

Research Article

Land use change pattern of the greater one-horned rhinoceros (*Rhinoceros unicornis*) in Chitwan national park of Nepal

Prayag Raj Kuikel*, Khadga Basnet

Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu, Nepal

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ABSTRACT

Land use change pattern shrinking habitats of greater one-horned rhinoceros (*Rhinoceros unicornis*) in lowland of Nepal. It has been attributed to many factors including habitat conversion, fragmentation, infestation of weeds and climate change. We examined the land use change and habitats utilization by *R.unicornis* overtime in the Chitwan National Park and surrounding area of Central Nepal through field observations combined with geographical information system (GIS) data and satellite images. We used landsat Imageries of 1993, 2000, 2010, and 2014 to examine land use change in the Chitwan Valley. These findings were verified through field observation. Sighting locations of *R. unicornis* in different land were carried in field observation and from literature review. We found that land use has significantly ($\chi^2=271.87$, $\alpha=0.05$) changed over time and influenced habitat utilization of *R. unicornis* in the Chitwan Valley. We also analyzed effect of land use change on habitat of rhinoceros and shifting of rhinoceros from the east area to west area with changing preferred habitat as grassland and riverbeds over time. Interestingly, we found that preferred habitat of *R.unicornis* significantly ($\chi^2=410.2$, $\alpha=0.05$) different in the Chitwan Valley and, preferably habitat is sparse forest/grasslands and riverbeds. Infestation of *Mikania micrantha* decouple with climate change are also responsible factors for changing land use pattern of the eastern and central lowland of Nepal. Our findings provide information useful for implementing effective strategies for long-term conservation of wildlife in the Nepal and beyond.

Key words: Chitwan National Park, land use pattern, *Rhinoceros unicornis*, riverbeds, sparse forest

INTRODUCTION

The demand for land to fulfill requirement of the burgeoning human population in South Asia poses the loss and fragmentation of wildlife habitats, which may lead to the extinction of wildlife species in (Dinerstein, 2003). In the civilized World; agrarian, transportation, communication tools are responsible for the loss and fragmentation of habitats of the wild animals (Huston, 2005; Kafley, Khadka, & Sharma, 2009). Furthermore, the induced human intervention like indiscriminate fire, cattle grazing, thatch collection further enhances the degradation of the habitat may change suitable habitat to unsuitable for specific species (Dinerstein, 2003).

Chitwan National Park (CNP) contains some original features of landscapes with suitable habitats for large mammals such as greater one-horned rhinoceros (*Rhinoceros unicornis*), Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*) and Royal Bengal tiger (*Panthera tigris*). However, the increasing human pressure in the habitat of CNP and its Buffer Zone may lead to a change in species number and composition (Dinerstein, 2003; Talukdar, 2013; Thapa, Acevedo, & Limbu, 2014).

Internationally, around 17212-18915 white rhinoceros (*Ceratotherium simum*), 5366-5630 black rhinoceros (*Diceros bicornis*), > 3700 greater one-horned rhinoceros (hence forth rhinoceros), < 80 Sumatran rhinoceros (*Dicerorhinus sumatransis*) and 75 javan rhinoceros (*Rhinoceros sondaicus*) were estimated in the nature (International Rhino Foundation, 2021; Pant, Maraseni, Apan, & Allen, 2020). White rhinoceros are surviving in semi-arid drainage

grassland of the southern Africa. Black rhinoceros are critically surviving in small subpopulation in different reserve of Africa. They have been using dry woodland savannah. Among Asian rhinoceros, greater one-horned rhinoceros are down listed from endangerment to vulnerable species whenever population rapidly recovered in the Kaziranga National Park of the India. They has been inhabiting moist riverine grassland and alluvial floodplain of Ganges, Brahmaputra, Sindh rivers and their tributaries (Dinerstein, 2003; Talukdar *et al.*, 2008). Sumatran rhinoceros and javan rhinoceros are the rarest large mammal in the World. They utilized rain forests and lowland forests respectively (Emslie *et al.*, 2016; Patton, Campbell, & Parfet, 2007; Talukdar, 2013).

