WII-MoEF-NNRMS Pilot Project

'Mapping of National Parks and Wildlife Sanctuaries'

Volume V
Kaziranga National Park, Assam

FINAL TECHNICAL REPORT

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जहाँ है हरियाली।
वहाँ है खुशहाली॥

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

December, 2008

Mapping of Kaziranga Conservation Area, Assam

Project Report

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Principal Investigator

Forestry and Ecology Division
Indian Institute of Remote Sensing (NRSC)
Indian Space Research Organisation
Dept. of Space, Govt. of India
Dehradun-248001

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8.	Abstract	Mapping of Kaziranga on 1:25,000 scale was carried out in this Govt. of India, Min. of Env. and Forests, NNRMS- funded project, which envisages preparation of detailed baseline database of national parks and wildlife sanctuaries. Both thematic and topographic mapping was done. The study highlighted that Kaziranga has semi-evergreen forests, tall and short grass areas, shallow water bodies called *beels* and river water. The tall grass areas as well as beels are fairly well distributed throughout the park while short grass areas are more in Baguri Range. The floral and faunal diversity in the park is unique and animals such as rhino, wild buffalo, elephants and swamp deers are in high density. Though Kaziranga is heavily guarded, yet erosion, poaching, cattle grazing etc. are the major problems in the area.
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Chapter-1
1. Introduction

Human encroachment of natural habitats is one of the most critical issues facing wildlife and biodiversity conservation today. As human populations increase in size and demand more space and resources, the natural habitats are shrinking. The encroachment leads to range reductions, human-wildlife conflicts and in some cases local species extinctions. The natural habitats worldwide are being destroyed or converted to other land uses and the species supported by those habitats are inevitably threatened. The first step towards ensuring the long-term survival of the species, and thus the biodiversity, is to generate basic information required for their effective management. The information should incorporate data on distribution, biology and habitat requirements of species, especially the endangered ones.

Habitat is a combination of food, water, shelter and space to meet the needs of wildlife. The tiger, rhino and the elephant, at the apex of the food web, are indicator species of the healthy ecosystem. Their conservation means preservation of the entire spectrum of species sharing the same habitat. These mega fauna have played an important role in the rise of the international conservation movement. However, the long-term survival of these animals is uncertain largely due to the loss and fragmentation of their habitat, poaching and illegal trade of their body parts. Tigers, elephants and rhinos are categorized as flagship species for the landscape as they form an effective link between species-oriented management and management of the biological diversity.

The exceptional diversity of habitats within a relatively small area is responsible for an amazing variety of wild flora and fauna in India. Over-extraction of natural resources, deforestation and forest clearing, soil erosion, sedimentation, floods, drought etc. are some of the major threats to wildlife habitats. Habitat fragmentation and the loss of corridors are some of the major consequences of the classical human development paradigm more so in developing countries. The high interspersion of human habitations and their

livestock populations in majority of the wildlife sanctuaries, national parks and biosphere reserves in India makes wildlife protection a formidable task. Over time, the corridors have disappeared due to degradation and depletion of the forests linking protected areas. This has jeopardized the corridor efficacy and restricted the animal movement across protected areas.

Mapping of wildlife habitats and database generation is considered as one of the basic needs for restoration and conservation of wild habitats. Quick survey of existing protected areas and identification of new sites is what is immediately required. Wildlife managers have been traditionally using topographic maps to generate management maps of interest. The advent of remote sensing (RS) has revolutionalized the process of data gathering and map making. The technology has been used world-over for natural resources assessment and monitoring during past century. Remote sensing supplements or replaces to a large extent the tedious ground survey. Ground methods have limitation as whole area can not be covered in one go and, in many cases, the information collected may not be as accurate as possible through remote sensing aided by limited ground survey.

The geographic information system (GIS) provides a means of database creation, rapid retrieval, data integration/analysis and map and information generation. A GIS can be used to create alternate management scenarios before selecting the best suited one for wildlife management. It also helps in faster review of the distribution and conservation status of several components of biodiversity in decision making for nature conservation and management (Scott *et al*., 2002). A GIS can also be used to predict species distribution patterns based on limited field data even when the information is poor or non-existent. The global positioning system (GPS) is yet another device which greatly facilitates in the field surveys, mapping and database creation. The GPS has become extremely popular among foresters during past one decade.

