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Research Article

Mapping and analysis of the Himalayan musk deer habitat in Annapurna conservation area

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Abstract

Himalayan musk deer (*Moschus chrysogaster*), commonly known as *Kasturi mriga* is listed as an endangered species by IUCN and protected by the National Park and Wildlife Conservation Act 1973 of Nepal. The study was carried out in two village development committees within the Annapurna conservation area region- Ghandruk and Shikha. Plots were laid using random sampling, and the corresponding GPS coordinates were recorded. The habitat of musk deer was analyzed through land cover analysis and vegetation analysis. Ivelv's electivity index (+1 to -1) was calculated to determine the preference or avoidance of habitat by musk deer, in which positive values showed preference and negative values showed avoidance. The vegetation analysis was performed by applying the importance value index. The habitat map based on preference and avoidance was prepared using GIS. *M. chrysogaster* showed higher preference to the slope ranging from 25º to 35º (IV- 0.29), followed by the slope 15º to 25º (IV- 0.16). North-west aspect and North aspect had the IV values of 0.51 and 0.42 respectively that showed the greater predilection of musk deer to these aspects. Musk deer was widely distributed in the altitudinal range of 3400m to 3600m (IV- 0.27) that was followed by the altitude of 3300m to 3400m (IV- 0.26). Musk deer preferred the shrub land and grassland in maximum extent. The study sites were dominated by Birch-Rhododendron forest, which were widely used by the musk deer. The preferred plants were *Rosa spp*., *Betula spp*., *Abies spp*. whereas the herb species mostly consisted of Lichen/Moss and Khar/grass. The habitat map showed a notably smaller extent of preferred area, indicating an obligation towards conservation of the species in its present habitat. Regular patrolling and investigation of musk deer habitat and effective conservation strategies regarding habitat management is recommended.

Keywords: *M. chrysogaster*, conservation, GIS, habitat preferences, Ivelv's electivity index.

Introduction

Himalayan musk deer (*Moschus chrysogaster*), is one of the three species of musk deer which lives in Nepal. The ecology of *M. chrysogaster* shows predilection towards forests, meadows, and shrubland on moderate to steep slopes (Green 1986, Jnawali *et al*. 2011). The herbivorous deer feeds on grasses, shrubs, forbs, flowers, twigs, shoots, lichens, and mosses (Green 1986). It is found distributed in Alpine and sub-Alpine scrub and coniferous forests and prefers high altitudes with around 25-50% crown cover and ground cover (Aryal and Subedi 2011, Qamar 2008).

The Himalayan musk deer is a globally threatened species listed on CITES Appendix I. It is also classified as an endangered species by IUCN and is protected under the National Park and Wildlife Conservation Act, 1973 in Nepal (IUCN 2015). This species, despite having a 30177.19 km^2 potential habitat throughout Nepal, is in a continuous declining state due to different threats, including hunting to obtain musk, poaching and, habitat over-exploitation (Aryal and Subedi 2011, Harris 2016, Meng *et al*. 2011, Zhou *et al*. 2004). The high-valued musk obtained from the male musk deer lead to

the illegal killing of this species (Zhou *et al*. 2004, Homes 1999). Moreover, habitat degradation and illicit livestock grazing has affected the musk deer population (Qureshi *et al*. 2013).

These endangered species are protected through the establishment of the National Park and Wildlife Reserve however the population of musk deer is still declining due to various factors like over exploitation, pollution, habitat destruction, poaching and human and livestock pressure in its habitat (GoN 2014, Aryal 2005).

The Annapurna conservation area alone provides significant habitat of over 1116.85 km^2 (Aryal 2005). But, relatively high-volume illegal wildlife trade links pass through this range in addition to human interference from trekking routes. Thus, without intervention, this species is liable to extinction (Harris 2016).

The conservation of the musk deer is a matter of global concern. For effective planning and endurance of conservation activities, it is necessary to locate the major hotspots of the species. The main aim of this research is to analyze the habitat preference of *M. chrysogaster* and prepare a habitat map showing the preference of habitat so that the output of this research will bear great value to the managers and planners to plan effective conservation plan, strategies with appropriate actions for the long term survival of the species. This research may serve as the baseline for future studies and effective management of musk deer habitat promoting in-situ conservation.

