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COMMUNICATION

HABITAT SUITABILITY AND THREAT ANALYSIS OF GREATER ONE-HORNED RHINOCEROS *RHINOCEROS UNICORNIS* LINNAEUS, 1758 (MAMMALIA: PERISSODACTYLA: RHINOCEROTIDAE) IN RAUTAHAT DISTRICT, NEPAL

Saru Rimal, Hari Adhikari & Shankar Tripathi

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COMMUNICATION

Habitat suitability and threat analysis of Greater One-horned Rhinoceros *Rhinoceros unicornis* Linnaeus, 1758 (Mammalia: Perissodactyla: Rhinocerotidae) in Rautahat District, Nepal

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Abstract: The Greater One-horned Rhinoceros *Rhinoceros unicornis* has been listed as a Vulnerable species on IUCN Red List, Appendix I of CITES, and a protected animal under the National Parks and Wildlife Conservation Act 2029 B.S., 1973. In Nepal, it was found only in Chitwan, Bardia, Shuklaphanta and Parsa national parks, but it has recently been also reported from the forests of Rautahat. The main objectives of the study were to assess habitat suitability and threats for rhinoceros in Rautahat at an elevation range of approximately 300–1,000 m. Remote sensing data and geospatial modeling techniques were used to assess habitat suitability of rhinoceros. Vegetation assessment was carried out for tree, shrubs, and herbs of plot size 10m × 10m, 5m × 5m, 1m × 1m respectively for habitat suitability. Threat analysis was carried out using purposive sampling among local people and their perceptions were collected on the movement of rhinoceros and threats. The integration of nine explanatory variables showed that about 0.06%, 29.18%, 20.45%, and 50.31% of the study area was found to be most suitable, suitable, moderately suitable and unsuitable habitat respectively for rhinoceros. Out of 30 respondents, 37%, 23%, 20%, and 20% identified the main threat to rhinoceros to be unmanaged habitat, poaching, human-wildlife conflict and environmental factors, respectively. This study recommends parts of the Rautahat District to be extended as the habitat of rhinoceros and starting of immediate conservation initiatives in the area.

Keywords: Habitat suitability, Rhinoceros, threat analysis, vegetation analysis.

Nepali Abstract

एक सिंगे गैंडा IUCN को रातो सुचिमा र CITES को Appendix I मा परेको जिव हो । नेपालमा एक सिंगे गैंडा चितवन, बर्दिया, शुक्लाफाँटा र पर्सा राष्ट्रिय निकुञ्जमा मात्र प तर हालसालै एक सिंगे गैंडा रौतहट जिल्लाको जंगलमा देखियो । यस्तो अवस्थामा रौतहटमा गैंडाको वासस्थानको अवस्था र खतराहरुको बारेमा अनुसन्धान गर्नुपर्ने आवश्यकता छ अध्ययनको उद्देश्यहरु १. वासस्थान उपयुक्तता पता लगाउनु २. रौतहटमा गैंडालाई हुनसक्ने खतराको विश्लेषण गर्ने थियो । अध्ययन क्षेत्र रौतहट जिल्ला नेपालको दक्षिण भागमा प यसको उचाई लगभग ३०० देखि १००० मि. छ । यसका लागि Remote Sensing र Geospatial Modeling प्रविधिको प्रयोग गरेर वासस्थानको अनुकुलता पत्ता लगा थियो । उपयुक्त वासस्थानको खोजिको क्रममा प.रा.नि. को गैंडाको निरन्तर आवागमन रौतहटमा भएको पाईन्छ । वनस्पतिको मुल्याङ्कनका लागि रुखका लागि १० मि. × १० बुट्यानका लागि ५ मि. × ५ मि. र झारका लागि १ मि. × १ मि. को प्लटमा अध्ययन गरियो । गैंडालाई हुने खतराबारे जनसमुदायमा Purposive Sampling को माध्य बुझियो र गैंडाको हलचल र हलचल हुँदा आउने खतराबारे जनसमुदायको मानसिकता कस्तो छ बुझियो । ९ वटा variables को समिश्रणबाट गैंडाको लागि अध्ययन क्षेत्रको ०. सबैभन्दा उपयुक्त , २९.१८% उपयुक्त, २०.४५% मध्यम उपयुक्त, र ५०.३१% क्षेत्र अनुपयुक्त छ । गैंडाले हाल प्रयोग गरेको वासस्थान संरक्षित क्षेत्रबाट बाहिर पर्छ जहाँ, गैंड बेरै खतरा छ जस्तै, शिकारको खतरा (३७%), द्वन्द (२३%), अव्यवस्थित वासस्थान (२०%) र वातावरणिय तत्वहरु (२०%) । यस अध्ययनले यो बताउछ कि रौतहट जिल्लाको केहि ठ गैंडाको वासस्थानको लागि बढाउन सकिन्छ र तुरुन्तै संरक्षणका लागि पहल गर्न आवश्यकता छ ।

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For **Author Details** & **Author Contribution** see end of this article.