Out of 752 rhinoceros of Nepal, 694 were distributed in riverine grassland of Reu, Rapti and Narayani rivers of CNP. 38 were inhabited in mixed riverine forests and floodplain tall grasslands of Karnali and Babi rivers of Bardia National Park (BNP) and remaining 17 were recorded in mixed riverine forests and tall grasslands of Chaudhar and Mahakali rivers of Suklaphanta National Park (SPNP) (DNPWC, 2015, 2021; IUCN, 2020; Naresh Subedi *et al.*, 2013). Rhinoceros have preferred rivers area, riverbeds, sparse forests for wallowing, grazing and browsing respectively. They refused in dense forests safe from flooding in monsoon and rarely visited cultivable land for agricultural products in winter. The most preferred land of rhinoceros was grassland dominated by *Saccharum spontaneum* (Dinerstein, 2003; N Subedi, 2012; Thapa *et al.*, 2014).

Previous documents noticed that abundance and distribution of rhinoceros has been changed over

*Corresponding Author's E-mail: kuikelpr@gmail.com

time in CNP. Population of rhinoceros has increased in the western area of CNP (DNPWC, 2015; Pant, Maraseni, Apan, & Allen, 2021; Naresh Subedi *et al.*, 2013). It has paid little attention from ecologists to elucidate such type of habitat shifting of rhinoceros in CNP. Therefore, we work to examine land use change and preferred habitat of rhinoceros together with effect of land use change pattern in habitats of rhinoceros in CNP.

MATERIALS AND METHODS

Study Area

The study area, CNP and surrounding area, is situated in the south-central Nepal covering 1800 sq. km in the subtropical lowlands of inner Terai. The area was gazetted as the country's first national park in 1973, recognizing its unique ecosystems of international significance. UNESCO declared CNP a World Heritage Site in 1984. It consists of a diversity of ecosystems-including Churia hills, Ox-bow lakes, and the flood plains of Reu, Rapti and Narayani rivers. Churia hills rise slowly towards the east from 150 m to more than 815 m. The western portion of the park is comprised of lower but more rugged Someshwor hill. The park shares its eastern boundary with the Parsa National Park (PNP) (Figure 1).

The average temperature from October to February is 25°C, which offers an enjoyable climate. From March to June, temperature can reach as high as 43°C. The hot humid days are followed by monsoon season that typically runs from June until September.

It harbors healthy population of animal including endanger species such as Asian elephant, Bengal tiger, rhinoceros, gharial (*Gavialis gangeticus*), golden monitor lizard (*Varanus flavescens*). Vegetation consists of deciduous, mixed, and riverine forests punctuated by grassland communities (Lehmkuhl, 1994).

Land use change pattern of Rhinoceros

We examined land use change pattern, preferred habitat of rhinoceros and effect of land use change on habitat of rhinoceros through satellite image, geographical information system (GIS) and field observation. Satellite image data and GIS coupled with fieldwork have proven effective for collecting information about land use change pattern of rhinoceros. Computer Software Erdas Imagine 10.2.2 was used for image processing and analysis. For effective land cover map in the modeling process, we followed the land cover classes: river area, sparse forest, dense forest, riverbed, bushes, cultivable land and barren land. Landsat imageries of 1993, 2000, 2010 and 2014 with topographic maps (1:25000) were used for interpreting land use of CNP and surrounding area. We also explored land use change pattern of Padampur area (10 sq.km), an eastern part of CNP: recently gifted to nature by relocating villager to other area of Chitwan Valley. As per study objectives, remote sensing and GIS techniques were employed for spatial data generation, integration, update and analysis.