The habitat evaluations based on the inputs from RS tend to be more realistic and unbiased because of the independent data capture by the sensors onboard satellites. Adams and Gentle (1978) used digitized aerial photograph to

monitor changes in waterfowl habitat assessment of elk (Bright, 1984), reindeer (George *et al.*, 1984) and kangaroo (Hill and Kelly, 1987). Wiersema (1983) studied ibex habitat using Landsat imagery and concluded that remote sensing data contributes in better understanding of environment and the processes. Kushwaha *et al.* (2004) evaluated the habitat for sambar and muntjak in Chaubatia Reserve Forest at Ranikhet and demonstrated that RS and GIS can play a very significant role in wildlife habitat evaluation. Alfred *et al*. (2001) used RS and GIS to mark suitable habitat for chinkara in Rajasthan sate of India. By now, it is well established that use of remote sensing technique is time- and cost-effective for wildlife habitat mapping, monitoring and evaluation.

Chapter-2
2. Objectives

This study is part of the ambitious plan of the Ministry of Environment and Forests, Government of India to create large-scale spatial database for the national parks and sanctuaries of the country for scientific management of the protected areas under the leadership of the Director, Wildlife Institute of India, Dehradun. Since protected areas were not mapped using large-scale satellite imagery in past, it was decided to take up five national parks and sanctuaries for pilot studies. After initial discussions, Dudhwa National Park in Uttar Pradesh, Corbett National Park in Uttarakhand, Kaziranga National Park in Assam, Tadoba-Andhari Tiger Reserve in Maharashtra and Indira Gandhi Wildlife Sanctuary in Tamilnadu were selected in close cooperation with the respective state Chief Wildlife Wardens. These five protected areas fall in five different biogeographical zones of the country (Rodgers and Pawar, 1988).

The study aimed to generate the reliable and latest baseline spatial information on forest type and density using satellite imagery and topographic features, supplemented by latest satellite imagery, as mapped by Survey of India for this task. It was thought appropriate to incorporate the plant and animal density, diversity/richness information as value addition to the above mentioned maps so that the wildlife managers could use the information directly for conservation and management. It is expected that the information generated in this project will be of direct relevance for preparation/revision of the plans for wildlife management in Kaziranga National Park. It is hoped that the experienced gained in the present study would be useful in mapping of the remaining protected areas of India.

Chapter-3
3. Study Area

3.1 General

The present study was carried out in Kaziranga National Park (KNP) (26°30'-26°45'N, 93°00'-93°45'E), which is one of the most important protected areas of India. The park is famous for its great Indian one-horned rhino (*Rhinoceros unicornis*) though other animals like elephants, tigers, wild buffaloes, ungulates, wild boars etc. are also found in the park. It includes parts of Brahmaputra river and areas falling in Nagaon, Golaghat and Sonitpur districts. Two reserve forests *viz.*, Panbari and Kukrakata are also part of KNP. Small but important areas for many forest bird species also lie outside the park. Kaziranga was declared as a reserve forest in January, 1908 with an initial area of 226.2 km^2. Subsequently, more areas were added and it declared as a game sanctuary. Kaziranga acquired the status of wildlife sanctuary in 1926. In 1952, the Executive Committee of the Indian Board for Wildlife recommended the area to be made in to a national park. The Assam Rhinoceros Bill was passed in 1954 and steps were initiated to conserve the rhino, the flagship species and its habitat. Finally, Kaziranga was declared as national park in February, 1974 and since then the area is under intensive wildlife management. In the year 1985, the Kaziranga National Park was declared as World Heritage Site by UNESCO under criteria N (ix) and N(x) of the natural heritage (Vasu, 2002).

The KNP is the floodplain of the river Brahmaputra. Great amount of silt is brought by the Brahmaputra and its tributaries during the rainy season year after year and deposited along its course at several places. The Majuli island is another similar example of older alluvial deposits. The riverine areas, thus formed, are initially colonized by *Saccharum* spp. and other pioneer grasses as soon as the land mass becomes stable. Tree species like *Bombax ceiba*, *Lagerstroemia* spp. and *Tetrameles nudiflora* take over the tall grasses within short span of time. *Bombax ceiba* by far is the earliest colonizer among trees. This type of land formation and vegetation succession can be observed on the new river islands (locally called chaporis). That there was a constant change of the land masses can be visualized from the fact that the Jiya Diphlu (live Diphlu) river, which flows into the Brahmaputra