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INTRODUCTION

Of the five remaining extant species of rhinoceros, three live in Asia: the Greater One-horned Rhinoceros *Rhinoceros unicornis*, Sumatran Rhinoceros *Dicerorhinus sumatrensis* and Javan Rhinoceros *Rhinoceros sondaicus,* and two are found in Africa: the White Rhinoceros *Ceratotherium simum* and Black Rhinoceros *Diceros bicornis* (Thapa 2016). In Nepal, the Greater One-horned Rhinoceros is found in Chitwan National Park (CNP), Bardia National Park (BNP), Shuklaphanta National Park (ShNP) and Parsa National Park (PNP), and it has recently been reported in the forests of Rautahat District. The Greater One-horned Rhinoceros (Indian Rhino), hereafter "rhinoceros", has been listed as a Vulnerable species on IUCN Red List of Threatened Species (Talukdar et al. 2008) and is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Rhinoceros is listed as the protected animal under National Parks and Wildlife Conservation Act 2029 B.S., 1973 by the Government of Nepal.

Rhinoceroses are mostly solitary with the exception of mothers and calves and breeding pairs, although they sometimes gather at bathing areas. They are active mostly at night, early in the morning and in the late afternoon (Laurie 1978). In the middle of hot days they are commonly seen resting in the shade, or mud, wallowing and bathing in lakes, rivers, and pools. A recently published report by WWF Nepal showed that habitat loss and poaching are emerging as major threats to rhino conservation (Rookmaaker et al. 2016). Poachers kill rhinoceros for their horns, which are highly valued and used in Chinese traditional medicine to reduce fever and fear, and as an aphrodisiac (Crawford 1994).

Rautahat District is connected on the west to Bara District, which includes PNP. In the past few years Rhinoceros have frequently visited the area from PNP searching for suitable habitats, and the previous trends showed migration of rhinoceros from CNP towards the east via PNP to Rautahat. CNP is contiguous to PNP in the east and PNP, in turn, has some forest connectivity to Rautahat forests on the eastern side. Rautahat District is unique being outside the protected area and highly populated with diverse ethnic communities. Of the three rhinoceroses found in Rautahat, one was killed recently by poachers (Acharya & Ram 2017). Thus, it became necessary to find out the habitat suitability and threats to the rhinoceros in the study area for proper management.

Habitat suitability modeling for wildlife is currently gaining interest in wildlife conservation and management. To define habitat suitability, multivariate models are applied in combination with remote sensing (RS) and geographic information system (GIS). Remote sensing is an invaluable source of information and GIS is an excellent tool for creating land cover and habitat factor maps required for habitat modeling. Remote sensing has been used to produce land cover maps since the 1970s (Bradley & Fleishman 2008; Adhikari & Schneider 2012; Tripathi et al. 2012).

This study used remote sensing data and GIS technology with field study for analysis of habitat condition to predict suitable habitat for rhinoceros in Rautahat. Habitat suitability models have become well-accepted tools to understand the habitat attributes of different organisms, evaluating habitat qualities and developing wildlife management and conservation strategies (Verner et al. 1986; Kafley 2008). Habitat models are based on the relationship between animal and environment (Kushwaha et al. 2005). The habitat suitability index (HSI) modeling assumes that the amount of habitat is related to the potential of the land to support individuals or populations of wildlife and that habitat designated as high quality are more suitable than those assigned lower quality ranking. HSI models are analytical tools for determining relative potential of an area to provide habitat for wildlife (Clevenger et al. 2002).

The main objectives of this study were (1) to assess habitat suitability, and (2) to do a threat analysis for rhinoceros in the study area using geospatial datasets on topography, climate, land use and statistical modeling at the landscape scale in Rautahat District.