Fieldwork was carried out between December 2016 and September 2017. Field work was done to verify image interpretation through ground truthing and

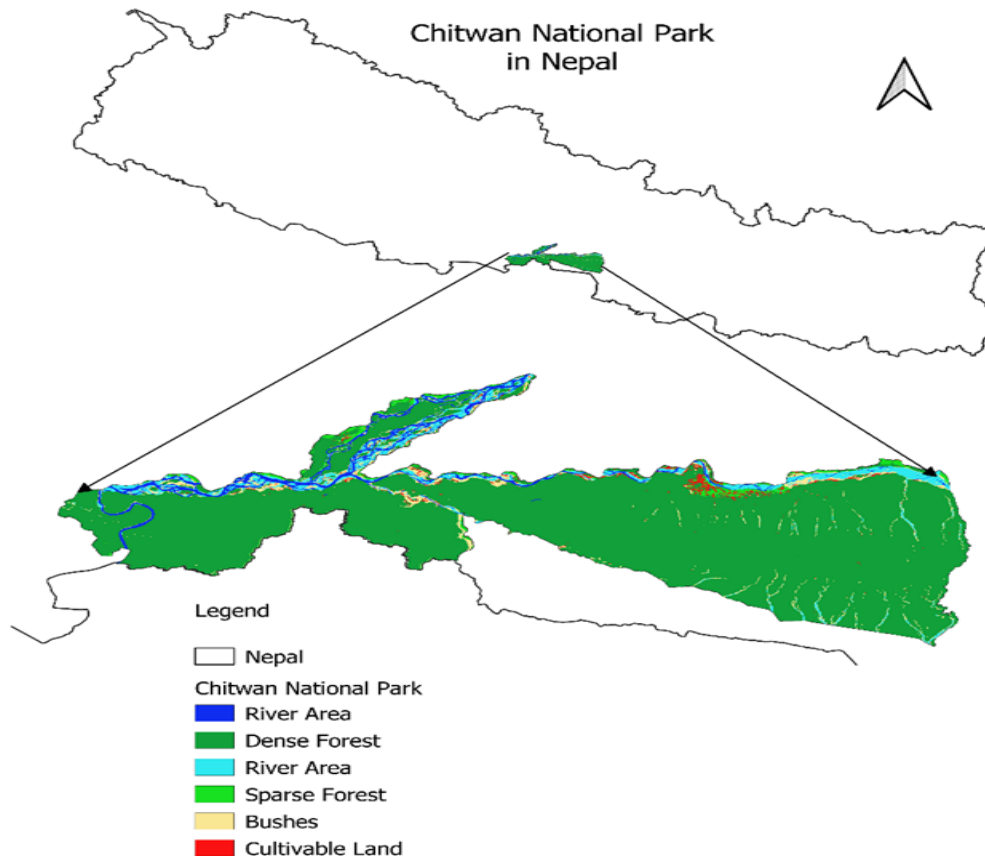


Figure 1. CNP of Nepal - Study Area

collected information about land use change detected from the time series image interpretation and sighting locations of rhinoceros on rhinoceros potential areas which were demarcated by 16 blocks in Chitwan (NTNC, 2012) through elephant riding (34 hours) and on foot (165 hours). We recorded sighting locations of rhinoceros directly in the east and west area of the park, and indirectly in the island of Narayani river by dung piles. Age and sex of rhinoceros were identified according to (Dinerstein, 2003; Laurie, 1978). Age of animal was classified as calf (1-4 years), sub adult (4-6 years) and adult (>6 years). Physical features more pronounced male animals. Sighting locations were digitized in map (1: 25000) using Arc GIS 10.4 (Environmental Systems Research Institute (ESRI), Redlands, California, USA) with the help of satellite land cover data. In the field, we used binoculars to observe and count rhinoceros from distance, 1:25000 topography maps for locating the areas of sightings in different habitats. We took Global positioning system (GPS) points of all rhinoceros sighted areas. We covered most of the potential rhinoceros' habitats by elephant riding, canoe riding in the Rapti river from the Icharni island to the Reu-Rapti junction, and walking on riverine grasslands of the intensive study area. We used GIS software ARC/INFO and remote sensing software ERDAS IMAGINE (Hexagon AB, Stockholm, Sweden) to analyze spatial distribution pattern of the rhinoceros

Most research reports indicate that the most preferred habitat of rhinoceros was riverine grassland floodplain of Reu, Rapti and Narayani rivers in Chitwan National Park (Dinerstein, 2003; Lahkar, Talukdar, & Sarma, 2011; Thapa *et al.*, 2014). Our studies have also been focused on such areas for investigation of land use change pattern and sighting locations of rhinoceros in these areas.

