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*The present paper describes land cover classification and habitat mapping for the Tibetan wild ass (*Equus kiang*), also commonly known as* kiang*, in the Surkhang VDC, Upper Mustang, Nepal. Remote sensing techniques were applied for this classification, employing an ASTER satellite image from October 2002. The whole region was classified into 6 land cover types, relevant to the application of habitat mapping for the* kiang*. The classes are: grassland, shrubland, bare land, water bodies, snow cover, and agriculture and settlement. The area of each land cover type was tabulated to give a general picture of the land cover situation. Habitat information was collected mostly from the literature and partially from a field visit. GIS tools for spatial analysis were used to identify the suitability of the habitat in the region. The whole region was classified into 3 different suitability levels, ie primary, secondary, and non-suitable, based on use and potential use by the species in the particular area. The region with suitable habitats was delineated so that any further conservation activities related to* kiang *habitat can be concentrated within this boundary as a management implication.*

Keywords: *Land cover classification;* Equus kiang*; Tibetan wild ass; habitat mapping; remote sensing; GIS; Nepal.*

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Introduction

Satellite technology and GIS are now well-accepted tools for establishing and modeling spatial information about wildlife habitat (Mongkolsawat and Thirangoon 1999). Habitat is any spatial unit that can be occupied by an individual animal, no matter how briefly (Liu 2001). All habitats include at least a source of food, protective cover and space, and water (Dasmann 1981; Best 1984). A habitat map records the structure of the landscape. The map structure, related directly to real features on the ground, can help in understanding the environment. It shows the inter-connectivity of landscape features, their immediate context, and the wider area in which environmental influences operate. This type of map helps to show how ecological principles can explain patterns of biodiversity. By understanding the extent and distribution of an organism's habitat, resource managers can predict the distribution and abundance of target wildlife species populations (Morrison et al 1992).

FIGURE 1 The *kiang* (*Equus kiang*). (Photo by Patricia D. Moehlman)

Knowledge of habitat type is of vital importance for species conservation and restoration activities. The availability of a suitable habitat determines the existence of an individual species. Similarly, a complex of various habitat types, with their spatial dimensions and contingencies, can either favor or hamper the potential for existence of a species, depending on the type. This is of greater importance in terms of species ecology than habitat mapping. Habitat classification involves grouping of components into homogeneous habitat units, on the basis of characteristics significant to wildlife species. It also distinguishes between land cover categories (Best 1984). Habitat mapping is similar to any type of land cover mapping (Lindgren 1985; De Wulf et al 1988; Liu 2001).

Habitat analysis at the landscape level, using remotely sensed data and GIS, offers the potential to help explain species diversity patterns at fine-scale resolutions (Debinski et al 1999). Wildlife issues that can be addressed with GIS technologies include determination of wildlife and habitat distribution and abundance, identification of wildlife–habitat associations, and development of long-term habitat and population monitoring programs (Ramsey et al 1999).

General description of the *kiang*

Equus kiang, the Tibetan wild ass, is one of the world's least-studied species. The *kiang* (Table 1; Figure 1) was originally

TABLE 1 Characteristics of *Equus kiang*.

Equus kiang	
Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Perissodactya
Family	Equidae
Genus	Equus
Species	*Equus kiang*
Common name	*Kiang*
Synonyms	*Nepalensis*
English name	Tibetan wild ass
IUCN Category	Data Deficient (DD)
CITES Category	Appendix II

named by Moorcroft in 1841 (Groves 1974; Schaller 1998; Walker and Nowak 1999; Hilton-Taylor 2000). Only recently has this genus received specific status, although it is still sometimes referred to as a subspecies of *E. hemionus* (Wilson and Reeder 1993; Wang 2002).

