraints to effective and efficient market chain development and management. The main factors responsible for increasing the production of agroforestry products are the rise in awareness among LRPs/ LRGs about agroforestry practices along with institutional and policy development to facilitate the marketing of agroforestry products. The paper concludes by highlighting the controlling factors in agroforestry business.

Key words: Agroforestry market chain, agroforestry products, market trend, participatory appraisal

Nepal's food insecurity is worsening as traditional agroforestry systems being practiced are unable to adapt to, or make use of, changing market and climatic conditions. Improving the agroforestry practice aside, one of the ways to improve food security is to enhance agroforestry marketing practices. Agroforestry product marketing is a dynamic and complicated process, which covers various activities and agencies from producers to the consumers (Amatya *et al.*, 2015). One of the main problems of agroforestry product marketing in Nepal is small scale production resulting in low productivity in volume and quality (Pandit *et al.*, 2014). Sustainable marketing mechanism differs with the location and available infrastructures. The market chain and trends of all agroforestry products produced in research sites are not known. Therefore, a study was undertaken to identify the existing market mechanism for agroforestry products of the project research sites, to assess the market chain of the full range of agroforestry products harvested and to explore the factors responsible for changing agroforestry products market chain and trends, its barriers and constraints, opportunities and limitations.

Materials and methods

In order to investigate food security and livelihoods of rural people, a five year joint project of Government of Nepal and Australian Government is being implemented in six sites of two districts (Kavre and Lamjung) in Nepal since 2013. The market mechanisms were looked at involving project beneficiaries categorised as Local Resource Persons (LRPs) and Local Resource Groups (LRGs) who are also the

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members of six Community Forest User Groups of the case study districts. Various agroforestry products related with primary food security such as vegetables, fruits, spices, flowers and timber products were grown by these LRPs/ LRGs' in their fields. These groups developed various types of marketing mechanisms to overcome some of the constraints of small-scale agroforestry products.

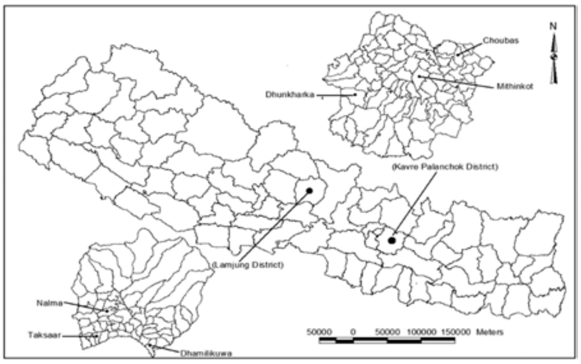

Fig. 1: Location of study area

This study adopted a descriptive qualitative case study approach to obtain an in-depth analysis of context in which agroforestry market chain occurs. It also employed quantitative methods to analyse the quantity and price of the products related to the benefits gained by different social actors along the market chain. The qualitative strategy is aimed to generate insights into the processes and practice through which the agroforestry product market chains are organised. Emphasis is given to the analysis of behaviours of market actors. The quantitative strategy complements qualitative analysis by brining insights of the distribution of benefit from agroforestry product trade.

A commodity selection process was conducted to identify the most promising market options (Ostertag *et al.*, 2007). Thirty-seven commodities were selected in the beginning from six sites: Dhungkharka, Mithinkot, and Chaubas in Kavre, Dhamilikuwa, Jeeta Taksar, and Nalma in Lamjung (NAF, 2014). This framework was developed based on three criteria as described below:

Step 1 Selection criteria: The value chains were evaluated in focus group discussion using seven criteria: a) market and market demand b) economy of scale and outreach c) high value d) stakeholders' interest and commitment (women and poorest households) e) coordination f) short turnover and g) leverage.

Step 2 Weightage percentage: The first criteria 'market and market demand' was given 20% weightage, the second to fifth criteria were given 15% and the rest two were given 10% weightage each.

Step 3 Assessing commodities fit against each criterion: Each criterion was given a score in a range from 1 to 5, with 5 representing maximum compliance and 1 minimum compliance. Overall ranking was determined using a weighted average of the seven criteria.

Primary information regarding products, market chain, trends and market growth were collected through field visits using Participatory Rural Appraisal (PRA) tools and technique and review of literatures. Information was also collected through key informants' interview and focus group discussion. Discussions were also held with CFUG (Community Forestry Users Groups) executive committee members, LRPs, local teachers, and government line agencies supporting LRPs and LRGs members for agroforestry intervention in the project sites and traders of agroforestry products. Information required for the analysis of the agroforestry products, data on prices and costs were collected at successive levels of the market chain. To identify the market actors involved in the market chain, a snowball sampling method (Hair *et al*., 2010) was used. The direction of the snowballing approach was from farmers to consumers. The researchers participated directly in the marketplace. They were able to describe the market chain due to their direct participation and observation of marketing places of agroforestry products at the local, district and national level, they were able to describe the market chain. Initially, information was collected from farmers who helped to identify the traders. Subsequently, the identified traders were approached for the necessary information as well as for identification of other traders and cooperation to who they sold the products.

To analyse the overall agroforestry product market chain, Rapid Market Appraisal (RMA) was used to identify and assess the problems and opportunities related to the market system and to understand how the trade is organized, operates and performs. As an iterative process and interactive research methodology, RMA was used to better understand complex market systems in a short time (ILO, 2000; Ostertag *et al.*, 2007; Perdana *et al.*, 2013) using in-depth interviews and focus group discussions.

Secondary information of agroforestry products market chain and their trend and marketing mechanisms, and their barriers and constraints, opportunities and limitations were gathered to supplement primary data. The main source of secondary data were LRP and LRG member's records and reports of other line agencies and traders, agroforestry markets and marketing mechanisms, and related published and unpublished documents, literatures and journals. Key agriculture and forestry related policy documents were also reviewed to understand the market chain of agroforestry products and change over market chain actors and price of agroforestry products at the local, district and national level.

In total 93 market actors were involved in the study, in which 80 persons were purposively selected from LRP and LRG members and 13 persons were randomly selected from the local, district and national level traders. The participation of women in this study was 43%. Among 93 respondents only 10% were Dalits, 50% were from ethnic community and 40% were Brahmin and Chhetri. In the study population, agriculture, business and services were found major occupation. Out of them, majority (80%) of the total respondents were dependent mainly on agriculture based occupation.

Results and discussion

A total of 16 commodities were selected in the first phase which received at least the score of good compliance (Table 1). In the second phase, the high scoring (maximum compliance) commodities such as buffalo milk, goat meat, banana, tomato, cardamom, ginger and round chillies were selected which scored more than four.