MATERIAL AND METHODS

Study area

The study area is situated in Chandrapur Municipality, Gujara Rural Municipality and Phatuwa Bijayapur Rural Municipality of Rautahat District in the central part of Nepal (Fig. 1). It is located between85.23–85.50 ^{0}E and 26.73–27.23 ^{0}N. Lower tropical zone lies below 300m and covers 64.4% of the total area of Rautahat and upper tropical zone covers 5.6% of area and elevation ranges from 300–1,000 m (District Report 2011). It covers an area of 112,600ha. Forest covered by Rautahat District is 29,400ha or 26.11% of the forest area including the central 'Charkoshe Jhadi' of Nepal. Charkoshe Jhadi is the broad strip of forests south of the Siwaliks from east

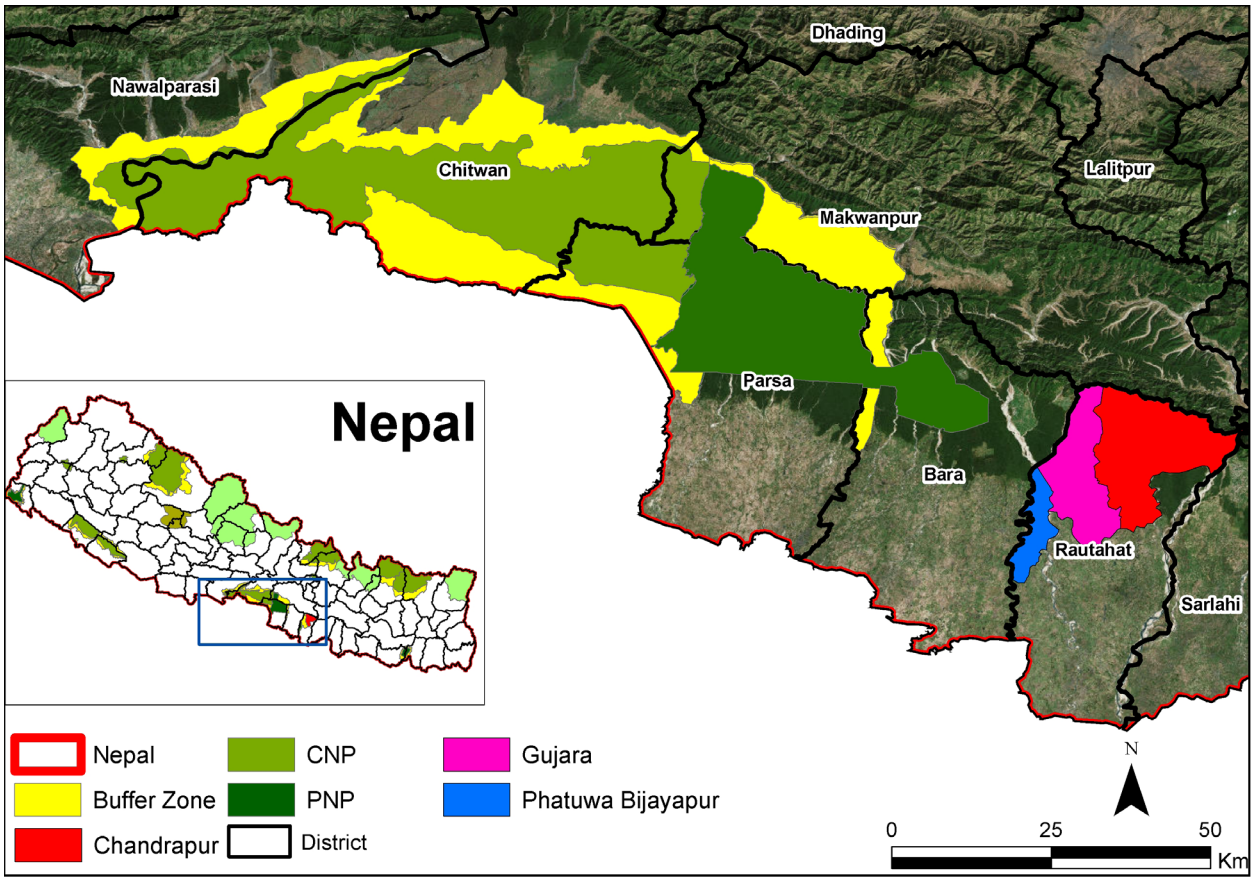

Figure 1. Location of study area

to west along almost the entire length of Nepal. Much of this wildlife-rich habitat has now been lost except those areas that lie in a protected area network. Sal forest *Shorea robusta* is the primary forest type along with mixed hardwood and riverine forests. The climate of Rautahat is tropical to sub-tropical, temperature ranging from 19.6–40 ^{0}C and average rainfall is 2,968mm per year (Annual Report, District Forest Office, DFO 2016, Rautahat). Rautahat District is the easternmost district identified under Terai Arc Landscape (TAL) programme (MoFSC 2015).