Equus kiang is widely distributed in Tibet (China), Nepal, and India (Wilson and Reeder 1993; Schaller 1998; Moehlman 2002; Wang 2002). It is found in the Dolpo and Mustang areas of Nepal (Schaller 1998; Moehlman 2002). The species was first spotted in Nepal in June 2001 (37 individuals in Chuksung, Upper Mustang or UM), raising the recorded number of mammalian species in this country to 185 (TRN 2002). The recording of the *kiang* as a new species in Nepal has increased concern over its habitat status in UM. Land cover in UM has not been studied since 1986. Therefore, a habitat study of the *kiang* was thought to be important and innovative, as it would generate new knowledge and renew existing information on the land cover resources in UM.

Until *kiangs* were sighted in Nepal, it was thought that they were endemic only in the desolate high-altitude grasslands of the Tibetan plateau. This is reflected in the prefix “Tibetan” in the animal’s common name. One reason why this species was said to be found living and roaming only in the alpine desert-like environment of the Tibetan plateau may be its adaptation to the harsh weather, climate, and terrain peculiar to this natural habitat.

Kiangs have been decimated or eradicated from large tracts in recent decades, and this trend will continue as pastoralists and their livestock increase. The habitat of this species needs careful management, but first it requires detailed study, which has not yet been attempted (Schaller 1998). Maps on habitat and distribution are even more important when there is little information available on a particular species. Such maps could be used to locate the species in the region and also to help locate a conservation restoration program for the UM region. The present study was carried out with the objective of characterizing the land cover in the region and preparing a suitability-based habitat map of the *kiang* in Surkhang.

Materials and methods

Study area

The present study was carried out in Surkhang, one of the 7 Village Development Committees (VDCs are the smallest administrative unit in Nepal) of UM, Nepal. The study area ranges approximately from 28°50’19”–29°09’10” N and 83°49’41”–84°15’16” E. Land cover classification and habitat mapping were carried out for this VDC over an area of about 784 km^2.

The region is situated in the Himalayan rain shadow and receives less than 100 mm of rainfall annually (HMGN 1999). Altitude ranges from 3000 m to over 6000 m. The entire area is under snow cover for 4–5 months from November to March. The UM region is considered the southernmost extension of the Tibetan plateau. Alluvial fans, jutting sandstone ridges, abandoned glacial moraines, and broad sandy terraces are the visible forms of landscape in the region. Mean annual daytime temperature is usually around 21°C, but at night it may fall to 5°C. Only herders and pastoralists visit the wilderness area of this VDC to the north, often for only 2–3 months in summer.

More than 40% of the UM is rangelands and pastures at altitudes from 3000 m to higher than 5000 m (Blamont 1997). The area is known to be extremely rich in flora and fauna, especially steppe habitats. Though UM covers only 1.74% of the country’s total land area, it contains a high percentage of threatened mammal species. This region is relatively undisturbed and serves as an excellent refuge for Tibetan wildlife species (Shah et al 2002). It is also a corridor for many trans-Himalayan migratory birds. Its high-altitude rangelands are home to the endangered snow leopard and other species, including the Tibetan wolf, the Tibetan argali (a mountain sheep), lynx, brown bear, and endangered plant species (UNDP 2000).

Remote sensing data

The most recent surface radiance image (October 2002) and a digital elevation model (DEM), both obtained from ASTER (Advanced Spaceborne Thermal

TABLE 2 Description of land cover classes used to classify the study area.

Land cover class	Description
Agriculture and settlement	Villages and community settlements, adjoining crop fields and tree stands. Usually trees and crop fields are near the clustered houses. Almost all of this class lies along riverbanks. This is the pattern of settlement throughout the UM region.
Bare land	Land surface with little or no cover (ie less than 10% vegetation cover). Rockfall areas are also included in this class.
Water bodies	Perennial rivers, streams, rivulets, glacial lakes (frequently found above 5000 m), and other permanent water bodies; small rivers that remained dry during the time of image acquisition are not included.
Grassland	Prevalent land cover in the area, occurring above 4000 m. All high-altitude pastures with smooth slopes consist of alpine grasses. Habitat highly favored by blue sheep and other grazers.
Shrubland	Second most prevalent class as of 3000 m, with dominant *Lonicera obovata* and *Caragana* spp., sometimes also *Berberis* spp.
Snow cover	Peaks with permanent snow cover, usually found above 6000 m.

