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]* and 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

[1] Department of forest research and survey, Kathmandu, Nepal, * Email: subedi.iof68@gmail.com
[2] Institute of forestry, Central Campus, Pokhara, Nepal

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).

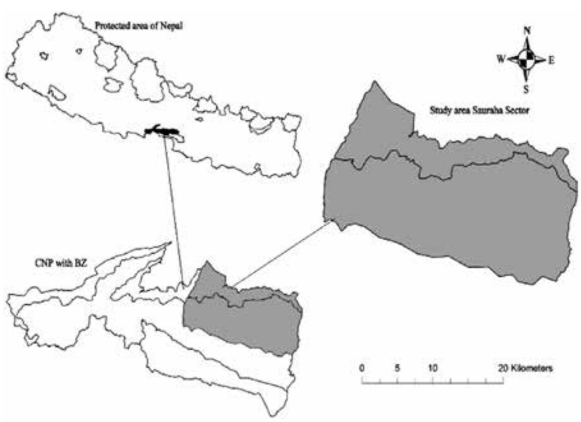

Fig 1: Map showing the location of study area

Methodology

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

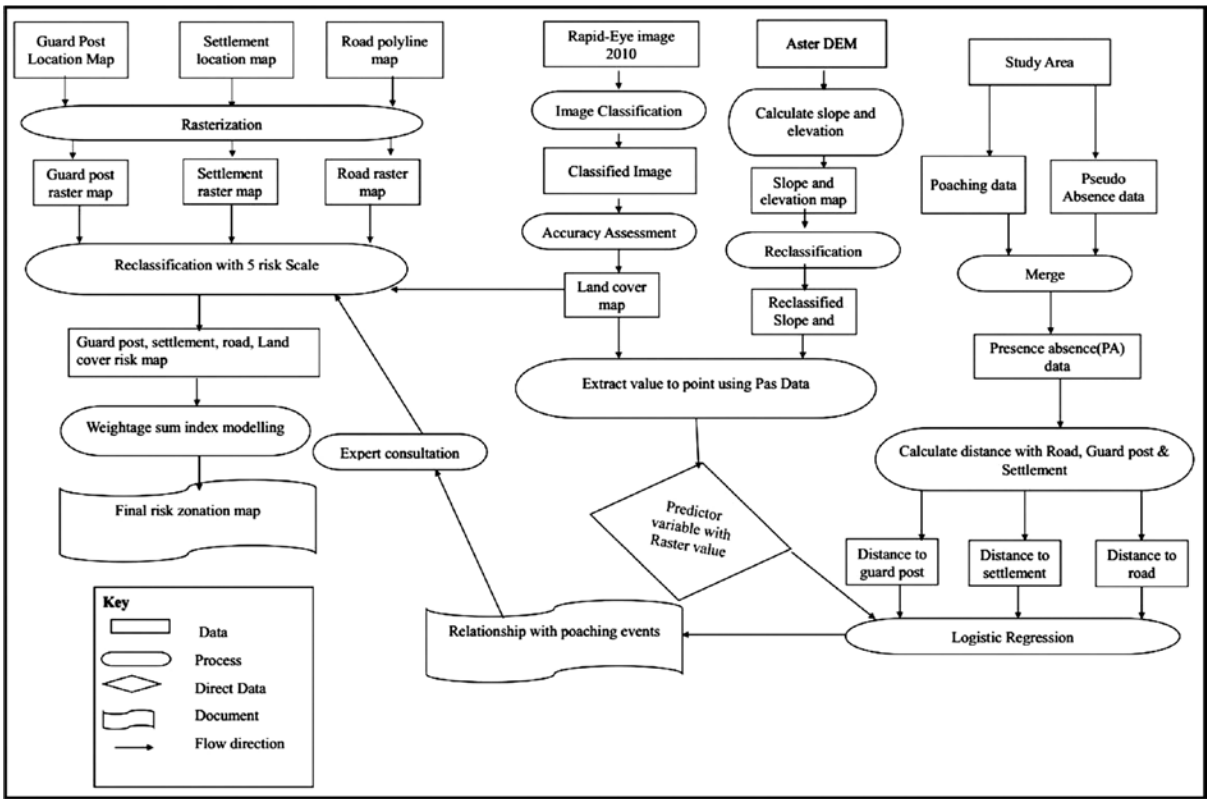

Fig. 2: Overall methodology for the risk mapping

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.