Bara District includes a part of PNP and lies west of Rautahat District. This district is dominated by 35% *Shorea robusta* forest. The major tree species are *Shorea robusta, Terminalia tomentosa, Acacia catechu, Adina cordifolia, Dalbergia sissoo,* with other riverine tree species. The major shrub and grass species in the study area are *Hemalthriya compresa*, *Imperata cylindrica*, *Saccharum spontaneum*, and invasive alien weeds *Mikania micrantha*, *Chromolaena odorata*. This district is an important habitat for a large number of animals including Tiger *Panthera tigris*, One-horned Rhinoceros, Elephant *Elephus maximus*, Sloth Bear *Melursus ursinus*, Nilgai *Boselaphus tragocamelus*, Sambar Deer *Rusa unicolor*, Spotted Deer *Axis axis*, Wild Boar *Sus scrofa*, and a number of birds, including White-rumped Vulture *Gyps bengalensis*, Eurasian Black Vulture *Aegypius monachus*, Himalayan Griffon Vulture *Gyps himalayensis,* Indian Pitta *Pitta brachyura*, and Great Hornbill *Buceros bicornis*; though it is outside the protected area (Annual Report 2016, District Forest Office Rautahat).

Explanatory variables for modeling habitat suitability assessment

A range of explanatory variables was derived from geospatial datasets. Table 1 presents the complete list of variables. All topographic, climatic, and land use data available for the study area were resampled to 30m resolution and UTM 45N, WGS 84 projection system (Fig. 2). The habitat used by rhinoceros and the variables related to this habitat were established based on the existing information available for the species. In total, nine explanatory variables (aspect, slope, forest cover, precipitation, temperature, road, water, settlement, and

Table 1. Habitat suitability variables and analysis

Data Type	Weighted Influence	Format (Source)	Suitability criteria
Aspect (30m × 30m)	5	Raster (Jaxa DEM) 1*	Most suitable: Flat and South Suitable: East Less Suitable: North Unsuitable: West
Slope (30m × 30m)	10	Raster (Jaxa DEM) 1*	Most suitable: 5 Suitable: 10 Less Suitable: 15 Unsuitable: >15
Forest Cover (30m × 30m)	20	Raster (Globcover) 2*	Most suitable: 0–20 Suitable: 40–70 Less Suitable: 20–40 Unsuitable: > 70–90
Precipitation (1km × 1km)	5	Raster (Worldclim) 3*	Most suitable: 290–315 Suitable: 265–290 Less Suitable: 240–265 Unsuitable: 211–240
Temperature (1km × 1km)	5	Raster (Worldclim) 3*	Most suitable: 28.5–29.8 Suitable: 27–28.5 Less Suitable: 26–27 Unsuitable: 24.9–26
Road	5	Vector (Department of Survey) 4*	Most suitable: > 500m Suitable: 300–500 m Less Suitable: 200–300 m Unsuitable: < 200m
Water	20	Vector (Department of Survey) 4*	Most suitable: within 1km Suitable: 1–1.5 km Less Suitable: 1.5–2 km Unsuitable: > 2km
Settlement	10	Vector (Department of Survey) 4*	Most suitable: > 1km Suitable: 0.5–1 km Less Suitable: 0.3–0.5 km Unsuitable: < 0.3km
Land Cover	20	Vector (Department of Survey) 4*	Most suitable: river and grassland Suitable: Forest Unsuitable: Cultivation

1* http://global.jaxa.jp/press/2015/05/20150518_daichi.html
2* https://landcover.usgs.gov/glc/TreeCoverDescriptionAndDownloads.php
3* http://www.worldclim.org/tiles.php?Zone=28
4* Department of Survey, Min Bhawan, Kathmandu, Nepal

land cover) related to habitat requirements of rhinoceros were used (Table 1).

Remote sensing satellite data were used as a source of information, and spatial analysis of the data was performed in Arc GIS Desktop 10.2.2 to process the data. Weightages that influence the habitat of rhinoceros by these different variables were decided after expert consultation from PNP (Table 1).

A four level suitability was depicted on the map with reference to habitat used by rhinoceros. Areas away from human settlements and close to water bodies were categorized as highly suitable while areas near roads and human settlements but away from water bodies were considered as unsuitable for rhinoceros (Thapa & Lichtenenegger 2005).