Emission and Reflection Radiometer Sensor), were used for land cover classification. ASTER covers a wide region, with 14 bands from the visible to the thermal infrared, with high spatial, spectral, and radiometric resolution. The spatial resolution varies with wavelength: 15 m in the visible and near-infrared (VNIR) region, 30 m in the short-wave infrared (SWIR) region, and 90 m in the thermal infrared (TIR) region.

The image of the study area, consisting of only 9 bands from VNIR to SWIR (the bands in the thermal region were excluded owing to their coarse resolution), was geo-referenced with the help of topographic map sheets. Naturally visible features such as ridges and river joins were used to locate Ground Control Points (GCPs), as they offer the advantage of easy location. A first order polynomial transformation with a nearest neighbor resampling technique was used, as this method offers the advantage of computational simplicity (Lillesand and Kiefer 2000) by directly assigning the digital number (DN) in the input file that most overlaps the pixel in the output file, making it unnecessary to alter the original input pixel values (Richards 1993). The root mean square error was 0.21 pixels.

The Normalized Difference Vegetation Index (NDVI) was calculated from the reflected solar radiation in the near-infrared (NIR) and red (RED) wavelength bands using the algorithm:

$$\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}$$

The NDVI is a nonlinear function, which varies between –1 and +1, but is undefined when RED and NIR are both zero. The NDVI can be used as an indicator of the amount of green biomass, and is a promising tool for distinguishing regions with and without vegetation in image analysis, which is often used to improve classification results.

Principal component (PC) images allow redundant data to be compacted into fewer bands—that is, the dimensionality of the data is reduced. The PC bands are non-correlated and independent, and can often be interpreted more easily than source data. Moreover, they yield better classification results (ERDAS 1999).

Aspect in general has greater significance for vegetation characteristics, as it determines the amount of radiation available for plants. Aspect and slope are used as predictors of vegetation types throughout the world (Hamilton et al 1997). NDVI and PC images were obtained from the ASTER image. Similarly, images of altitude, slope, aspect, and stream networks were derived from DEM.

Supervised image classification is an essential tool used for extracting land cover information from remotely sensed image data (Richards 1993). Training areas were selected throughout the study area in order to obtain representative samples for each land cover class (Lillesand and Kiefer 2000). Field observations, aerial photograph interpretation, topographical maps, and GPS surveys were used at this stage. These training sites included all the types of land cover designed for classification work. Spectral signatures were collected from a wide range of altitudes, from 3000 to 5600 m, and from sites with differences in topographic slope and aspect, as species characteristics differ for varying slope and aspect. Ground truth data were collected for both classification and evaluation. The region was classified into 6 land cover types based on relevance for habitat mapping. These classes are described in Table 2.

Habitat mapping

Habitat conditions indicate the health of an ecosystem and the presence or absence of a particular wildlife

TABLE 3 Criteria for assessment of *kiang* habitat suitability.

Criteria	Primary habitat	Secondary habitat
Elevation	4650–5350 m	4650–6000 m
Distance from nearest community	> 5 km	> 5 km
Slope	0°–15°	0°–15°
Land cover	Grass/shrub/ water	Grass/shrub/ water/bare
Distance from water	< 2 km	> 2 km
Distance from temporal pasture	> 5-km radius	< 5-km radius
Habitat		Other than primary

species. Although details of habitat quality can be assessed with the use of habitat suitability index models, the life form approach and the guilding approach, a general overview of the habitat in terms of vegetation type, land use, and geo-topographical features can also be used in predicting habitat (BCDP 1994).

Literature on the *kiang* and its habitat (Groves 1974; Schaller 1998; Walker and Nowak 1999; Moehlman 2002; Shah et al 2002) was reviewed. First-hand information collected during the field visit was also used to describe the general habitat preference of the species. Suitability criteria were then developed and the region was classified into 3 habitat types, designated as primary, secondary, and non-suitable.