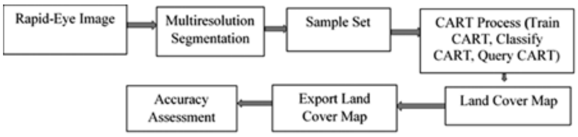

Fig. 3: Flow chart of image classification using CART Pre-processing of poaching events data

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).

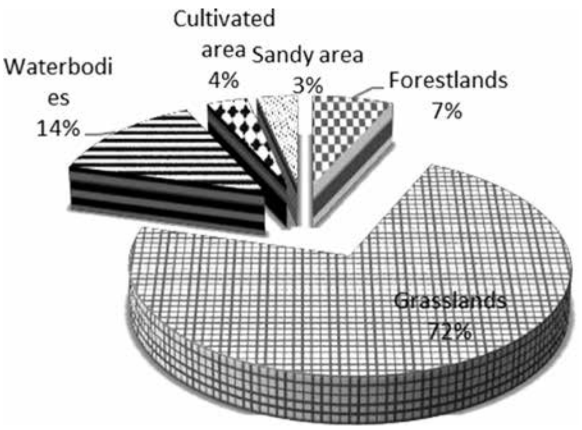

Fig. 4: Distribution of poaching events with LULC

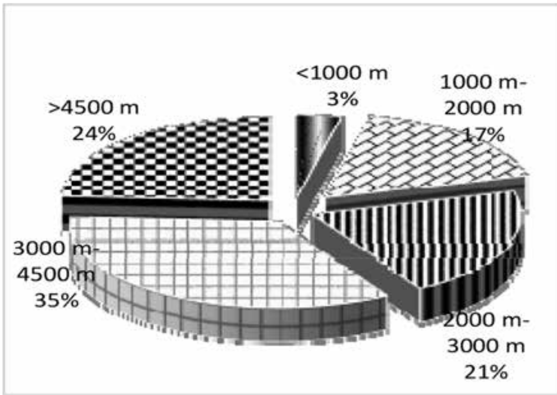

Fig. 5: Poaching incident and distance from guard post

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)

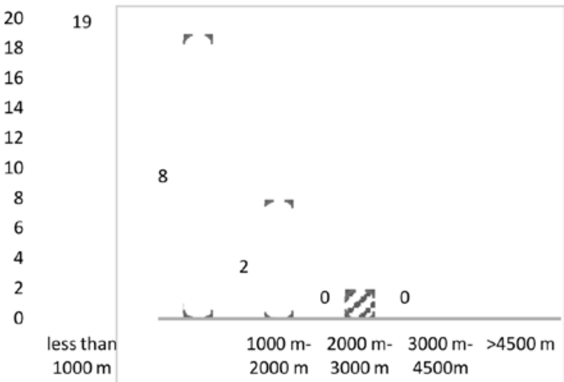

Fig. 6: Poaching events with distance from road

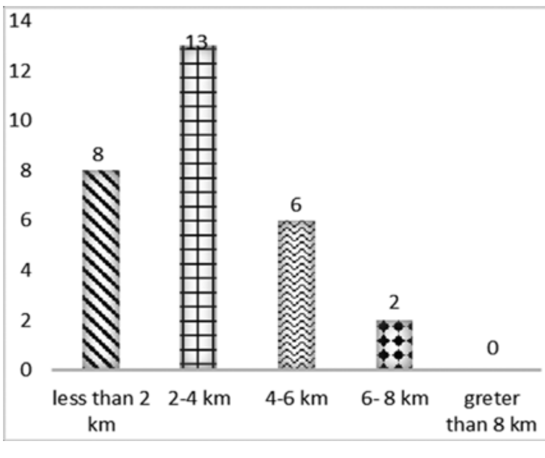

Fig. 7: Poaching events with distance from settlement

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.