Material and methods

Study area

This study was carried out in Ghandruk VDC of the Kaski district and Shikha VDC of the Myagdi district in Annapurna Conservation Area (ACA). the ACA was the first conservation area and largest protected area of Nepal, covering the area of 7629 km^2 (NTNC 2016). It is located between 28° 15’ to 28° 50’ North latitude and 83°34’ to 84°25’ East longitude in the Western Development Region (NTNC 2016) (Fig. 1). The area ranges in altitude from 790m to the peak of Annapurna I at 8,091 m (NTNC 2016). There are two distinct climatic regions within a span of 120 km and an altitude of 1000 to 8000 m (NTNC 2016). Annual rainfall averages 3,000 mm in the South and less than 500 mm in the North (NTNC 2016). The ACA has a wide habitat range, from sub-tropical Sal forests, to perennial snow, harboring 22 different forest types, with 1226 plant species including 55 endemics, 30 mammals and 456 birds (NTNC 2016). The area is considered as a suitable habitat for many rare and endangered fauna like *Moschus chrysogaster*, *Ailurus fulgens*, *Panthera uncia*, pheasants, and many more (NTNC 2016).

Data Collection and Analysis

The potential habitat of the Himalayan musk deer were identified through an interview with staff of the Annapurna Conservation Area Project (ACAP) and a subsequent field survey. Through random sampling, habitat use plots (U) of 20m×20m were laid out in the areas along Deurali in Ghandruk and Khopra in Shikha VDC. Other parameters, such as slope, aspect, altitude, and land cover, were recorded from the same plots. Simultaneously, habitat availability plots (A) were laid out in a random direction a distance 100-150 m away and the same parameters were recorded. For Vegetation analysis, the following sample plot sizes were employed: 10m×10m for trees, 4m×4m for woody undergrowth, and 1m×1m for herbs and grasses. The habitat preference