"Primary habitat" in this study is the type that *kiangs* can use throughout the year and which offers the basic habitat requirements of food, shelter, and water. "Secondary habitat" serves some specific needs, such as breeding, bathing, etc. This includes areas that are either not available throughout the year or not always required for all individuals. "Non-suitable habitat" is the type which serves no purpose for the *kiang*, either because of ecological factors such as the unavailability of food, water, and cover, or unsuitability due to topography, ie low altitude, higher slope, or disturbance factors such as demographic interference.

In classifying a place as unsuitable, disturbance factors must be taken into account. In addition, habitat that does not fall into the previous 2 categories, ie primary and secondary, is also classified as non-suitable. This habitat type cannot be used by the species for food, shelter, or water, but may be of limited use in connecting spatial units of discontinuous suitable habitat types.

Altitude is the major topographical factor that determines *kiang* habitat. Altitudes between 4650 and 6000 m were identified as a suitable habitat for the *kiang*. Similarly, slope is also an important topographical factor. A slope of less than 15° is a suitable habitat. An altitudinal range from 4650 to 5340 m was considered the primary habitat, as *kiangs* were observed there, while altitudes from 5350 to 6000 m were considered secondary. Altitudes higher or lower than this were considered non-suitable owing to ecological restrictions on the presence of *kiangs*.

Grassland, shrubland, and water are sources of food and cover. These cover types, in relation to the limitations of altitude, determine whether a place is a primary, secondary, or non-suitable habitat type. Similarly, water and bare land are other important habitat components that can be either primary or secondary, depending on the requirement of the species. Bare land within the 4650–6000 m altitudinal range serves as a breeding habitat (during July and August) and thus was considered to be secondary, as such areas are not used by the *kiang* throughout the year.

The nearest water source need not be close, as *kiangs* do not use water frequently. However, *kiangs* enjoy taking baths in summer. Two conditions were established in the habitat, ie for food requirements and social activities. An area further than 2 km from the nearest water source was considered to be secondary habitat, which *kiangs* use for social activities like bathing, while areas closer than 2 km were considered primary habitat, as water is required for drinking.

An undisturbed region is a must for the wild species to survive. Based on the topography and type of human movement in the region, areas closer than 5 km from the nearest community were considered non-suitable habitat, as *kiangs* do not tolerate the slightest level of disturbance by humans. In the remote areas of the UM region, it is less likely that local people visit more than 5 km of linear distance from their place of settlement, due to the harsh topography.

Transhumance is prevalent in Mustang, with people taking domestic sheep and goats to pastureland uphill during summer. The communities of Surkhang VDC take their domestic sheep and goats to a pastureland called Damodar Kunda Valley, a biodiversity hotspot

TABLE 4 Description of band combinations (BC) and accuracy obtained.

BC	Constituent bands	Overall accuracy
1	Bands 1, 2, 3, 4, 5, 6, 7, 8, 9	77.78 %
2	Bands 1, 2, 3, 4, 5, 6, 7, 8, 9 and Aspect	79.07 %
3	Bands 3, 5, 7, 8, 9, PC1, NDVI and Aspect	91.73 %
4	Bands 3, 5, 7, 8, 9, NDVI and Aspect	92.25 %