Table 1: Result of agroforestry commodity selection process

Commodity name	Kavre			Lamjung		
	Dhung kharka	Mithinkot	Chaubas	Dhamili kuwa	Jeeta Takshar	Nalma
1. Buffalo milk	√√√√	√√√√	√√√	√√√√	√√√	√
2. Goat meat	√√√	√√√	√√√	√√√	√√√√	√√√
3. Timber	√√	√	√√√	√	√	√
4. Lauth salla	√√√	x	√√	x	x	x
5. Brooms	√√	√	√√	√	√√√	√√√
6. Ginger	x	√√√√	x	√	√	x
7. Lapsi	√	√	√√	x	√	√√√
8. Cardamom	√√√	x	√√√√	x	x	√√
9. Banana	x	√	x	√√√√	√√√√	√√
10. Honey	√	√	√	√	√√√	√
11. Bamboo	x	√	x	√	√√√	x
12. Drum stick	x	x	x	√√√	√	x
13. Round chilli	x	√√√	x	x	√	√√√√
14. Tomato	√√√√	x	√√√	x	x	√√
15. Tejpat	√√	√	√	√√√	√√√	√√
16. Satawari/Kurilo	x	√√√	√	√	√	√
Number of products selected	5	5	5	5	6	4

Scale: x- no compliance (0 score); √ – little compliance (1—2 score);√√- compliance (2—3 score); √√√- good compliance (3—4 score); √√√√ – max compliance (4—5 score).

At least one maximum compliance agroforestry product was thus selected from each of the six sites. These included tomato from Dhungkharka, ginger from Mithinkot, cardamom from Chaubas, round chilli from Nalma and banana from two sites (Jeeta Taksar and Dhamilikuwa) in the beginning (Fig. 1).

As identified through research, producers, collectors, retailers, and cooperatives were the major actors in the market chain in the study areas. The following section describes their roles and practices in the market chain prices at different market levels, and the growing markets of agroforestry products.

Producers

Farmers involved in producing agroforestry products were the main producers. Producers in the study areas tended to sell what was produced and did not engage in further processing or value adding activities. Generally, they were producing vegetables and other products in small quantity, and then these products were collected by collectors in one place through a group of farmers or cooperatives and delivered to wholesalers in Kathmandu valley (Table 2). They had engaged in the market chain mostly through collectors and retailers, but generally they had limited access to market information and were seldom in a position to negotiate higher rates. Regardless of the negotiation approach taken, producers usually perceived that their products were bought at a price that was lower than expected because of their limited access to market information, weak bargaining position, and the dominant role of traders. Their current practice is limited on small scale production resulting in low productivity in terms of volume and quality (Pandit *et al*., 2014).

Collectors, wholesalers, and retailers

Collectors play an important role in the agroforestry product market chain. First, they search for potential buyers in the marketplace and enquire as to the buyers' requests. Guided by their information network, they visit smallholders, searching for products available for harvest, which suit the request. They also explore upstream to increase their supply. They repeat this process frequently because supply, quality, and prices change so often. Second, the harvest of multiple producers is sorted into lots for sale to the wholesalers and retailers. Third, they serve to minimise and facilitate the number of contacts in the market chain.

Competition between other collectors was mostly from neighbouring villages. They had access to market information such as current prices, demands and specifications. From their informants, the collectors were aware of prices offered by other collectors. Their role ended when the products were delivered to the buyers, wholesalers or retailers.

Wholesalers are the middle traders who purchase products in huge amounts at significant discounts from collectors or agriculture products marketing cooperatives, and then distributed among the retailers at higher prices. On an average wholesaler in Kathmandu received 13—17% benefits from their marketing activities.

Retailers were town or city based traders who had bought agroforestry products from collectors. They had well-established contacts with most collectors in the study area, as they had been engaged in an extensive business relationship for some time. Similar to the relationship between producers and collectors, links with larger traders were a matter of mutual trust built upon a gradually established relationship. The retailers had purchased agroforestry products from the wholesalers and sold to the end users at a marked up price. The best example of a retailer would be the small family-operated fruit shop on the corner of a market, hotels and supermarkets. On an average, retailers in Kathmandu received 20—25% benefits from agroforestry products marketing.

Table 2: List of agroforestry products in the study area

Study site	Agroforestry products	Study site	Agroforestry products
Lamjung		**Kavre**	
Aapchaur CFUG, Dhamilikuwa	Banana Cauliflower Potato Tomato Black pepper Milk	Kalapani CFUG, Dhungkharka	Tomato Cabbage Cauliflower Potato Mustard leaves Radish Garlic Milk
Lampata CFUG, Jeeta Taksar	Banana Ginger Turmeric Honey Broom grass Sugarcane	PhagarKhola CFUG, Chaubas	Cardamom Pumpkin Marigold flower Lapsi Utis timber Pine timber
Khundru Langdi CFUG, Nalma	Round chilly Potato Tomato Onion Goat	Sa Pa Ru Pa CFUG, Methingkot	Ginger Chilly Tomato Milk Goat

Aapchaur CFUG of Dhamilikuwa, Lamjung

The main agroforestry products marketed from the Dhamilikuwa of Lamjung district were banana, black pepper, milk, cauliflower, potato and tomato. These products were sold in local markets located in the district through three market actors (producers, retailers and consumers). The major constraints of this marketing mechanism were price variation due to the lack of information and services in the local market, lack of storage facilities. In addition, they also lacked skill and knowledge on quality and value enhancement through grading and processing. However, the development of road transportation system in the village and telephone communication has helped farmers significantly for marketing of their agroforestry products. Producers and retailers of local markets had known very well with each other and had mobile telephone communication facilities to plan and organize agroforestry product marketing in this action research test site.

Farmers of Dhamilikuwa were selling their fresh products directly to the retailers of surrounding township such as Bhoteodar, Sundar bazaar, Besisahar and other local markets, which are located in nearly one hour driving distances from Dhamilikuwa. Retailers have contact directly to the farmers by telephone and then farmers supplied their fruits and vegetables based on demand of these retailers. Farmers harvest their products, clean it in fresh water and then packet in plastic bags and send to the retail markets. Figure 2 shows the agroforestry products marketing mechanisms of Dhamilikuwa.

Fig. 2: Market chain of agroforestry products of Dhamilikuwa

Retailers were also selling these products to consumers without any value addition work. In this site, the "Radha Krishna Agriculture Cooperative" was found passive due to low volume of agriculture products.

The production capacity of these traded agroforestry products (Table 3) of Dhamilikuwa site was found high because there was very good irrigation facilities compared with other five action research sites. The number of farmers, land areas and per unit production have been increased compared with 3 years ago. The main factors responsible for the increment were awareness raising in agroforestry by the project team and developing institution of LRGs and LRPs. In addition, farmers were also diverted into cash crops. The price of agroforestry products at local market was also increased by 15% compared

Table 3: Agroforestry products, their quantity and per unit price at different markets

Agroforestry products	Approximate production quantity	Price (Rs) at different level of markets		
		Farm gate (local)	District	National
Banana	25000 darjan	40/darjan	65/darjan	80/darjan
Cauliflower	5000 kg	45/kg	55/kg	60/kg
Potato	6000 kg	40/kg	50/kg	55/kg
Tomato	3000 kg	50/kg	65/kg	75/kg
Black pepper	50 kg	800/kg	1200/kg	1400/kg
Milk	50000 litres	40/litre	60/litre	65/litre

Note: 1 darjan = 12 banana

with three years ago. However, low volume of production was the major constraint for developing and managing agroforestry product marketing mechanism in this site.