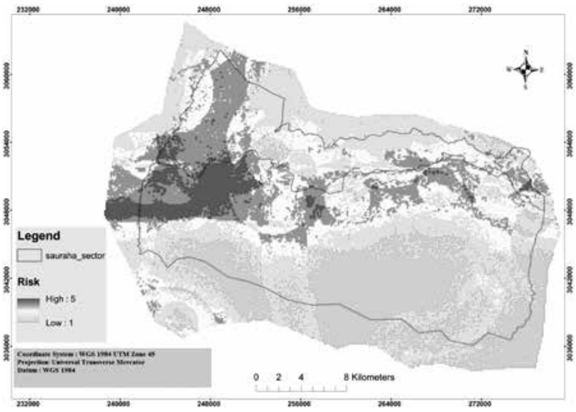

Fig. 8: Rhino poaching risk zonation map

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).

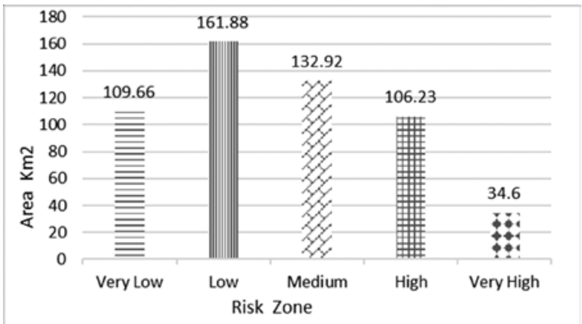

Fig. 9: Area covered by different risk zone

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.

Acknowledgements

This paper is based on a part of the author's B.Sc. Forestry thesis submitted to the Institute of Forestry, Pokhara Campus, Nepal. We are obliged to the Project Coordination Unit, National Trust for Nature Conservation (NTNC) for financial support to conduct the study. We are deeply indebted to whole CNP family for providing the important data, their support and guidance during field work. We are grateful to the Department of National Parks and Wildlife Conservation (DNPWC) for allowing permission to conduct the research in the study area. We express our cordial thanks to Mr. Binod Prasad Heyojoo, Mr. Yajna Prasad Timalsina, Mr. Navin Kumar Yadav, Kamal Jung Kuwar, Amul Kumar Acharya, Shiva Khanal and Buddi Sagar Poudel for their critical

suggestions and guidance during the study.

References

Acharya, D. 2006. **A Report about Rhino Poaching in Chitwan National Park, Nepal**. Media Consultancy, Nepal.

Aryal, R. S., Box, P. O., Lane, N. P. 2009. **Report on the Facts and Issues on Poaching of Mega Species and Illegal Trade in Their Parts in Nepal.** Transparency International Nepal. Review Literature and Arts of The Americas 1—61.

Aryal, R.S. 2002. Wildlife trade in Nepal. *Environment* **7 (8)*:*** 1—5.

Bhattrai, G. and Rupakheti, N. 2014. **Flora and Fauna of Nepal in CITES Annexes**. Kathmandu: Department of National Park and Wildlife Conservation. Retrieved from https://drive.google.com/file/d/0B_AvMj98dT2hWDQ4VVNFbXJHUmc/view?usp=sharing

Brown, S., Schreier, H., William, A., Thompson and Vertinsky, I.1994. Linking Multiple Accounts with GIS as Decision Support System to Resolve Forestry/Wildlife Conflicts. *Journal of Environmental Management* **42**: 349—364.

CNP. 2015. **Chitwan National Park (CNP). Poaching Incident Trend.** Unpublished manuscript.

ESRI. 2010. **Environmental Systems Research Institute :GIS Based Practices in Wildlife Management**. Retrived from: https://www.esri.com/library/bestpractices/wildlife-management.pdf

Hosmer, D.W., Lemeshow, S. and Sturdivant, R. X. 2013. **Applied Logistic Regression**. 3rd edition. John Wiley and Sons, New York, USA.

IUCN. 2017. **The IUCN Red List of Threatened Species. Version 2017-1**. <www.iucnredlist.org>. Downloaded on 08 July 2017.