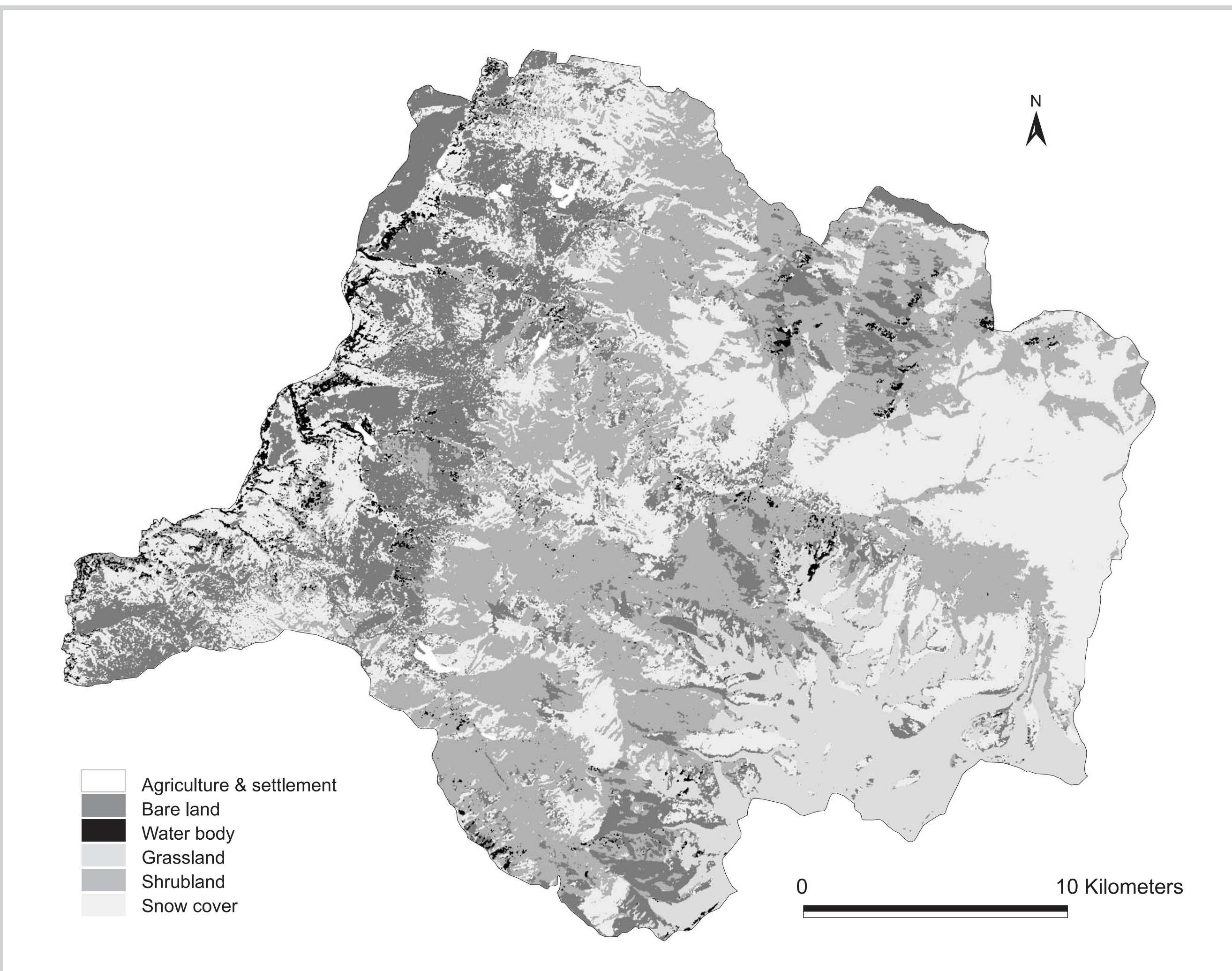
(Koirala and Shrestha 1997) located at 4900 m. This pastureland has been reported by Moehlman (2002) as one of the two potential *kiang* habitats in Mustang. This valley is also of religious significance to Hindus and Buddhists, and pilgrims visit this place during summer. The combined effect of transhumance and religious activities makes this area unsuitable for the *kiang* for about 4 months during summer. Thus, an area closer than 5 km from the center of the valley, where Damodar Kunda is located, was considered a secondary habitat. The criteria for habitat mapping based on the discussion above are summarized in Table 3.

Layers of data containing altitude, distance from community, slope, and land cover were prepared. The stream networks, derived from DEM, were used to find the distance from a water source, together with the water bodies identified by image classification. This was

TABLE 5 Results of classification, as a percentage and in km^2, for land cover classes.