Table 3 shows that price difference of banana between farm gate price, local/district markets and national markets. The price of banana at national market was very high compared with other agroforestry products. Farmers of this site were using chemical fertilizers such as Di-ammonium phosphate, urea and muriate of potash, etc to produce rice, maize, wheat, potato, tomato and cauliflower, etc. The use of chemical fertilizers ranged from 25—150 kg per households, which cost Rs 45/kg. In addition, some farmers also had used insecticides such as Novan to protect potato and tomato crops from fungal diseases. More chemical fertilizers were used in cereal crops compared with vegetable crops. The average total cost of production of marketable agroforestry products such as cauliflower, potato and tomato was calculated Rs 30 per kg. Agroforestry products of the test site were sold in local level markets, and therefore, load, unload and transportation costs up to the local markets was only Rs 2—3 per kg.

Lampata CFUG of Jeeta Taksar, Lamjung

The major agroforestry products marketed from the Jeeta Taksar site were banana, ginger, turmeric, broom, honey and black sugarcane. These products were sold in local markets through three market actors (producers, retailers and consumers). There was lack of market information and services in the local market. In addition, they did not have storage and transportation facilities. They also lacked skill and knowledge on quality and value addition through grading and processing. Development of road transportation system in the village had helped them significantly for marketing of their agroforestry products. Banana farmers had harvested their products targeting to festival and other local level religious functions.

Local fruit sellers and retail shop keepers of local market, called Sotipasal, had direct contact with farmers or producers, and farmers supplied their banana fruits and other fresh products based on demand of fruit sellers and shop keepers. Farmers harvest their products, clean it in fresh water and then delivered to the markets. Figure 3 shows the agroforestry products marketing mechanisms of Jeeta Taksar site.

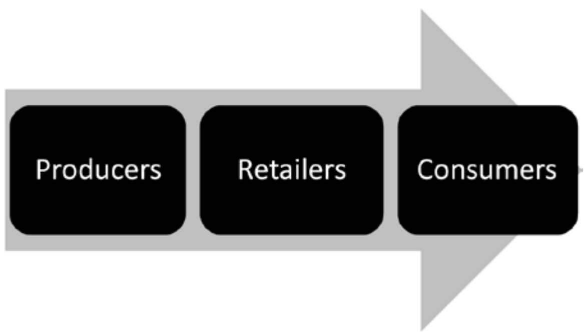

Fig. 3: Market chain of agroforestry products of Jeeta Taksar site

The production capacity of traded agroforestry products (Table 4) of this site can be improved in coming years because there are increasing trend in number of farmers, land areas, per unit production and price of agroforestry products

Table 4: Agroforestry products, their quantity and per unit price at different markets

Agroforestry products	Approximate quantity	Price (Rs/unit) at different level of markets		
		Farm gate (local)	District	National
Banana	20,000 darjan	40/ darjan	60/ darjan	100/ darjan
Ginger	2500 kg	20/kg	60/kg	95/kg
Turmeric	800 kg	100/kg	140/kg	160/kg
Honey	800 mana	600/mana	650/mana	750/mana
Broom grass	600—800 kucho	30/kucho	40/kucho	40/kucho
Sugarcane	3500 sugarcane	45/sugarcane	65/sugarcane	80/sugarcane

Note: 1 mana=568 ml (approximately) Kucho is made from broom grass

compared with three years ago. The main factors responsible for increasing agroforestry production were increase in awareness level. However, farmers were facing problem in selling ginger. A product collection centre was established in 2012 for marketing of agriculture products, which was found passive due to the low production of agriculture commodities.

Table 4 shows that price difference of banana and ginger between farm gate price, local markets, district markets and national markets was very high compared with other agroforestry products marketed from this test sites.

Farmers of these sites were using Di-ammonium phosphate and urea mainly in rice field and some farmers were also found using chemical fertilizers in vegetable farms. The use of chemical fertilizers ranged from 5—25 kg per household, which cost Rs 47/kg. In addition, some farmers were also using insecticides in rice field. The use of chemical fertilizers and insecticides in marketable agroforestry products were nominal, and transportation cost was not required because almost all agroforestry products were sold in local markets.

Khundru Langdi CFUG of Nalma, Lamjung

The main marketable agroforestry products of Nalma site were round chilly, potato, tomato, onions and goat production. These products were sold locally moving through producers to consumers because the productions were very low compared with local demands. There was lack of market information and services in the local market. They also lacked skill and knowledge on quality and value addition through grading and processing.

Agroforestry products such as round chilly, potato, tomato and onion were sold in local markets, while farmer had kept goat for meat production but there was no organized way of selling them in market. Local and district level contractors visit the households having goats, and buy them to supply in district level markets. One saving and credit institution and mother group were found functioning in this test site but they were not taking any care of agroforestry products marketing because production quantity was very low and the consumption was within the village.

The production capacity of traded agroforestry products is provided in table 5. It was revealed that trend of agroforestry marketing was increasing as compared with three years ago. The main factors responsible for increase in agroforestry production are the increase in the level of awareness and development of institutional capacity of LRG and LRP.

Table 5 shows that price of agroforestry products such as potato, tomato and onion in Nalma was higher than the price of these products in district and national level markets. This could be the effect of attribute to the high demand of these products compared with local level production.

Table 5: Agroforestry products, their quantity and per unit price at different markets

Agroforestry products	Approximate quantity	Price (Rs/kg) at different level of markets		
		Farm gate (Local)	District	National
Round chilly	60 kg	250/kg	300	350-400
Potato	1000 kg	60/kg	40	55
Tomato	900 kg	70/kg	65	75
Onion	600 kg	60/kg	45	50
Goat	50 goats	400/kg of meat	700	800

Majority (60%) of the farmers were producing organic products and those farmers, who were using chemical fertilizers, had used in low volume. The average cost of chemical fertilizer is Rs 52/kg. The average cost of production of round chilly, potato, tomato and onion was Rs 35 per kg, and these products were sold in local village.

Sa Pa Ru Pa CFUG of Methingkot, Kavrepalanchok

The main agroforestry products sold by the LRP and LRG members from the Methinkot research sites were ginger, chilly, tomato, milk and goat. Beside these, different kinds of vegetables such as potato, cauliflower, cabbage, radish, pumpkin, cucumber, etc were also sold by the CFUG members. Agroforestry market chain is from producers to consumers through collectors and retailers. Producers lacked price information, and knowledge on quality and value enhancement through grading and processing.

Local traders and traders of Banepa and Kathmandu valley also visit Bhakundebesi market to purchase ginger and other vegetables, and goats, which is 2 km far from this site. There is one agriculture co-operative, which is also involved in ginger marketing. Figure 4 shows the agroforestry products marketing mechanisms of Methinkot site.