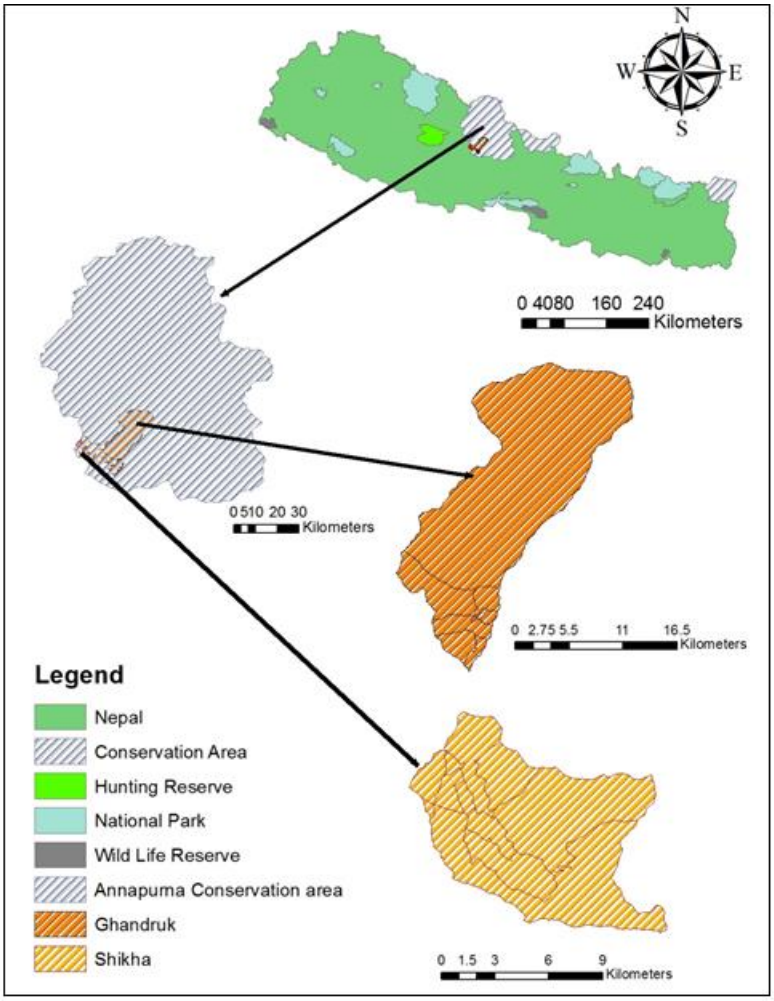

Figure 1. Map of the study area

of musk deer was analyzed through Ivelv's electivity index. Following Ivelv's electivity index (I) {hereafter Ivelv's Value (IV)} formula was used to calculate habitat preference of musk deer

IV = U% - A% / U% + A%

Where "U" represents use plots and "A" represents availability plots. All together, 58 plots (32 use plots and 26 availability plots) were analyzed in the study area. The collected data were used to calculate species richness, density, relative density, frequency, relative frequency, dominance, and relative dominance by using the following relation (Ilyas 2015)

The GPS points recorded in the field were fed into Arc GIS to prepare the distribution map. The habitat map of *M. chrysogaster* was prepared based on its preference and avoidance using Arc GIS version 10. From the digital elevation model of the Gandaki and Dhaulagiri zones, digital elevation models of Ghandruk and Shikha were derived using the data management tool i.e. CLIP. The slope and aspect of the study area were derived through a spatial analyst tool. Giving 0 value to the avoided and 1 value to the preferred habitat, the slope map, aspect map, DEM itself and vegetation map were reclassified. The GPS coordinates were added in the reclassified map. All components were combined to give equal weighting to the preference of slope, aspect, elevation, and vegetation. Through raster calculator of map algebra under spatial analyst tool, the habitat map was prepared.

Results

Based on IV values, the habitat preference of *M. chrysogaster* was analyzed. The graph (Fig. 2) below shows how IV first increases with

increasing slope up to 24-35 degrees, then begins to decrease, and finally becomes negative at higher slopes. We infer that musk deer avoid flat land due to higher human disturbances and steeper slope but prefer gentle slope.

M. chrysogaster preferred the North-west aspect followed by North due to the cold and wet environment (Fig. 3). Musk deer was found to be distributed widely in the altitudinal range of 3100-3600m. The abundance of musk deer increased with increasing altitude. The most preferred altitude within the study area was 3400-3600m (Fig. 4). The shrub land and grassland were highly used by musk deer for grazing and as an escape cover. Open forests with sparse cover were widely used, whereas closed forests were generally avoided (Fig. 5).