Class	Percent cover	Area in km^2
Agriculture and settlements	0.31	2.44
Bare land	20.19	158.31
Water bodies	1.82	14.25
Grassland	36.01	282.34
Shrubland	32.57	255.38
Snow cover	9.11	71.40
Total	**100.00**	**784.11**

FIGURE 2 Land cover map of Surkhang, Upper Mustang, Nepal. (Map by Benktesh D. Sharma)



done to include water sources missing in image classification due to limited spatial resolution. Similarly, a layer with the distance from temporal pastures was also created. Analytical queries on the criteria mentioned in Table 3 were formulated and implemented in GIS, and the areas of each habitat type were identified. After the two suitable areas were identified and unified, all other areas were designated as non-suitable.

Results and discussion

Classification results

Detailed analysis of the available spectral and DEM information that showed 4 combinations (in Table 4) was promising in terms of distinguishing the 6 classes (Sharma 2003). To find the most suitable bands for classification, these combinations were classified using a maximum likelihood classifier with a 95% confidence interval, and the results were evaluated. The same set of signatures was used for each combination. The overall accuracy obtained is given in Table 4.

Since classification of band combination (BC) 4 gave the best overall classification accuracy, consisting of bands 3, 5, 6, 7, 8, 9, NDVI and aspect, this was used for final classification and preparing the land cover map of the region.

A 3 x 3 majority filter was applied in order to smoothen the salt-and-pepper appearance in the classified image according to the methods and rationale described by Eastman (1997). Land cover statistics, expressed as area in km^2 and as a percentage, are presented in Table 5, and the land cover map is presented in Figure 2.

Habitat suitability for the *kiang* in Surkhang, Upper Mustang

The spatial analysis carried out gave the following results for *kiang* habitat suitability:

FIGURE 3 Areas of different habitat types (in km^2). (Map by Benktesh D. Sharma)

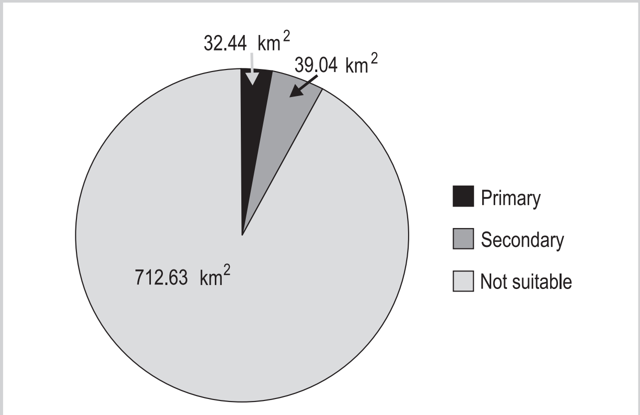


FIGURE 4 Habitat suitability map for the *kiang* in Surkhang, Upper Mustang, Nepal. (Map by Benktesh D. Sharma)

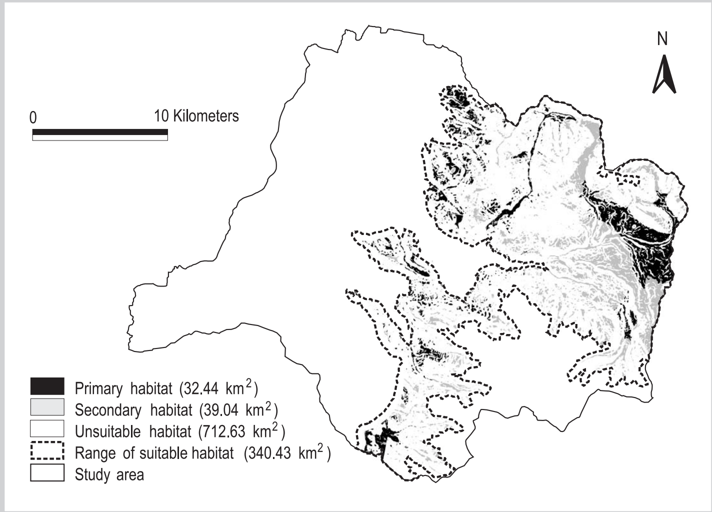


Figure 3 shows that in Surkhang, an area of about 71 km^2 was found to be a suitable habitat for the *kiang*. This is 9.12% of the total area. Of the suitable habitat types, only 32.44 km^2 (about 4%) is primary, while slightly more, ie 39.04 km^2 (4.97 %), is secondary.