Suitable habitat categories included the areas currently being used by rhinoceros and the areas that could be potentially used. Overlay process was carried out to produce suitable area map (Fig. 4 (a)). Nine

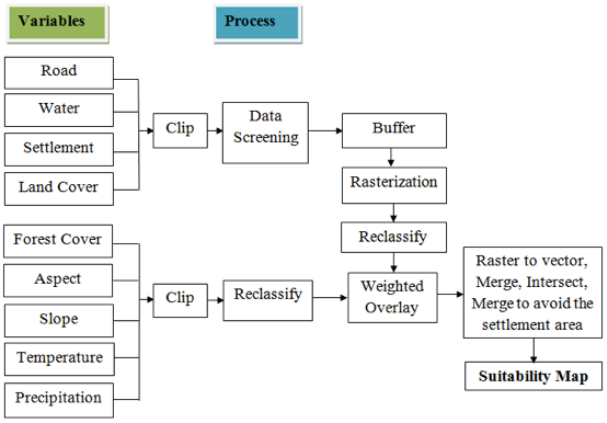

Figure 2. Process of preparing suitability map

suitability maps were prepared based on the explanatory variables (Fig. 4 (b–j)) used in this study.

Field measurement

The field measurements from a total of 26 plots (10m × 10m) were conducted between May–June 2017 and used in this study for habitat assessment (Fig. 3). According to key informant survey, possibility of rhinoceros sightings can be high in this time-period. Sample plot centers were taken in the morning and positioned using Garmin Global Positioning System (GPS) with an accuracy of 2–5 m.

Various quadrats of 10m × 10m were randomly assigned to tree species. Within a quadrat, 5m × 5m quadrats were allocated randomly in the corner for shrub species. Likewise, herbs were recorded from nested sampling of 1m × 1m quadrat within the 5m × 5m quadrat. The distribution of nested sampling within main quadrat (Mandal & Joshi 2014) is shown in Fig. 3.

All plant species within each quadrat were identified and counted. For the entire tree stems, diameters at breast height (DBH) at 1.3m were measured using diameter tape, and height of each stem was measured by a clinometer. A local parataxonomist and field guide identified the tree species. Leaves of unidentified tree species were brought to the faculty of forestry at the Agriculture and Forestry University (AFU) for identification.

Threat analysis

Field visits were undertaken to major places where rhinoceros encounters had been reported, and relevant staff of PNP and district forest office were interviewed. A questionnaire survey was conducted among 30 respondents in the study area, including protected area managers, experts and community representatives; their

Density of species = (Total Number of individuals of a species) / (Total number of plots sampled × area of a plot) 1

Relative density of species (RD) = (Total individuals of species) / (Total individual of all species) 2

Frequency of species = Number of plots in which a particular species occurs / Total number of plot sampled × 100 3

Relative frequency of species (RF) = Frequency value of a species / Frequency value of a species × 100 4

Relative dominance of species = Total basal area of a species / Total basal area of all species x 100 5

Basal area = $\pi d^2 / 4$ 6

IVI = Relative density + Relative frequency + Relative dominance 7

PVX = MX (√FX) 8

where PVX = prominence value of species X; MX = mean percentage cover of species X; FX = Frequency of occurrence of species X

knowledge about rhinoceros and its habitat, threats to rhinoceros in the study area and possible conservation measures were documented.

The vegetation data collected in the field were used to calculate the importance value index (IVI), density, frequency, and relative frequency of the tree species by using the following procedure (Smith 1980).

To calculate the prominence value (PV), the percentage cover of each species is assumed in each quadrat recorded in classes as follows: for high coverage = >50%, medium = 26–50 %, low = 0–25 %. These data were used to calculate prominence value for each species (Jnawali 1995) and it is used to calculate the availability of plants in the study area.

RESULTS

Habitat Suitability Mapping

Suitability map based on RS and GIS application showed that only about 0.06% (28.8ha) of the area was found to be most suitable, approximately 29.18% (13198.23ha) of the area was found to be suitable, 20.45% (9248.58ha) was moderately suitable and about 50.31% (22759.65ha) was unsuitable habitat for rhinoceros in the study area (Fig. 4 (a)).

Vegetation Analysis

Of the total species of trees recorded in the study area, *Shorea robusta* (IVI=56.35) was found to be the most dominant species followed by *Adina cordifolia* (IVI=19.17), *Mallotus philipenensis* (IVI=15.43), and *Trewia nudiflora* (IVI=15.33). Among shrub species, *Leea macrophylla* was the most abundant species (PV=350.49) followed by *Chromoleana odorata* (PV=266.84) and *Clerodendron viscosum* (PV=258.75), and among herb/grass species *Imperata cylindrica* was the most abundant species (PV=285.33) followed by *Cynodon doctylon* (PV=158.85) and *Saccharum spontaneum* (PV=98.51).