Effect of land use change on habitat of rhinoceros was determined by percentage of sighting location of rhinoceros in different habitats and land use change pattern of these habitats with reference to field observation, GIS and satellite data. Data were analyzed using Chi-Square test. Infestation of *Mikania micrantha* was assessed through circular plots in rhinoceros potential area demarcated by DNPWC (2012) included only Rapti's riverbeds, adjacent riverine forests and grassland of 1 km wide apart north to south. Study also examined condition of land cover, water bodies, drought, and flood

and retreat vegetation by literature review, field verification with GPS locations in CNP. Previous data about these parameters obtained from literature review (e.g. articles, reports, newspapers, dissertations, books).

RESULTS

Land use change pattern

We found that dense forest increased by 196 Sq. Km, grassland/ sparse forest decreased by 154 Sq. Km, cultivable land decreased by 56 Sq. Km and barren land increased by 56 Sq. Km over time in CNP (Table 1). River area and bushes almost remained constant over time in CNP. Dense forests are highly increasing in 2010 compared to 2000 and 2014 from 50% in 1993 to 64.6% in 2014. Sparse forests and cultivable land are continuously decreasing in 2000, 2010 and 2014. Sparse forests decreased from 18% in 1993 to 7.0% in 2014. Barren lands are drastically increasing from > 1 sq. km in 1993 to 56 sq. km in 2014. River beds only increased from 2000 to 2010 by 14 sq. km. Land use change pattern are significantly ($\chi^2=271.87$, $\alpha=0.05$) different in CNP and surrounding area over time. We also calculated land use change in Padampur (10 Sq. km, a part of eastern area of CNP) which is recently gifted to nature and found that dense forest decreased by 1.3 Sq. km, sparse forest/grassland increased by 2.0 Sq. Km, river bed decreased by 1.7 Sq. Km and cultivable land increased by 0.1 Sq. Km (Table 2). It is not significantly ($\chi^2 = 5.6248$, $\alpha=0.05$) different only in Padampur area.

Preferred habitat of Rhinoceros

We found that 300(49%) sighting locations in sparse forest/ grassland, 228 (38%) in riverine forest, 60 (10%) in riverbeds and river and 18 (3%) in dense forests (Figure 2). Grassland/ sparse forests decreased in the eastern and the western area of CNP and riverbeds increased in the western area over time. These habitats accounted high sighting locations of rhinoceros. Dense forests and barren land drastically increased in CNP and surrounding area but these habitats rarely used by rhinoceros at refuge from flood and during mating.

Effect of land use change on habitat of Rhinoceros

Our field study showed that preferred habitats as riverbeds, pure stands of *Saccharum spontaneum* and

Table 1. Land use change pattern in CNP over time

Land cover percentage	1993		2000		2010		2014	
	Sq. km	Change	Sq. km	Change	Sq. km	Change	Sq. km	Change
River area	28	2	28	0	28	0	28	0
Sparse forest	252	18	168	-84	112	-56	98	-14
Dense forest	700	50	728	+28	882	+154	896	+14
River bed	98	7	98	0	112	+14	112	0
Bushes	168	12	154	-14	112	-42	112	0
Cultivable land	140	10	140	0	98	-42	84	-14
Barren land		<1		<1	28	>+27	56	+28