A range of suitable areas was delineated by including all the suitable areas in one large polygon that would serve as the boundary of the region with *kiang* habitat suitability. Conservation efforts conducted with respect to *kiang* habitat should be carried out inside this boundary. The suitable range covers an area of 340.43 km^2. The range thus specified provides a general picture of the habitat status of the *kiang* in Surkhang, and includes some patches of non-suitable habitat type as well. These non-suitable habitat types inside the range can have limited use, extending from one suitable type to another. The habitat suitability map for the *kiang*, with the identified regions, is presented in Figure 4.

Conclusions

Classification of land cover is possible with a high level of accuracy by using an ASTER image of the region. Similarly, habitat suitability mapping is possible when information on habitat requirements for the target species is available. This is the first study that employed image analysis for these purposes in the study area. Very few studies have been carried out in UM in general, and little information is available on *kiang* habitat. As a species that lives on open terrain found in UM, the *kiang* has approximately 71 km^2 of suitable area available at the moment. The total area for suitable habitat was found to be about 340 km^2 within Surkhang, UM. However, if disturbance factors, especially transhumance, could be halted or regulated, the area suitable for the *kiang* would increase considerably.

This study provides information on land cover and *kiang* habitat that can be used in the management information system (MIS) of the King Mahendra Trust for Nature Conservation (KMTNC), which is currently managing the UM region. These data should be used for zoning activities such as zoning the *kiang* habitat types in any conservation or restoration activities planned in the area. Information coming from rangeland-related studies such as botanical studies could be used together with the data from this study to further advance *kiang* habitat studies. In future, a similar study using older remote sensing images could help increase understanding of the land cover dynamics of the region. Such a multitemporal analysis would show the changing land resource and development activities in the region and can help responsible authorities and institutions understand the impact of their work.

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REFERENCES

BCDP [Biodiversity Conservation Database Project]. 1994. *Final Report*. Kathmandu, Nepal: KMTNC [King Mahendra Trust for Nature Conservation].

Best R. 1984. Remote sensing approaches for wildlife management. *In:* [no editor.] *Renewable Resource Management: Application of Remote Sensing.* Proceedings of the RNRF Symposium on the application of remote sensing to resource management, Seattle, 22–27 May 1983. Bethesda, MD: RNRF [Renewable Natural Resources Foundation], pp 55–96.

Blamont D. 1997. Upper Mustang's shifting animal husbandry practices. *In:* Miller D, Sienna C, editors. *Rangelands and Pastoral Development in the Hindu Kush-Himalayas.* Proceedings of a Regional Experts' Meeting, Kathmandu, 5–7 November 1996. Kathmandu, Nepal: ICIMOD [International Centre for Integrated Mountain Development], pp 171–191.

Dasmann RF. 1981. *Wildlife Biology*. 2nd edition. New York: John Wiley & Sons.

De Wulf RR, Goossens RE, McKinnon JR, Cai WS. 1988. Remote sensing for wildlife management: Giant panda habitat mapping from LANDSAT MSS images. *Geocarto International* 1:41–50.

Debinski DM, Kindscher K, Jakubaskas ME. 1999. A remote sensing and GIS based model of habitats and biodiversity in the Greater Yellowstone Ecosystem. *International Journal of Remote Sensing* 20:3281–3291.

Eastman JR. 1997. *IDRISI for Windows. User's Guide.* Version 2.0. Worcester, WA: Clark University.

ERDAS Inc. 1999. *ERDAS Field Guide.* 5th edition. Atlanta, GA: ERDAS Inc.

Groves CP. 1974. *Horses, Asses and Zebras in the Wild.* Hollywood, CA: Ralph Curtis Books.

Hamilton LS, Gilmour DA, Cassels DS. 1997. Montane forests and forestry. *In:* Messerli B, Ives JD, editors. *Mountains of the World: A Global Priority.* New York: Parthenon, pp 281–311.