Fig. 4: Market chain of agroforestry products of Methinkot test site

Change in rainfall pattern and lack of irrigation facilities have hindered the cultivation of agroforestry products (Table 6). However, there is increasing trend in number of farmers, land areas and price of agroforestry products compared with three years ago due to increase in the awareness level of participating farmers.

This site is near to Kathmandu market, but farmers were getting nearly 47% low prices compared with national market price. Farmers of Methinkot sites were forced to sell their products in low price compared with national markets.

Table 6: Agroforestry products, their quantity and per unit price at different markets

Agroforestry products	Approximate quantity	Price (Rs/unit) at different level of markets		
		Farm gate (Local)	District	National
Ginger	4000 kg	65/kg	75/kg	100/kg
Chilly	2500 kg	75/kg	100/kg	125/kg
Tomato	30000 kg	30/kg	40/kg	55/kg
Milk	72000 litre	65/litre with fat	65/litre	65/litre
Goat	150 goats	400 per kg of meat	700/kg	800/kg

Farmers of Methinkot sites had used chemical fertilizers (Di-ammonium phosphate and urea) ranging from 25—200 kg per household, which cost Rs 40 per kg. Insecticides were also being used in vegetable farms. The average cost of production of tomato was calculated at the rate of Rs 25 per kg. The transportation cost of vegetables from this research sites to Banepa was about Rs 2 per kg.

Kalapani CFUG of Dhungkharka, Kavre

The main agroforestry products of Dhungkharka site were tomato grown in plastic tunnel during off-season and main season, cauliflower, cabbage, mustard leaves, chilli, potato, radish, garlic, and milk (Table 7). Beside these vegetables, farmers of Kalapani CFUG also sold chilly, squash, young shoot of squash and pumpkin, egg plants, and sponge guards. Agroforestry products were distributed through a chain of producer, agriculture cooperatives/local collectors, wholesaler, retailers and consumers.

Two co-operatives (Paribartanshil Multi Purpose Co-operative and District Micro Enterprise Association) are under operations for the marketing of agroforestry products in Dhungkharka VDC. Figure 5 shows the agroforestry products marketing mechanisms of Dhungkharka site.

Fig. 5: Market chain of agroforestry products of Dhungkharka test site

According to the wholesalers of Kalimati (located at Kathmandu), fruits and vegetable wholesale market, vegetable grown in Dhungkharka were in high demand in Kathmandu Metropolitan City compared with vegetables grown in low lying areas of Kavrepalanchok, Nuwakot and Dhading districts because farmers of Dhungkharka had grown vegetables following the Integrated Pest Management (IPM) techniques supported by the different government organizations and I/NGOs. Milk was marketed using the chilling centre located in Parthali Bhanjyang.

The production capacity of traded agroforestry products of Dhungkharka site has been increased in recent years with increasing trend in number of farmers, land areas, per unit production and price of agroforestry products compared with three years ago (Table 7) shows that farmers of Dhungkharka are obtaining reasonably high price compared with the farmers of other sites. This is due to the well organized vegetable collection and marketing mechanisms developed by the local peoples.

Farmers of Dhungkharka had used urea and potash, vitamins and fungicides in vegetable farms. The use of chemical fertilizers ranged from 25—50 kg per household, which cost Rs 50 per kg. The average cost of production of potato and tomato was about Rs 21 per kg, and cauliflower and cabbage was Rs 13 per kg. The transportation cost of these products was about Rs 4 per kg from Dhungkharka to Kathmandu.

Table 7: Agro forestry products, their quantity and per unit price at different markets

Agroforestry products	**Approximate quantity**	**Price (Rs/kg) (Rs/ litre) at different level of markets**		
		Farm gate (Local)	**District**	**National**
Tomato	27,000 kg	30	40	55
Cabbage	180,000 kg	20	30	45
Cauliflower	12,000 kg	20	35	50
Potato	60,000 kg	30	45	55
Mustard leaves	12,000 kg	15	25	30
Radish	9,000 kg	15	30	35
Garlic	4,500 kg	60	75	90
Milk	2500 litre/day	70/litre with 6% fat	65/litre after butter extraction	65/litre after butter extraction

Phagarkhola CFUG Chaubas, Kavre

The main agroforestry products grown and marketed from Chaubas site were cardamom, pumpkin, lapsi fruit, and the forest products from pine and utis trees. These products were traded through producers to consumers via local traders/collectors and retailers. Generally, farmers produce vegetables and other products in small quantity, and therefore, these products are collected by collectors or local traders in one place through a group of farmers or cooperatives and delivered to the city in retail shops. Retailers of Kathmandu valley and Banepa purchase agroforestry products from the traders of Chaubas and sell to the end users at a marked up price.

Cardamom and timber were the main products which were normally sold to contractor of Kathmandu through farmer's cooperative with initiative of LRP members and local traders. The Chaubas Multipurpose Co-operative which has 600 members is working to support in marketing of cardamom and other agriculture products. Figure 6 shows the agroforestry products marketing mechanisms of Chaubas site.

Timber brought from Chaubas is normally used to make furniture through which value in timber is added by nearly 40% compared with sawn timber sold in the market.

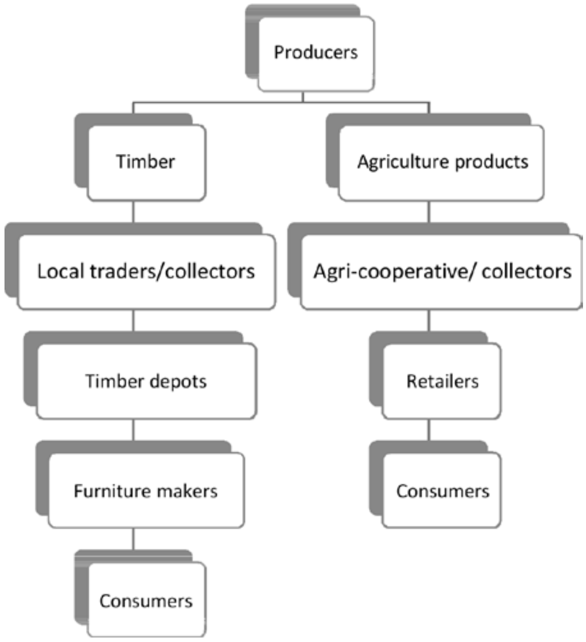

Fig. 6: Market channels of agroforestry products of Chaubas test site

The production of marketed agroforestry products of Chaubas site has been increasing in recent years with increasing trend in number of farmers, land areas, per unit production and price of agroforestry products compared with three years ago (Table 8) shows the large variation in price of pine timber in Kathmandu market, which is normally determined by the size of sawn timber. Pine timber obtained from plantation forests was small in size and were sold at the rate of Rs 800/

Table 8: Agroforestry products, their quantity and per unit price at different markets

Agroforestry products	Approximate quantity	Price (Rs/unit) at different level of markets		
		Farm gate (Local)	District	National
Cardamom	1000 kg	2200/kg	2200/kg	2400/kg
Pumpkin	20,000 kg	5/kg	25/kg	35/kg
Marigold flower	20,000 Garland	50/Garland	60/Garland	70/Garland
Lapsi	2,500 kg	15/kg	35/kg	45/kg
Utis timber	3,000 cft	200/cubic feet (cft)	400-450/ cft	500/cft
Pine timber	2,000 cft	300/cft	600-800/cft	800-1400/cft

Note: One cubic meter is approximately 35 cubic feet.