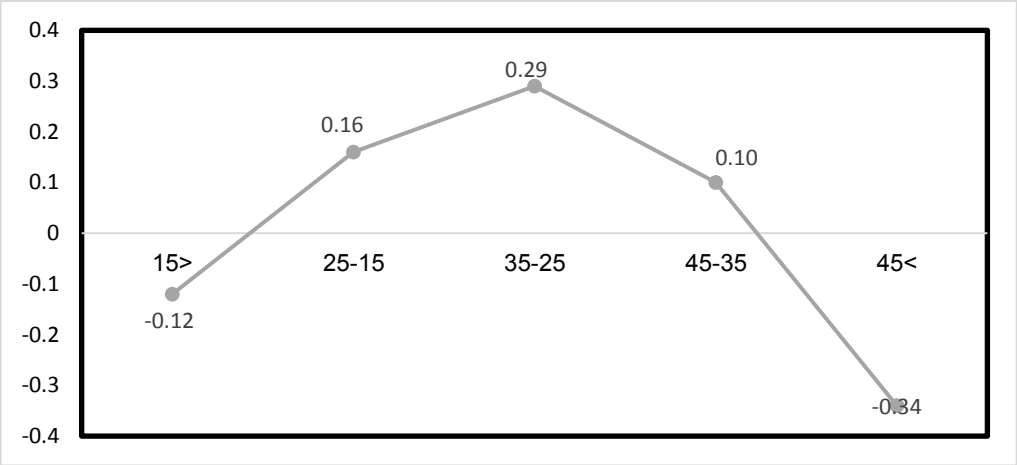

Figure 2. Slope prefered by the species

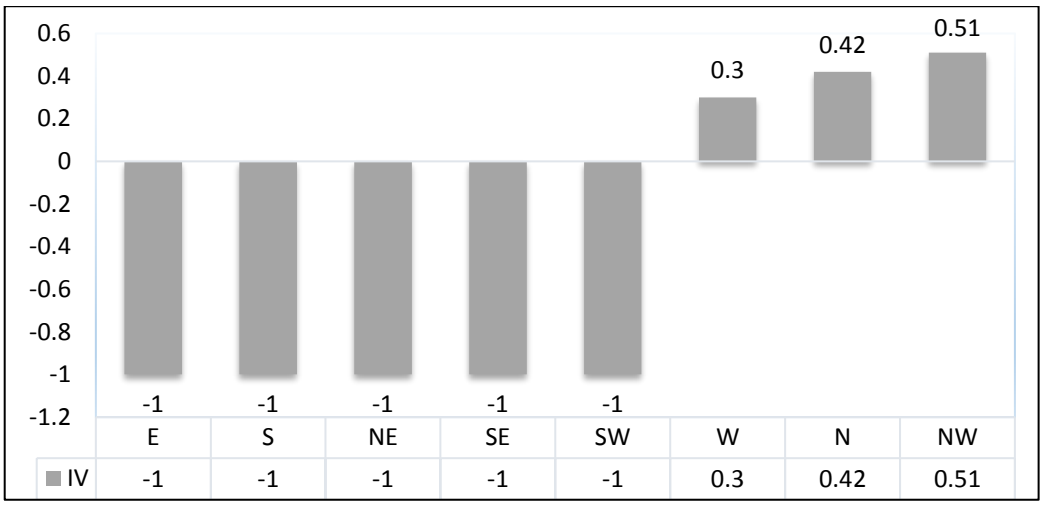

Figure 3. Aspect preferred by the species

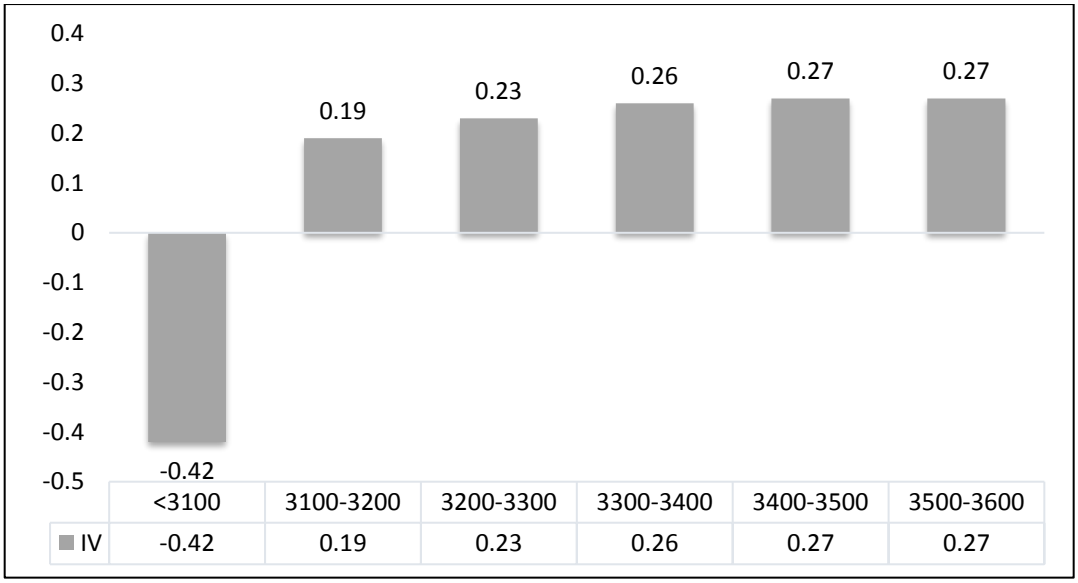

Figure 3. Altitude preference

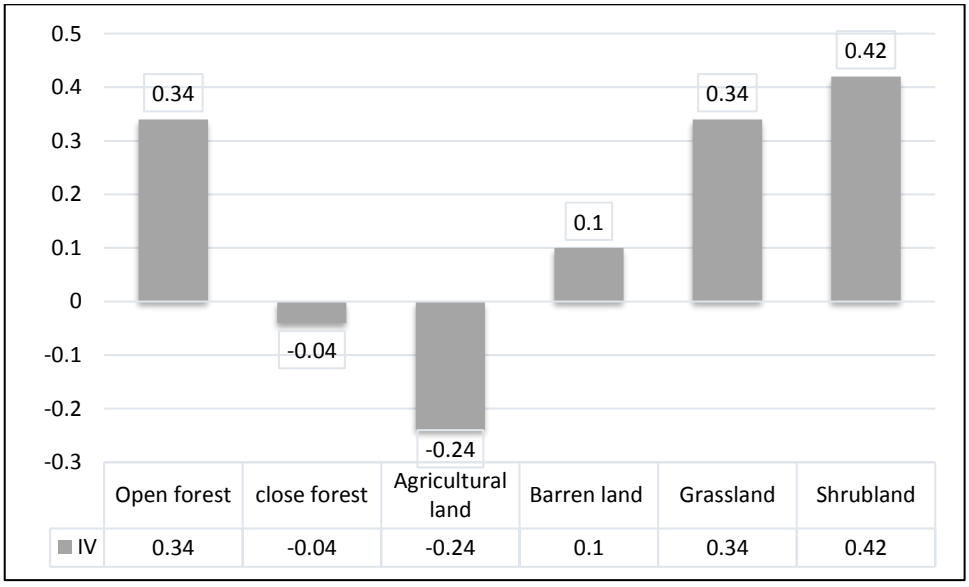

Figure 4. Landcover preferred by the species

Vegetation analysis

In the study area, eight species of trees, eight species of shrubs, and seven species of herbs were recorded. The dominant tree species in Ghandruk VDC were *Betula utilis* and *Pinus wallichiana*, whereas the most preferred species were *Betula utilis* and *Rhododendron ssp*. Shikha VDC was dominated by the *Rhododendron* forest and *Betula utilis*. *M. chrysogaster* showed higher preference to *Rhododendron* and *Betula utilis*. Among eight species of shrubs, five species were preferred and three were avoided. *Abies* and *Rosa* species were highly preferred by the musk deer. Lichen/moss and khar/grasses were highly preferred by musk deer (Fig. 6, 7 and Table 1). Habitat preference of the species has been shown in figure 8, for two study area.