Hilton-Taylor C, editor. 2000. *IUCN Red List of Threatened Species.* Gland, Switzerland: IUCN [The World Conservation Union].

HMGN [His Majesty's Government of Nepal]. 1999. *Daily Precipitation Records of Bheri, Rapti and Dhaulagiri Zone through 1996.* Kathmandu, Nepal: Department of Hydrology and Meteorology.

Koirala RA, Shrestha R. 1997. *Floristic Composition of Summer Habitat and Dietary Relationships Between Tibetan Argali (*Ovis ammon hodgsonii*), Naur (*Pseudois nayaur*) and Domestic Goat (*Capra hircus*) in the Damodar Kunda Region of Upper Mustang in Nepal Himalaya* [MSc thesis]. Osloveien, Norway: The Agricultural University of Norway.

Lillesand TM, Kiefer RW. 2000. *Remote Sensing and Image Interpretation.* 4th edition. New York: John Wiley & Sons.

Lindgren DT. 1985. *Landuse Planning and Remote Sensing.* Dordrecht, Netherlands: Martinus Nyhoff Publishers.

Liu X, 2001. *Mapping and Modeling the Habitat of Giant Pandas in Foping Nature Reserve, China* [PhD dissertation]. Enschede, The Netherlands: ITC [International Institute for Geo-Information Science and Earth Observation].

Moehlman PD, editor. 2002. *Equids: Zebras, Asses and Horses. Status Survey and Conservation Action Plan.* Gland, Switzerland: IUCN [The World Conservation Union].

Mongkolsawat C, Thirangoon P. 1999. Application of satellite imagery and GIS to wildlife habitat suitability mapping. *In:* [no editor.] *Proceedings of the 19th Asian Conference on Remote Sensing, Manila, 16–20 November 1998.* Manila, Philippines: AARS [Asian Association on Remote Sensing]. http://www.gisdevelopment.net/aars/acrs/1998/ts11/ts11008.shtml; accessed on 3 December 2002.

Morrison ML, Marcott BG, Mannan RW. 1992. *Wildlife–Habitat Relationships: Concepts and Applications*. Madison: The University of Wisconsin Press.

Ramsey RD, Black AT, Edgley E, Yorgason N. 1999. *Use of GIS and Remote Sensing to Map Potential Columbian Sharp-Tailed Grouse Habitat in Southeastern Idaho.* Idaho City, ID: Bureau of Land Management, United States Department of Interior.

Richards JA. 1993. *Remote Sensing Digital Image Processing: An Introduction.* Berlin: Springer-Verlag.

Schaller GB. 1998. *Wildlife of the Tibetan Steppe*. Chicago, IL: University of Chicago Press.

Shah KB, Ale S, Chapagain NR. 2002. New mammal records from Upper Mustang, Nepal, with notes on mammalian fauna of the area. *Journal of Natural History Museum* 21:33–44.

Sharma BD. 2003. *Land Cover Classification and* Equus Kiang *Habitat Mapping in Surkhang, Nepal* [MSc thesis]. Wageningen, The Netherlands: Wageningen University and Research Center.

TRN [The Rising Nepal]. 2002. More studies a must: Editorial. http://www.nepalnews.com.np/contents/englishdaily/trn/2002/oct/oct02/editorial.htm#2; accessed on 10 November 2002.

UNDP [United Nations Development Programme] Communications Office. 2000. Preserving biodiversity and culture in Upper Mustang, Nepal. *Newsfront,* Tuesday, 19 September 2000. http://www.undp.org/dpa/frontpagearchive/september00/19sept00/; accessed on 22 October 2001.

Walker EP, Nowak RM. 1999. *Walker's Mammals of the World.* 6th edition. Baltimore, MD: Johns Hopkins University Press.

Wang H. 2002. Equus kiang. *Animal Diversity Web.* http://animaldiversity.ummz.umich.edu/site/accounts/information/Equus_kiang.html; accessed on 1 March 2004.

Wilson DE, Reeder DM, editors. 1993. *Mammal Species of the World.* Washington, DC: Smithsonian Institution Press.