Table 9: Name of saving and credit groups and their annual interest rate

S.N.	District	Study sites	Name of Saving and credit Groups	Interest rate (%)
1	Kavre	Methinkot	Methinkot saving and credit cooperative, Jorsalla Agri-seed production cooperative and Panchakanya Agri-coperative	14% per year
		Dhungkharka	Nari Chetana saving and credit cooperative, Bindabasini saving and credit cooperative and Parbati saving and credit cooperative, etc.	14–16% per year
		Chaubas	Agri-saving and credit group and Chaubas multipurpose cooperative	14% per year 15% per year
2	Lamjung	Dhamilikuwa	Champabati saving and credit cooperative	15% per year
		Jeeta Taksar	Deep Jyoti cooperative	8% per year
		Nalma	Sunkot saving and credit cooperative	18% per year

cft in Kathmandu market. Additionally, farmers of the Chaubas had obtained low price for pumpkin compared with other agroforestry products. Until now, farmers of Chaubas have no problems to sale their products because local traders and Chaubas Multipurpose cooperative members have good linkage with district and national level traders of Kathmandu valley.

Farmers of Chaubas site had used chemical fertilizers (urea) in maize and millet production only which cost Rs 46 per kg. The transportation cost of agriculture products from Chaubas to Banepa was about Rs 8—10 per kg depending on season.

Analysis of results

Provision of funds

In all sites, there were provision of fund at specific interest rate for the promotion of agriculture, livestock and off-farm enterprises through local saving and credit groups and cooperatives (see Table 9). Both men and women are eligible for loan, which is provided with the recommendation by one of their committee member for one year. CHOICE Nepal- a local NGO working in Jeeta Taksar had provided Rs 200,000 as a loan to Deep Jyoti Cooperative for goat and poultry farming. The maximum limit of loan is Rs 100,000 per person per year at 8% interest rate.

In Nalma, very few persons had taken loan for agriculture purposes, and majority (90%) of the loan was for foreign job. In Dhungkharka site farmers had not taken loan for vegetable production. On the other hand, most household women and men have saved small amount (Rs 25/month) in these saving and credit groups.

Institutions supporting farmers

Different institutions are supporting LRP and LRG members for agroforestry products promotion and marketing. Agriculture Service Centre and Public Awareness Centre of Dhamilikuwa had provided training to the LRP and LRP members in cash crop production and marketing. Similarly, CHOICE, Nepal had provided about two million rupees in Deep Jyoti Cooperative in JeetaTaksar. Table 10 shows the local and district level institutions supporting farmers for agroforestry production and market chain development and management in six research sites.

Table 10: Institutions supporting agroforestry farmers

District	Institution	
	Local level	**District level**
Kavrepalanchok	CFUG, Farmer's cooperative, Ilaka Forest Office and Agriculture and Livestock Service Centre, Village Development Committee (VDC) and Municipality, etc.	District Forest Office (DFO), Federation of Community Forest User, Nepal (FECOFUN), District Agriculture Development Office (DADO), District Livestock Service Office (DLSO), District Soil Conservation Office (DSCO) and District Development Committee (DDC).
Lamjung	CFUG, Farmer's cooperative, CHOICE Nepal, Saving and credit group and Mother groups, Ilaka Forest Office, Agriculture and Livestock Service Centre, Public Awareness Centre and Municipality, etc.	DFO, FECOFUN, DADO, DLSO, DSCO, DDC, Federation of Ethnic Groups, District Irrigation Office and Micro-Enterprise Development Programme of the United Nations.

The Micro-Enterprise Development Programme (MEDEP) of the United Nations had also provided support for vegetables production and marketing in Dhungkharka and cardamom production and marketing in Chaubas site. Similarly, LRP and LRG members of Chaubas site had also received financial support from the Chaubas Village Development Committee for agroforestry production and marketing. Majority (86%) of the total respondents had reported that training and cross-visit opportunities provided by the Enhancing livelihoods and food security through improved agroforestry and community forestry in Nepal (EnLiFT) project had also played significant roles in promoting agroforestry activities in the respective research sites.

Gender and social inclusion

The involvement of women in agroforestry products promotion and marketing was very high in Chaubas and Dhungkharka sites with more than 75% participation of women followed by nearly 50% in Dhamilikuwa, Methinkot and Nalma and 42% in Jeeta Taksar. The involvement of Dalit and marginalized households in agroforestry production and marketing in study sites was low (nearly 10%) because they had very small land holding to produce agroforestry products. In addition, they were forced to work as wage labour for day to day survival of their family members. The involvement of ethnic communities such as Gurung, Tamang, Magar, Bhujel and Pahari was higher (50%) compared with the involvement of Brahmin and Chhetri (40%).

Issues and constraints of marketing

Agroforestry marketing mechanism is very good in Dhungkharka site compared with other sites. The major issue for developing well organized marketing system in all sites was small scale production. In addition, LRP and LRG members of Jeeta Taksar are facing problems to sell ginger. The involvement of Dalit and marginalized community in agroforestry products market chain is very poor. The main issues and constraints of market chain of all agroforestry products are discussed below:

The major strengths for agroforestry products promotion and marketing in study areas are because of relatively good road network, nearness to market, and good access of services of local and district level institutions, fertile land, long tradition in growing fruits, vegetables and other cash crops, active women and supporting farmers. However, the major constraints noted for agroforestry products marketing are small scale production, small number of local traders, occurrence of insects (aphids, white grub, red ant, etc), pests and diseases (damping off) and lack of common facilities for marketing of agroforestry products. In addition, capacity of local institutions such as farmer's cooperatives, saving and credit institutions and mother groups are low to promote marketing of agroforestry products.

The major limitation reported by the LRP and LRG members for the promotion of agroforestry products marketing is the out migration of youth in search of better opportunities.

Expectation of market chain changes

In Jeeta Taksar and Dhamilikuwa sites, the number of farmers, land areas and per unit agriculture production have been increased compared to last three years. The main factors responsible for increased agroforestry production are rise in awareness level, and effective communication. Additionally, farmers are more inclined to cash crops because of the attractive price of agroforestry products except in Nalma, the marketing situation of agroforestry products was found different where the price of potato has been increased by 50% compared to the last three years ago. This was attributed to the increase of potato price in Besisahar vegetable markets. Other factors responsible for increase in price of agroforestry products in Nalma were low production compared with local demand and problem of irrigation to increase the production price.