Table 2. Landuse change pattern in Padampur over time

Land cover percentage (Sq. Km)	1993		2014	
	Sq. km	% Change	Sq. km	% Change
River area	0.2	2	0.3	+0.1
Sparse forest	0.3	3	2.3	+2.0
Dense forest	1.8	18	0.5	-1.3
River bed	2.1	21	0.4	-1.7
Bushes	3.6	36	3.9	+0.3
Cultivable land	2.0	20	2.5	+0.5
Barren land		<1		<1

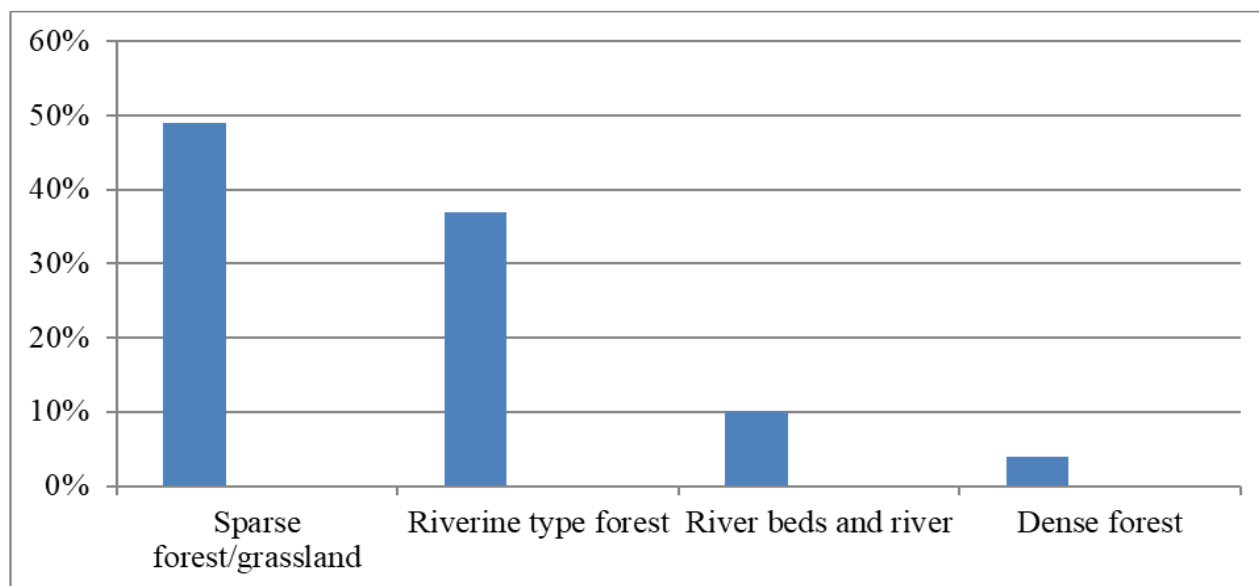


Figure 2. Sighting locations of rhinoceros in different habitat

proximity to water resource increased in the western area. Sighting locations of rhinoceros ultimately increased in the western area of CNP over time (Figure 3). The highest population of rhinoceros was in Sukibhar to Tiger Tops area. Effect of land use change on habitat of rhinoceros is significantly ($\chi^2=410.21, \alpha=0.05$) different in CNP. Infestation of *Mikania micrantha* was 23.3% in the eastern area and 18.3% in the western area. Study showed that infestation of *Mikania micrantha* was high orderly in the riverbeds, riverine forest and grassland. Study recorded 35 and 38 oxbow lakes in the eastern and western areas respectively. Effect of drought clearly saw in Patna Taal and Marchuli Taal of the eastern area. These areas became dry due to vegetative succession. Annual flood could not retreat vegetation, distribution of oxbow lakes and river's course change in the eastern area after establishment of 9 km dykes from Lothar to Kumrose. Study recorded 17 and 32 retreat area in the eastern and western area respectively. Pure stands of *Saccharum spontaneum* mostly found in retreat area of western area. These areas were preferred habitat of wild ungulates and became attractive area for rhinoceros.