Threat Analysis

Almost all the respondents were well informed

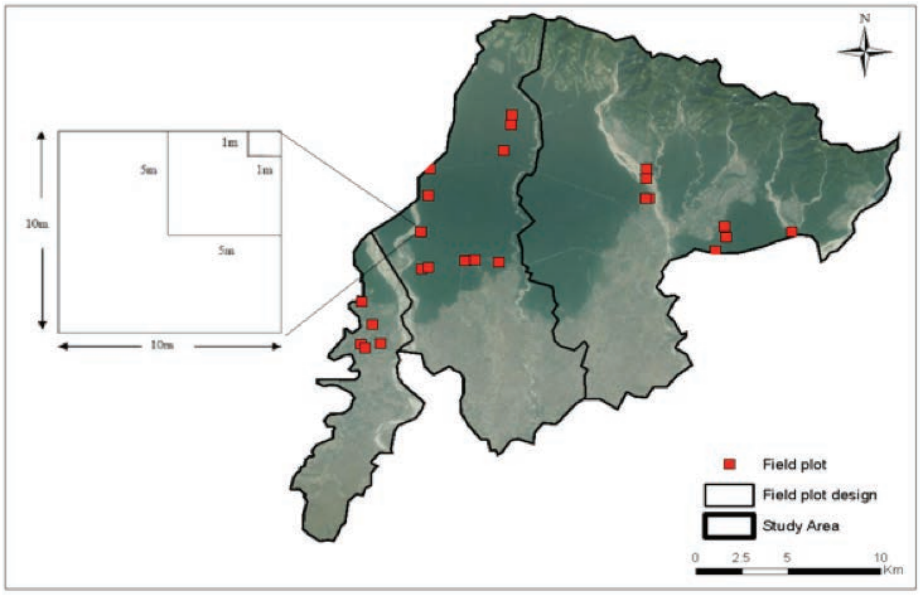

Figure 3. Map showing sample plot locations and layout of the quadrats

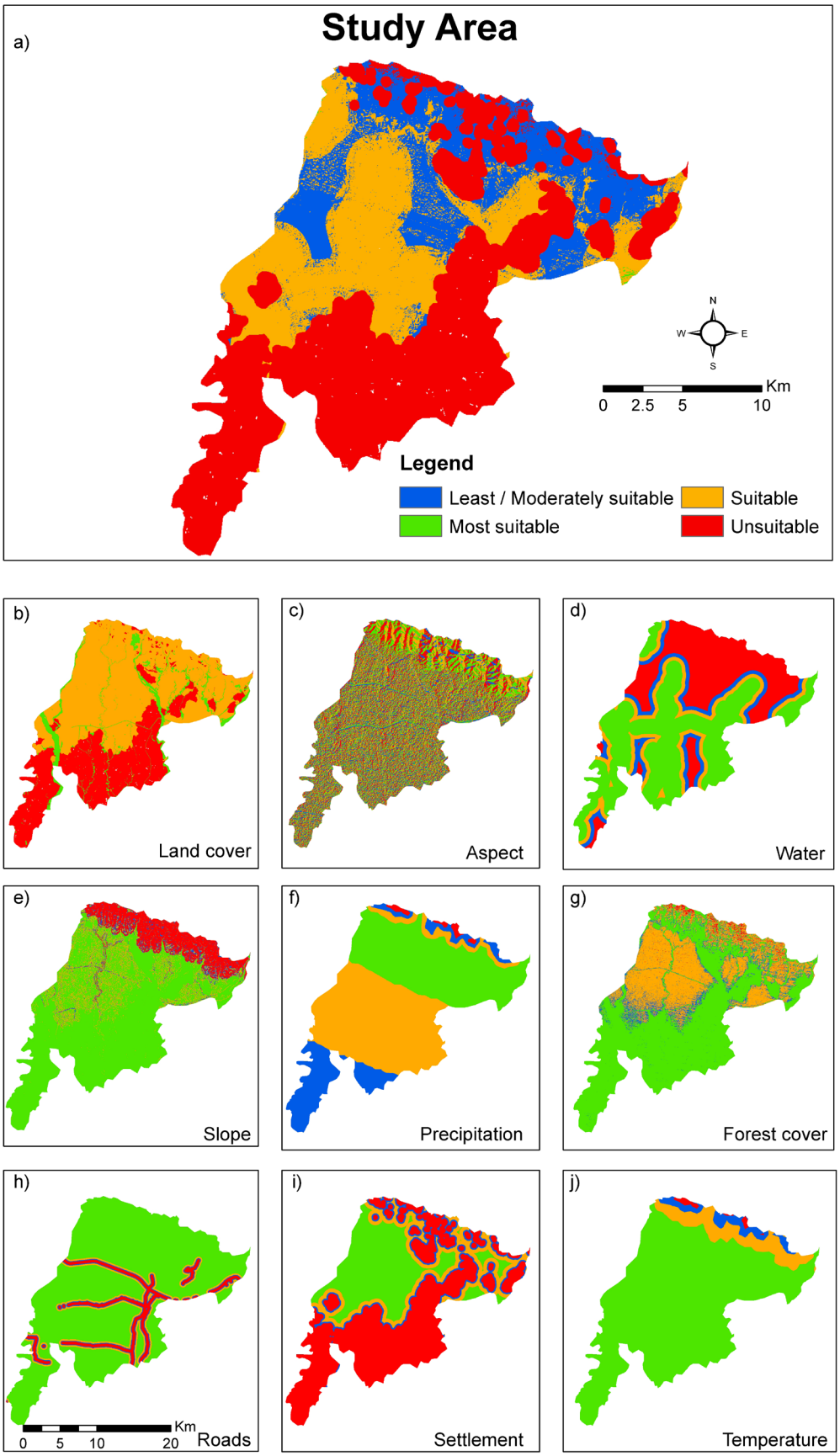

Figure 4. Habitat suitability map of the study area (a) and suitability map of different predictor variables (b–j).

about rhinoceros. About 10%, 87% and 3% of the respondents directly saw, heard and saw indirect signs of rhinoceros presence respectively. Particularly, activities of rhinoceros were found in March to June and October to November. Most of the respondents revealed that unsuitable habitat in PNP was the major cause of rhinoceros dispersal, followed by suitable habitat in Rautahat and encroachment in PNP. A small percentage (10%) of the respondents had no idea about rhinoceros in the study area (Fig. 5a); 43% of respondents answered that rhinos and their habitat were needed for biodiversity conservation; 30% for ecotourism; and 27% for future generations (Fig. 5b).

Among the 30 respondents of the questionnaire survey, about 37% answered that the main threat to rhinoceros and its habitat conservation was poaching, 23% of respondents said conflict, 20% answered that unmanaged habitat was also a threat to rhinoceros, so their conservation may become difficult. Twenty percent of the respondents considered environmental factors as one of the threats to rhinoceros (Fig. 5c). As many as 50% of the respondents answered that awareness program can be the main program for rhinoceros conservation, 32% of respondents gave their view that research programs can help to protect rhinoceros habitat, and 18% of the respondents said that regular patrolling can be helpful in rhinoceros conservation (Fig. 5d).

DISCUSSION

Habitat suitability mapping