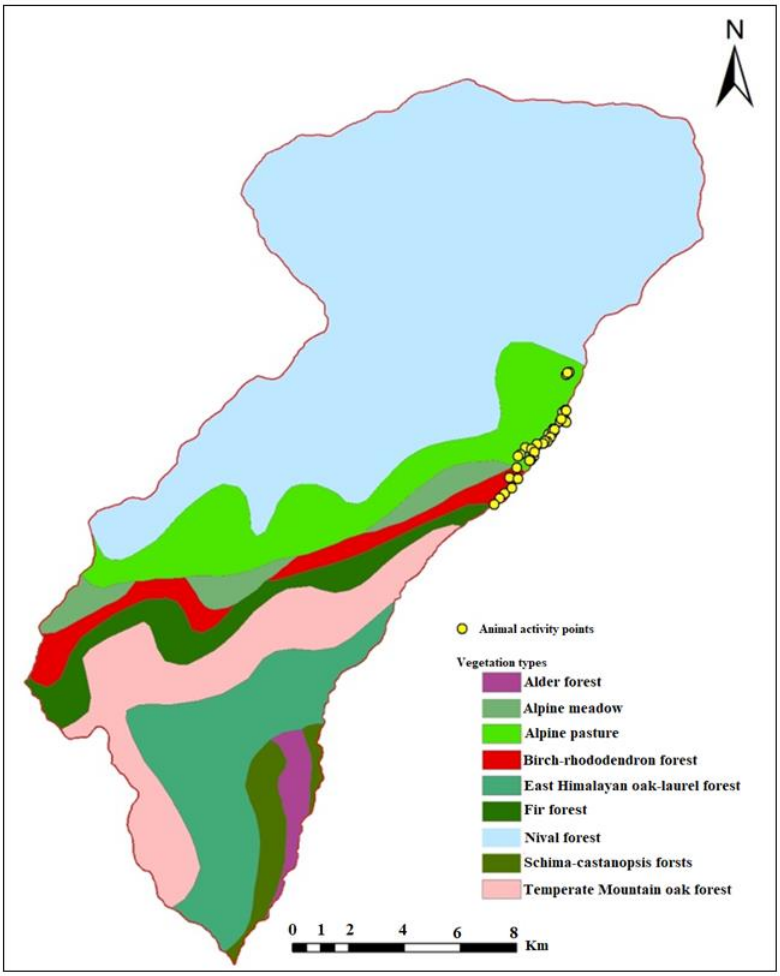

Figure 5. Classification of the study area based on preferred vegetation cover in Ghandruk

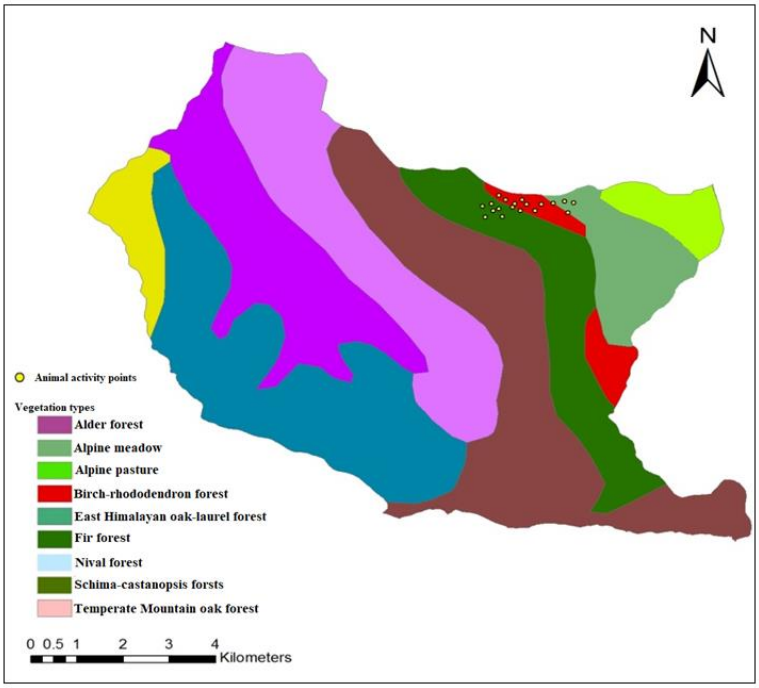

Figure 6. Classification of the study area based on preferred vegetation cover in Shikha

Table 1. Preferred tree species in different geographic areas

S.N	Tree Species	IVI (Ghandruk)	IVI (Shikha)	IV (Ghandruk)	IV (Shikha)	Preference
1	*Abies* spp. (Fir)	33.27	25.54	0.10	0.23	Preferred
2.	*Betula utilis* (Birch)	140.32	60.03	0.25	0.34	Preferred
3.	*Juniperus* spp. (Cypress)	21.56	-	-0.1	-	Avoided
4.	*Pinus wallichiana* (Blue Pine)	60.03	55.23	-0.3	-0.11	Avoided
5	*Quercus* spp.(Oak)	20.34	20.25	-0.05	-0.2	Avoided
6	*Rhododendron* spp. (Rowan tree)	42.34	124.56	0.16	0.54	Preferred
7	*Sorbus* spp.	15.30	-	-0.11	-	Avoided
8	*Laurel* spp. (Beechwood)	-	23.56	-	-0.03	Avoided