Similarly, the number of farmers, land areas and per unit agriculture production has also been increased in Chaubas and Dhungkharka sites compared with the last three years. The main factors responsible for this change were increase in demand, improvement in transportation facilities, increase in production, commercialization, mass production trend in village, market information flow, and skill and technology handover through training and field visit programs to farmers. In addition, market price of vegetables and milk in Dhungkarka has also increased by 30% compared with the last three years. Similarly, market price of cardamom, lapsi and marigold flower in Chaubas has been increased by 40%, 15% and 20% respectively compared to the last three years.

Agroforestry production in Methinkot site has been found negative as compared to the last three years. This is because of change in rainfall pattern, lack of irrigation facilities, reduction in per unit production.

The expectation of market chain changes of agroforestry products over the next five years shows that round chilly, banana, black pepper, tomato, potato, onion, ginger, turmeric and lapsi would increase and local cooperatives would come into picture for marketing. It is found that future agroforestry practices would be driven by only children and aged persons, as youth are leaving their village in search of better opportunities. In case of Kavre site it is expected that the production of selected items such as cardamom, marigold flower, ginger and tomato and other vegetables would increase and more farmers would be involved for commercialization of these products with strong network of farmers established and function in place. Price of cardamom will increase from Rs 2200/kg to Rs 3500/kg as with the labour cost (by 75% from Rs 350/day).

Conclusion

The analysis shows that 14 agroforestry products in Lamjung and 20 agroforestry products in Kavrepalanchok are being marketed. LRP and LRG members involved in these agroforestry products marketing in Lamjung district have good connection with local traders, fruits and vegetables shop keepers whereas LRG members of Kavrepalanchok district have good linkage with local collectors and wholesalers of the Kathmandu valley. Farmers of all sites are obtaining good price for their products. However, two critical factors controlling the effectiveness and efficiency of agroforestry marketing were: a) scale and b) service. Small-scale production and insufficient service to farmers from the village level agriculture collection centers and cooperatives are the major constraints for effective and efficient market chain development and management of full range of agroforestry projects. The number of farmers, land areas under agroforestry practices and per unit agriculture production and price of agroforestry products has also been increased compared to the last three years. The main factors responsible for increasing agroforestry production in research sites are the rise in the level of awareness among LRPs/ LRGs in agroforestry practices along with institution being empowered in their functioning.

Acknowledgements

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Human-Rhesus macaque conflict at Pumdivumdi/ Tallokodi, Pokhara, West Nepal

S. Sharma[1*] S. Acharya[2]

The study on conflict between human and Rhesus macaque was carried out at Pumdivumdi/Tallokodi in Pokhara valley in March, 2016. Questionnaire survey was carried out in 60 households to assess conflict, economic impact on livelihood of people and identify local deterrent method practiced. Purposive sampling method was used to select respondent for questionnaire survey. Majority of the respondents (58.3%) agreed that the damage of crops caused by monkeys was severe. According to 21.7% respondents, physical hurt and harassment were done by monkeys in the study area. There was a loss of more than NRs. 20,000 in 2015 in 32% of the total households surveyed. Maize was the most raided crop (31%) followed by potato (30%). Keeping dog in house (40%) was the most preferred local deterrent method followed by throwing stone and using catapult (21.7%).

Key words: Conflict, crop raiding, human, Pokhara, *Rhesus macaque*

There are six species of monkeys in Nepal, Rhesus macaque (*Macaca mulatta*), Assamese monkey (*Macaca assamensis*) and Hanuman langurs (*Semnopithecus ajax, Semnopithecus entellus, Semnopithecus hector* and *Semnopithecus schistaceus*) (Chalise, 2013). Rhesus monkeys are found in the tropical and subtropical forests in Nepal (Wada, 2005). The Assamese monkey is reported from Mid-hills and High Montana forest of Nepal and its ecological and behavioral details are still largely unknown (Chalise, 2006). Rhesus macaques are indigenous species of Bangladesh, India, Pakistan, Burma, Nepal, Thailand, Vietnam, Afghanistan, Southern China and some neighboring places.

Rhesus monkeys belong to the Cercopithecidae family (primate's order). According to IUCN, the Rhesus macaque is one of the least concerned primates in the world (Timmins *et.al* 2008). It is commonly found in the Terai and Mid-hills of Nepal (Aryal and Chalise, 2013). Rhesus monkeys are both arboreal and terrestrial. They eat fruits, leaves, roots, seeds, flowers, buds, soil, insects and other small animals (Rowe, 1996). Primates are problematical because control measures are usually not successful (Strum, 1994). Crop raiding is one of the causes of conflict from non-human primates which is mainly associated with farmers (Air, 2015).

The competition between human and non-human primates is a major problem in some areas where they are sharing the same food resources. Globally, primates are being problematical because of stealing food from human settlement or garbage found around forest and urban areas to supplement their natural diet. Further, monkeys are being more aggressive towards human (Sharma *et al.*, 2011). Due to this reason, monkeys are not liked in the areas of massive agriculture, horticulture and other plantations since they eat and damage the crops and orchards (Roonwal and Mohnot, 1977). Monkeys have become commensalism and competitors of human being in and around villages, towns and cities. These are "Urbanized monkeys" (Rajpurohit *et al.*, 2006).

The main reason behind human-monkey conflict is the massive cutting of fruit trees and plantation

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of exotic commercial species which do not supply food to monkey; this compels the monkeys to enter into human residential areas and crop fields. (Ahsan, 2014). When it is short supply of natural food, high quality and easily digested human food becomes alternative nutrition for monkey, which is the most important cause of crop raiding (Horrocks and Baulu, 1994). Hence, this negative attitude due to crop raiding has brought a question mark in the conservation of monkeys. In developing countries, farmers have limited economic source and rarely get compensation for their losses which leads severe negative attitude towards monkey (Nyhus *et al*., 2005, Linkie *et al*., 2007). Furthermore, farmers' incapability to cope with crop-raiding, lack of compensation schemes and economic loss leads to retaliatory killing of this species (Nyhus *et al*., 2005).

Crop raiding is a genuine reason for conflict between human and primates. In Nepal, crop damage is very common in the Mid-hills, High Mountain, Terai and immediate periphery of national parks and reserves. Primates are considered as the pest of field crops, Langurs in Sworgadwari forest of Pyuthan, Sangekhola of Tanahun, Assamese macaques of Hariharpur Gadhi, Rhesus macaques in Ghodaghodi of Kailali and Pashupati, Swoyambhu, Thapathali and Sankhu of Kathmandu, and elsewhere (Chalise, 2000).

Materials and methods

Study area

This study was carried out at Pumdivumdi/ Tallokodi, ward no. 25 of Pokhara Metropolitan city in Kaski District of Nepal. The study area 'Pumdivumdi' was selected as there was a serious issue of conflict between human and Rhesus monkey since last three years.