DISCUSSION

Land use change

Preferred habitat of rhinoceros has been decreased day by day in CNP and this change would decline conservation practice of ungulates in lowland of Nepal in near future. Dense forests and barren land has been increased, which are mostly avoided by rhinoceros; sparse forests/grasslands and bushes has been decreased, which are highly utilized by rhinoceros; river beds and river area has been remained constant, which fulfill daily activities of rhinoceros. Sparse forests/ grassland has been decreased from 20% to 7% also indicated by previous studies over time in CNP (DNPWC, 2016; Lehmkuhl, 1994). It has decreased by 6% in Kaziranga National Park in India (Talukdar, 2013). Riverine grassland serves to the most preferred habitat of wild ungulates including rhinoceros (Dinerstein, 2003; Odden, 2005; DNPWC, 2012). Unfortunately, increasing population of rhinoceros has been recorded in CNP and Kaziranga (Talukdar 2013). Human disturbance and landscape modification are main reason for landuse change. In contract, establishment of dykes and spurs on river beds reduced early successional vegetative area,

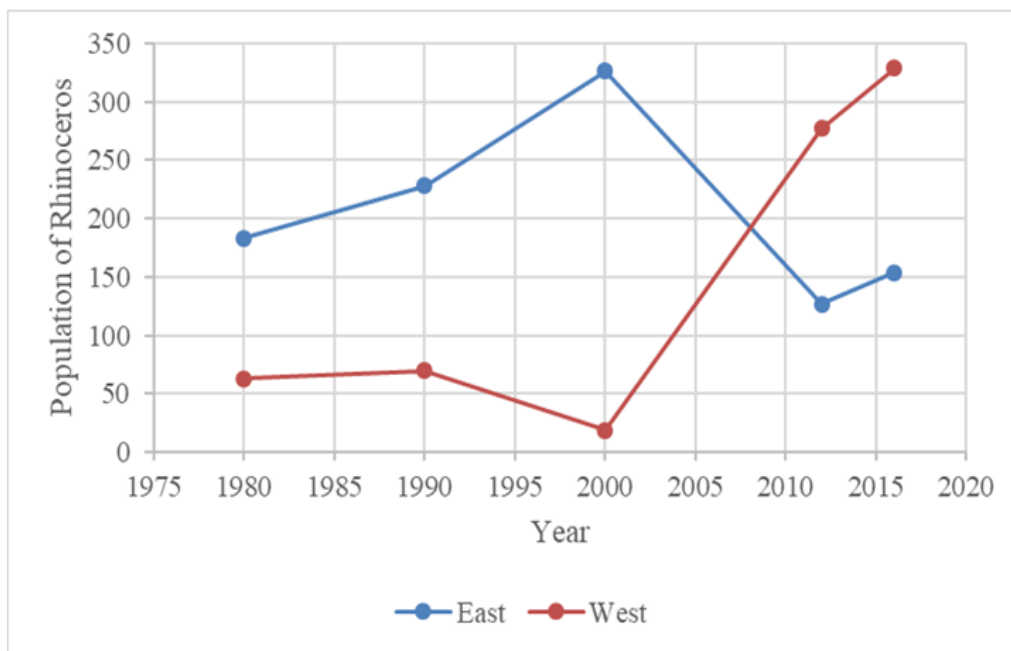


Figure 3. Population of rhinoceros over 20 years in East (Padampur, Sauraha area) and West (Sukhibar to Temple tiger area) of CNP

oxbow lakes in eastern area of CNP, and huge infestation of *Mikania micrantha* made worsen land area for wild ungulates including rhinoceros. Furthermore, over exploitation due to indiscriminate fire, over grazing and grass cutting induced habitat change of rhinoceros (Dinerstein, 2003; N Subedi, 2012; Naresh Subedi, Lamichhane, Amin, Jnawali, & Jhala, 2017; Thapa *et al.*, 2014). Vegetative succession play role to change land of Chitwan. Annual flood change river course and retreat vegetation and oxbow lakes which attract wild ungulates (Dinerstein, 2003; Odden, Wegge, & Storaas, 2005).