Jnawali, S.R., Baral, H.S., Lee, S., Acharya, K.P., Upadhyay, G.P., Pandey, M., Shrestha, R., Joshi, D., Laminchhane, B.R., Griiths, J., Khatiwada, A. P., Subedi, N., and Amin, R. 2011. **The Status of Nepal Mammals: The National Red List Series, Department of National Parks and Wildlife Conservation Kathmandu, Nepal.**

Keane, A., Jones, J. P. G., Edwards-Jones, G. and Milner-Gulland, E. J. 2008. The sleeping policeman: understanding issues of enforcement and compliance in conservation. *Animal Conservation* **11**: 75–82. doi:10.1111/j.1469—1795.2008.00170.x

Metzger, K. L., Sinclair, A. R. E., Hilborn, R., and Mduma, S. A. R. 2010. Evaluating the protection of wildlife in parks : the case of African buffalo in Serengeti. *Journal of Biodiversity Conservation* **19**:3431—3444. Retrieved from http://doi.org/10.1007/s10531-010-9904-z

NBSAP. 2014 . **National Biodiversity Strategy and Action Plan.** Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Ouko, E. O. 2013. Where , When and Why are there Elephant Poaching Hotspots in Kenya ?

M.Sc. Thesis, University of Twente, ITC, Netherlands.

Poudyal, M. 2005. A Study of the Reasons for an Increase in Poaching of the One-horned Indian Rhinoceros in Royal Chitwan. M.Sc. Thesis, University of Simon Fraser, Burnaby, BC, Canada.

Poudyal, M. and Knowler, D. 2005. Economic incentives and poaching of the one-horned Indian rhinoceros in Nepal. *PREM Working paper 05/07* . Retrieved from http://www.rhinoresourcecenter.com/pdf_files/117/1175857241.pdf

Poudyal, M., Rothley, K., and Knowler, D. 2012. Ecological and economic analysis of poaching of the greater rhinoceros (

Rhinoceros unicornis) in Nepal. *Journal of Ecological Applications* **19 (7):**1693—1707.

Sánchez-Mercado, A., Ferrer-Paris, J. R., Yerena, E., García-Rangel, S. and Rodríguez-Clark, K.M. 2008. Factor affecting poaching risk to vulnerable Andean bears *Tremarctos ornatus* in the Cordillera de Mérida, Venezuela: space, parks and people. *Journal of Flora and Faunna Oryx* **42 (3):** 437—447. DOI: https://doi.org/10.1017/S0030605308006996

Sheil, D. 2001. Conservation and Biodiversity Monitoring in the Tropics: Realities, Priorities, and Distractions. *Conservation Biology* **15 (4):** 1179—1182. doi:10.1046/j.1523-1739.2001.0150041179.x

Subedi, N., Jnawali, S., Dhakal, M., Pradhan, N., Lamichhane, B., Malla, S., and Jhala, Y. 2013. Population status, structure and distribution of the greater one-horned rhinoceros *Rhinoceros unicornis* in Nepal. *Fauna & Flora International, Oryx* **47 (3):** 352—360 doi:10.1017/S0030605313000562.

Thakur, S., Upreti, C. R., and Jha, K. 2014. Nutrient analysis of grass species consumed by greater one-horned Rhinoceros (*Rhinoceros unicornis*) in Chitwan National Park, Nepal. *International Journal of Applied Sciences and Biotechnology* **2 (4):** 402—408.http://doi.org/10.3126/ijasbt.v2i4.11119

Toxopeus, A. G. 1996. **Ism, an Interactive Spatial and Temporal Modelling System as a Tool in Ecosystem Management : with Two Case Studies: Cibodas Biosphere Reserve, West Java, Indonesia, Amboseli Biosphere Reserve, Kajiado District, Central-Southern Kenya.** ITC, United States.

Treves,A., Kerry A. Martin, Adrian P. Wydeven, Jane E. Wiedenhoeft; 2011. Forecasting Environmental Hazards and the Application of Risk Maps to Predator Attacks on Livestock, *BioScience*; **61 (6)** : 451—458. https://doi.org/10.1525/bio.2011.61.6.7

WWF. 2017. Greater One horned Rhino. Retrieved from http://wwf.panda.org/what_we_do/endangered_species/rhinoceros/asian_rhinos/indian_rhinoceros/ on 7/8/2017.

Zaman, M. A. 2012. "GIS and Remote Sensing Applications in Natural Resources Management in Bangladesh" Paper presented at the World Conference on Computers in agriculture, Federation for Information in Agriculture, Taipei, Taiwan.

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		