Rhinoceroses inhabit the alluvial floodplains with sub-tropical vegetation where water and green growth is found all year round (Prater 1971; Kafley 2008). The results of this study reveal that the rhinoceroses in Rautahat are also found in floodplain grasslands and riverine forest located near perennial water bodies that provide food, cover and wallows throughout the year. A study carried out in Bardiya has shown that rhinoceroses prefer three types of habitat including khair sissoo forest, riverine forest, and tall grassland, and they avoid Sal forest (Jnawali 1995).

Vegetation Analysis

Our study has found out that *Saccharum spontaneum* is the most important grass species for rhinoceros, which is also reported in earlier studies by Laurie (1982), Jnawali (1995) and Pradhan et al. (2007). Kafley (2008) identified the suitable condition for rhinoceros as the areas with the availability of contiguous grasslands interspersed with sufficient water bodies and sufficient distance from factors of disturbances. Similarly, this study has shown that rhinoceros prefers habitat with mixed forest type with grassland and nearness to water availability. Kafley (2008) documented that 443km^2 of the CNP is modeled as suitable. The result of this study revealed that 131.98km^2 of the study area is modeled as suitable habitat, which provides additional shelter to rhinoceros outside the protected areas.

No earlier studies of rhinoceros using GIS and other advanced applications were performed in the study area. Rhinoceros have been using the study area as major habitat for a long time, and this year also there was continuity in their regular visits (Acharya & Ram 2017). So, this study can be the basis for further studies and management of rhinoceros in Rautahat.