Preferred habitats

Rhinoceros has been utilizing flood plain grasslands and riverine forest. It has been followed by riverbeds and rivers. Rhinoceros preferred habitats in CNP are grassland plains of Reu, Rapti and Narayani rivers followed by riverine forests (Dinerstein, 2003; Dinerstein & Price, 1991; S. R. Jnawali, 1995; Lahkar *et al.*, 2011; Laurie, 1978). Regeneration of habitats has been supplemented in CNP after Padampur has been gifted to nature. It is extended form of Dinerstein (2003) and co-worker to regenerate buffer zone around CNP. Rhinoceros wallow about 3 hours /day during August to September but they wallow only about 1 hour/day during December and January (Dinerstein, 2003; Laurie, 1978; Thapa *et al.*, 2014). Rhinoceros roam far if the habitats fail to provide enough food and water (S. Jnawali & Wegge, 1993). Grassland over time changes into riverine forest and woodland area. Rhinoceros seek out early successive short grass dominated by *Saccharum spontaneum*. Oxbow lakes and other open water bodies are also very critical for rhinoceros (Dinerstein, 2003; Naresh Subedi *et al.*, 2017).

Effect of land use in habitats

Rhinoceros has been shifted toward the western area of CNP over time after land use change are significantly different in rhinoceros potential habitats. . Landscape modification and human disturbance are main causes for land use change (Thapa *et al.*, 2014).

Annual flood change course of river, regenerate oxbow lakes and retreat vegetation. Climate change and infestation of invasive species like *Mikania micrantha* modified wetland. These are critical habitat of rhinoceros in CNP (Dinerstein, 2003; Thapa *et al.*, 2014). With decreasing sparse forests over CNP and, decreasing riverbeds and river in the eastern area; increasing riverbeds and river in the western area of CNP, population of rhinoceros has been increased in western area. However, the grasslands in Chitwan are rapidly converting to woodland and are also infested by invasive weeds like *Mikania micrantha* (DNPWC, 2010; N Subedi, 2012). Human induced activities such as threats of poaching during political unstable period, translocation of rhinoceros for viable population in historical area, over grazing, grass cutting are high in the Eastern area of CNP (Dinerstein, 2003; NTNC, 2012; Naresh Subedi *et al.*, 2017). Population of rhinoceros has been increased on Sukhibhar to Temple Tiger over time. Laurie (1978) separately counted subpopulation of Kagendramali area but Dinerstein (1984) counted rhinoceros's subpopulation of these areas along with subpopulation of Sauraha area due to shifting of population of rhinoceros from Kagendramali to Sauraha area. At the ending, shifting habitats of rhinoceros was continued towards Sukhibar to Temple Tiger area from Sauraha area. Climate change and infestation of invasive species effect on flood plain of river which is prime habitat of rhinoceros in CNP. They also destroy or may be killed native species such as *Saccharum spontaneum*, which contribute more than 80% forage of rhinoceros in CNP. Proper management and protection of flood plan is necessary for long term preservation of rhinoceros in low lands of Nepal (Pant *et al.*, 2021). After establishment of dykes on bed of Rapti river, strong fluvial action of river ceased and stopped distribution of Oxbow lakes and retreat vegetation in eastern part of CNP which has contributed shifting of rhinoceros from these region (Naresh Subedi *et al.*, 2017).

CONCLUSION

Land use practice has been shrinking habitats of rhinoceros in lowland of Nepal. Land use change is different in CNP and surrounding area over time. Sighting locations of rhinoceros are high in sparse forests/grasslands. They have been decreased but number of rhinoceros is increasing form. With remaining original landscape features in the western area, population of rhinoceros has been shifted in the western area of CNP over time. Land use change is attributed by establishment of dykes, infestation of *Mikania micrantha*, human encroachment and climate. Therefore, survival of rhinoceros would be threatened condition in Nepal.

CONFLICTS OF INTEREST

Authors declare they do not have conflicts of interest.

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