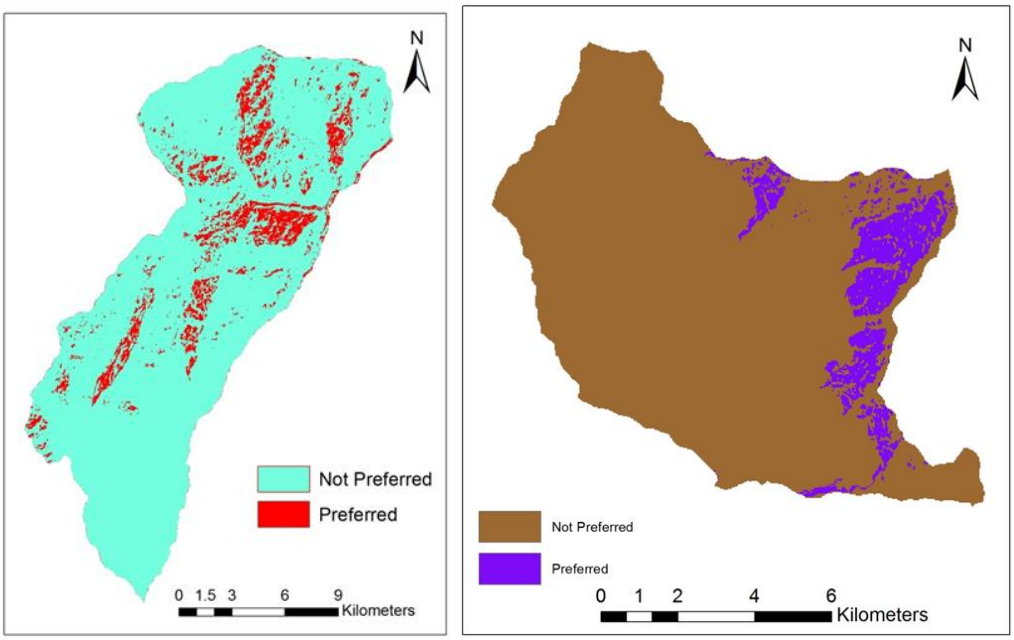

Figure 7. Habitat preference in Ghandruk (Left) and Shikha (Right)

Discussion

This study is the first GIS-based approach to identify the habitat preference of the *Moschus chrysogaster*. The landscape and vegetation preference of musk deer combined to bequeath the habitat map of the musk deer. From two figure 8, it is evident that the habitat preferred by the musk deer is very low and further decreasing due to increasing human disturbances and settlements. It is thus obligatory to conserve musk deer in its present habitat. Extensive field surveys to identify core habitats of musk deer, further research works to identify the abundance, distribution, and habitat preference of musk deer on the seasonal basis,

conservation plans, regular patrolling and investigation of musk deer habitat, and public awareness is highly recommended.

Musk deer is distributed in Ghandruk VDC along the Annapurna Sanctuary including Deurali, Hinku Cave, Ponde, Annapurna Base Camp etc. Musk deer is distributed in Khopra and Gharkhola of Shikha VDC. They were recorded from Poonhill during past but are currently locally extinct due to poaching. Musk deer preferred the gentle slope that range from 25º- 35º for daily activities, followed by the slope range 15º to 25º and 35º to 45º for resting purposes. The north-western aspect was mostly preferred by musk deer. The study was carried out within the altitudinal range of 3000- 3600 m. The most preferred altitudinal range of musk deer was 3400-3600m, followed by 3300 to 3400 m. However, musk deer avoid the altitude below 3000 m and above 4000m. Musk deer were found to be distributed in the shrubland in maximum extent. Also, they occured in the open forest and grassland, avoiding the agricultural land due to human interference. The deer preferred cliffs and caves as well for the escape purpose. The tree species most used by musk deer was found to be *Betula* in Ghandruk and *Rhododendron* in Shikha.

Conclusion

Musk deer showed higher preference to Birch-Rhododendron Forest followed by Fir forest but avoided the Pine forest. Shrubs like *Rosa spp, Abies spp, Rhododendron, Betula* etc. were preferred by musk deer but Acer spp. Juniperus etc. were avoided. Musk deer usually fed on Mosses and Lichens that had high IV value of 0.55. Additionally, he herbs like khar, *Arunadari, Berginia* etc. were also used by musk deer. Poaching and habitat degradation due to human activities (trekking route, NTFPs and firewood collection) were the major conservation threats to musk deer.

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