People's perceptions

Three to four rhinoceroses are found year-round in Rautahat District. During September 2016, one rhinoceros was shot by poachers. Rhinoceros have been using the Rautahat district as a major habitat for the past few years and continue to make regular visits (Acharya & Ram 2017). Respondents living in the study area reported frequent arrival of rhinoceros in their village and nearby forests. They have a positive attitude towards rhino conservation because of the importance of the species in ecotourism, and biodiversity conservation for future generations. Presently, cases of conflict between humans and rhinoceros are few, but they may increase in the future if concerned authorities are unable to apply proper conservation measures.

Conclusions and Recommendations

Factors affecting the population and habitat status of rhinoceros include poaching, conflict and environmental factors that include roads, rivers, settlements, forest cover, land cover, precipitation, temperature and terrain. The slope is the most important predictor of habitat suitability of terrestrial species, and rhinoceros locations were observed on gentle slopes with suitable vegetation cover and water availability. According to local people, the main causes of movement of rhinoceros were unsuitable habitat in PNP, suitable habitat in Rautahat, and encroachment in PNP. Unsuitable habitat in PNP is the result of weeds and dense forest cover due to forest protection. They want to conserve rhinoceros for ecotourism, biodiversity conservation and for future generations. The habitat used by rhinoceros in the study area is outside the protected area and poses threats like poaching, conflict with local people and unmanaged

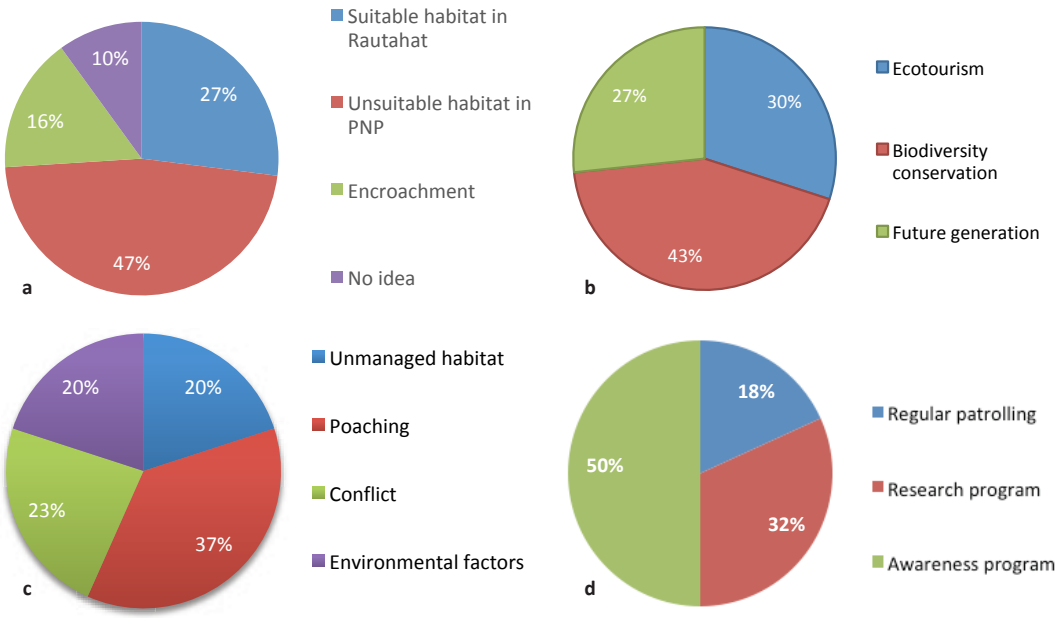

Figure 5. a - Causes of Rhinoceros dispersal; b - Importance of Rhinoceros; c - Threats to Rhinoceros; d - Programs for Rhinoceros conservation

habitats. Threats to rhinoceros in the Rautahat District need to be identified and suitably attended. If the government and conservation partners do not pay attention to this migration of rhinoceros from PNP to a new area like Rautahat and other suitable places, rhinoceros may decline in PNP. So, it is vital to conserve rhinoceros and its habitat. Hence, conservation efforts to create better permanent habitat should be provided to maintain remaining rhinoceros population.

Based on the present study, national level policy and conservation programs should be prepared for the conservation and management of rhinoceros in the study area. Since the study area is located outside the protected area, regular monitoring is required and strict laws need to be enforced for the conservation of rhinoceros. PNP and its buffer zone up to Bagmati River need to be extended for better protection of rhinoceros. This research is limited, as only two rhinoceros were present in the study area. The available time for the study was also short. We recommend further study to identify reasons for rhinoceros movement from PNP to the study area.

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Author Contribution: SR planned and conducted this research, HA and ST supervised this research. Hari, Saru and Shankar together worked on manuscript. HA and SR collected RS and GIS data. SR and ST collected field data.

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