The study area is located at 78°66'75.5" E longitudes and 31°22'80.6" N latitudes and at an elevation of 1234m. This area is dominated by Aryans and their main occupation is agriculture. This area is a tourist center too as it is near to Phewa lake and World Peace Pagoda. The population of Pumdivumdi was 7,391 (CBS,2011)

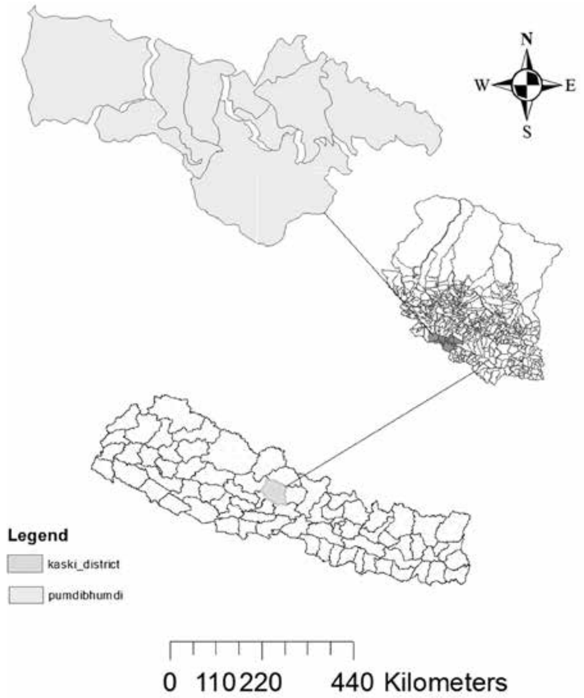

Fig. 1: Map showing the study area 'Phumdivumdi/Tallokodi'

Questionnaire survey

Purposive sampling method was used for questionnaire survey and 60 households were selected for this study. A pre-tested close and open ended questionnaire was used to collect the information from respondents. The information collected were period of monkey visit, monkey related problems, deterrent methods used by the locals, possible remedial measures of conflict.

Focus group discussion

Focus group discussion was conducted in the study area by representing all categories of users. The main issues regarding conflict, response of concerned authorities and resolving methods were discussed in the focus group discussion.

Informal discussion

Informal discussions were carried out with different key informants: executive committee members, teachers, elder persons, local leaders and social workers to get the overall information on human-Rhesus macaque conflict and verify the information collected in the focus group discussion.

Secondary information

Secondary sources of information such as published papers, theses, and reports were reviewed.

Data analysis

Data obtained were fed into Ms-Excel and Statistical Package for Social Sciences (SPSS) and analyzed accordingly. Results were presented in the tabular and graphic form.

Results and discussion

Frequency of monkey visit

Forty-five per cent of the total respondents accepted that monkeys were seen twice a day (Table 1).

Table 1: Frequency of monkey visit

Description	Frequency	Per cent	Cumulative Per cent
Every day	9	15.0	15.0
Once in a day	14	23.3	38.3
Twice in a day	27	45.0	83.3
More	10	16.7	100.0
Total	**60**	**100.0**	

Problems caused by monkey

Ninety-two per cent respondents of Hetauda (McCourt, 2005), 78% respondents of Lamjung (Adhikari,2013) and 76% respondents of Vijayapur area of Dharan reported crop raiding was main problem. Likewise, in this study, 58.3% respondents said that crop raiding was a serious problem for them (Fig. 2). Similarly, majority of the respondents (43%) strongly agreed that people were suffered from monkeys 10—15 times in a month (Fig. 3).

Thirty-two per cent respondents stated that there was annual financial loss of more than NRs. 20,000 due to crop damage followed by financial loss of 10000—20000 (30% respondents) (Fig.4).

Problems caused by monkey

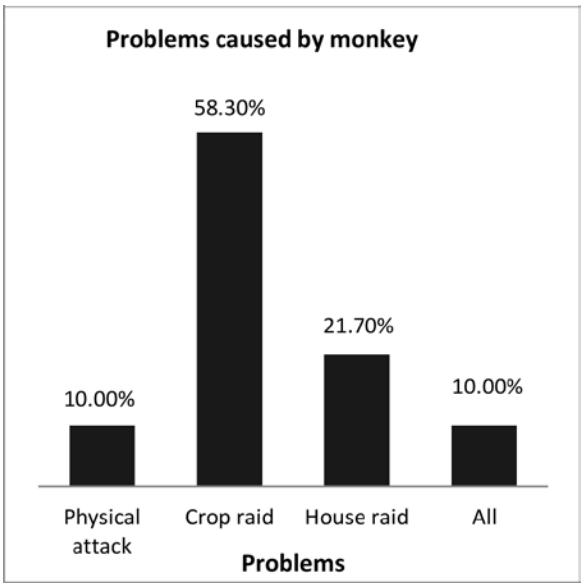

Fig. 2: Problems of the respondents

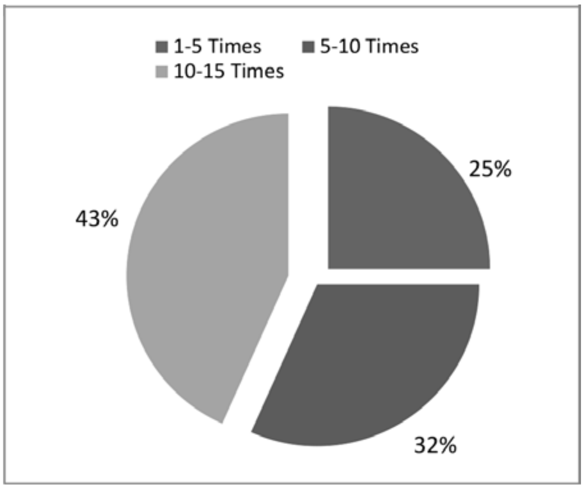

Fig. 3: Frequency of problems in a month

Annual financial loss due to damage of crops by monkeys

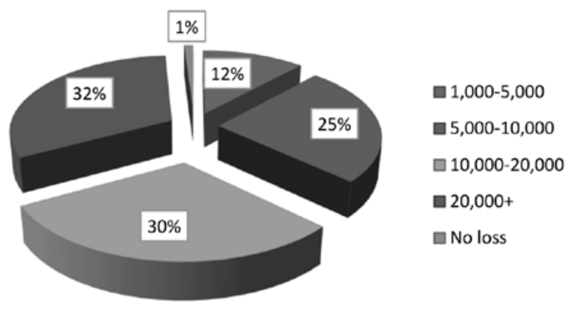

Fig. 4: Annual financial loss of individual family by monkeys

Most raided crops by monkey

According to the respondents, mostly monsoon crops i.e. maize, wheat, millet, rice and vegetables such as potato, cauliflower, cabbage and guard were raided most. Thirty-one per cent respondents agreed that the most raided crop was maize (Fig. 5).

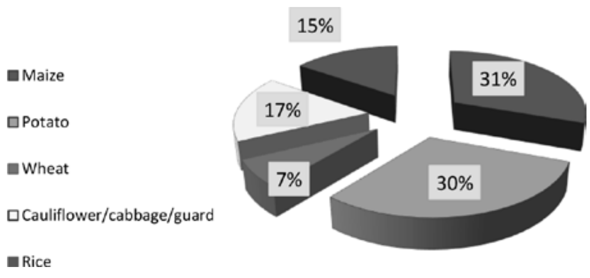

Fig 5: Most raided crops by monkeys

Local deterrent methods for monkeys

Forty per cent respondents opined that using dog was the effective deterrent method for monkeys which was followed by throwing stone and using catapult (21.7%) (Fig. 6). In the study of McCourt (2005) in Hetauda, 40% respondents agreed the deterrent method was throwing stone and using catapult.

Other strategies included flame rally to chase monkey, playing music through cassette player or radio with loud sound as well as planting thorny plants and non-palatable crops by farmers to prevent crop raiding.

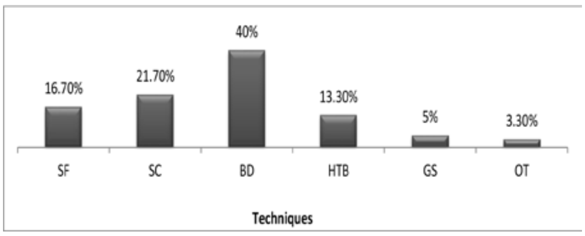

Fig.6: Local deterrent methods for monkeys (SF- shout and follow, SC- throwing stone and use of catapult, BD- by dog, HTB- hitting tin boxes, GS- gun shooting, OT-others)

Perception of people towards the conservation of Rhesus macaque

The response of majority of people towards the question asked on conservation of the species for ecosystem balance was negative i.e. 61.7% people denied for conservation (Table 2).

Table 2: Perception of people towards conservation of species

Description	Frequency	Per cent	Cumulative Per cent
Yes	10	16.7	16.7
No	37	61.7	78.3
Don't Know	13	21.7	100.0
Total	**60**	**100.0**	

Interventional support

None of the respondents have got interventional support from government or private agencies till this date. Also Rhesus macaque is not included in the list of animals in Wildlife Damage Relief Guideline (MFSC,2069)

Conclusion

From this study, it is found that severe human-Rhesus conflict exists in the study area due to crop raiding for four years which has compelled people to change crop pattern i.e. they have stopped growing potato and maize. In spite of Pokhara being a tourist center, people of Pumdivumdi are suffering a lot from Rhesus macaque which has led people to shift towards home stay business from agriculture. Majority of the respondents bear loss of NRs. 20,000+ due to crop raiding. Mostly, monsoon crops (maize, wheat, millet) and vegetables (potato, cauliflower, guard, and cabbage) are raided by Rhesus macaque during the month of March to July. This clearly implies that crop raiding was the serious issue in the study area that has severe impact on livelihood and economy of farmers. Besides financial loss, five dogs were killed by Rhesus attack and locals were also injured.

None of the related authorities is concerned about this issue in the study area. Neither interventional support is provided nor included in any legal document. The loss due to Rhesus macaque and negligence of concerned authorities has heightened negative attitude of people towards the species. This negative attitude has put question mark in the conservation of this species.

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Notes on *Bryum medianum* Mitt. (Bryaceae) collected from Tsum Valley, central Nepal

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Bryophytes are very important parts of ecosystem however their study is done less as compared to vascular plants in Nepal. There are 766 taxa of mosses in Nepal (Pradhan 2000, 2006). The genus *Bryum* Hedw. Represents the taxon of Bryaceae (Bryophyta). *Bryum medianum* Mitt. has been reported from Meghalaya, from Khasia hills (Gangulee 1969-1980) as well as Thailand and Malayasia. However, the specimen of this species has not been deposited in Nepal (Pradhan 2000, 2006); is a new addition to the specimens of bryoflora in Natural History Museum, Nepal when compared with other specis of the same genus in the = Natural History Museum, Nepal.

The study sites was Tsum valley located in Manaslu Conservation Area of Gorkha District. The species was observed during the biodiversity assessment. This species was recorded from Natural forest of *Pinus wallichiana*, *Quercus semicarpifolia*, *Rhododendron arboreum*, *Rubus peniculatus*, *Hedera nepalensis*, *Thallictrum reniforme*, etc were associated in the site.

The locality of this species consisted of moist environment with ca 10 cm litter deposition at the time of collection of the specimen. The species was photographed. It was then put in envelop and pressed along with other angiosperm. The specimen was dried and identified in the lab of Natural History Museum, Nepal. In this short note, the taxonomy based on the specimen of the species has been described.

Taxonomy

Bryum medianum Mitt. J. Proc. Linn. Soc., Bot., Suppl. **1**: 74 1859.

Plants small, closely tufted, bright green, reddish brown when dry. *Rhizoids* are reddish brown. *Shoots* erect, 4-4.5 cm long. Stems slender, short, branched. *Leaves* numerous, more crowded in the lower part of stem, erect, 1.5-2 × 1 -1.2 mm, oblong-lanceolate, sharply acuminate; margins entire, with distinct mid-vein. Seta erect, 3-7 cm long, dark reddish- brown. Capsule thick, cylindrical, 2-3 mm; operculum conical; peristome well developed (Fig.1).

Fig. 1: Collection site: A Map of Nepal; B Gorkha District and locality

Specimen examined: Central Nepal, Gandaki Zone, Gorkha district, Above Dumje, opposite to the trail to Chum valley, 2600 m, 12 September

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2012, *J. P. Gajurel, S. K. Rai, Bibas Rai & Bhim Rai,* Coll No: BRY 37a (Natural History Museum).

Distribution: Central Nepal (Dumje, Tsum valley, Gorkha District,Fig. 2), South India, Thailand, Malayasia.

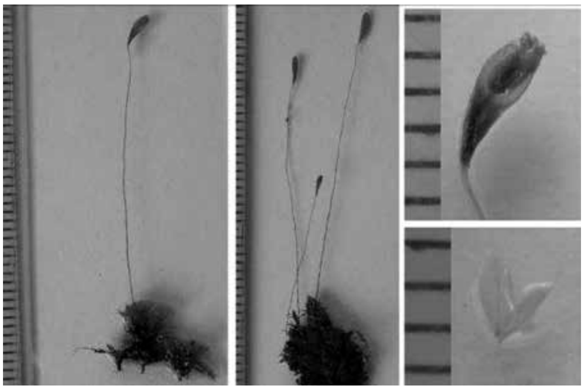

Fig. 2: Habit; A Entire Plant (moist); B Entire Plant (Dry); C. Capsule; D Leaf; the scale on margin represent mm.

Discussion

Bryophytes are less studied in Nepal as compared to higher plants. There are 766 taxa of mosses in Nepal (Pradhan 2000, 2006) which do not include *Bryum medianum* Mitt. This species have been collected and preserved in India, Thailand and Malayasia (Frahm *et al*. 2013; Gangulee 1969-1980). The potential distribution of this species was reported by Gangulee (1969-1980) in Nepal; however, there are no records on the specimen collected or deposited in Nepal. The present study, confirms his distribution range. This note on the *Bryum medianum* Mitt. concludes the new addition to bryoflora to Nepal and make contribution to existing checklist of bryoflora. As the number of specimens were localized in small area, it further recommends for conservation of the species in the natural habitat in Tsum valley.

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