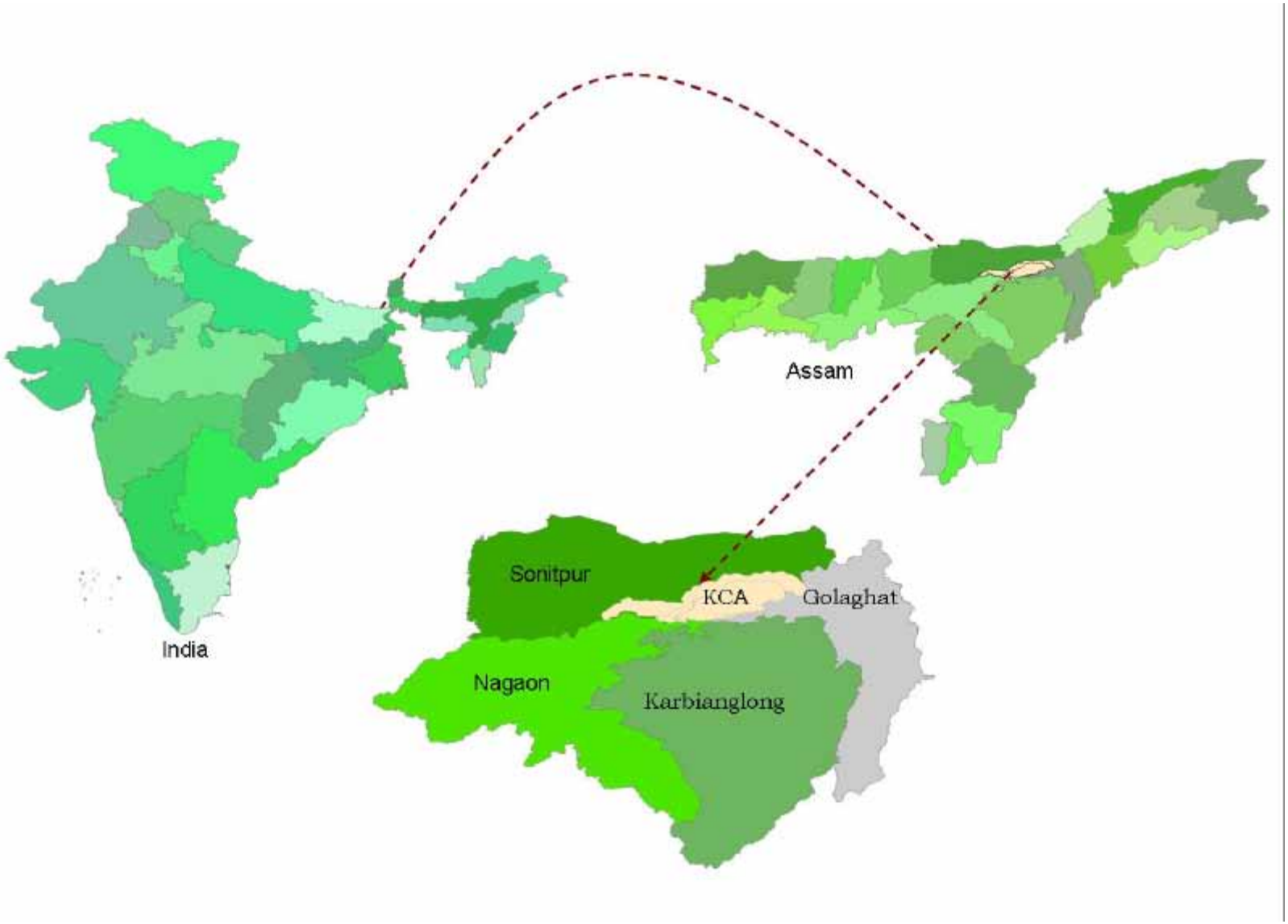


Fig. 1: Location of study area.

river through KNP after originating in the Karbi Anglong hills now divides the park into two almost equal halves. Originally this river had a course along the southern boundary of Kaziranga. The abandoned course of the Diphlu, known as Mori Diphlu (or dead Diphlu) forms the southern boundary of the park. Like Diphlu, the Dhansiri river, which originates in Naga hills, too has changed its course. Earlier this river flew through KNP but now the confluence of the Dhansiri is about 5km away from the eastern boundary of the park. The abandoned river course is now called as Mori Dhansiri.

Numerous channels of the Brahmaputra river criss-crossing entire area were once flowing through KNP during initial stages of land formations. When channels were land-locked by further silt deposition and change in the Brahmaputra river course, they formed the oxbow lakes or beels (local name for water bodies) of various sizes and depths. Some beels have silted up, producing swamps and marshes. The process of erosion and accretion may not stop so long as the Brahmaputra flows. The habitat of Kaziranga is such that water bodies and grasslands form a significant part of the park area. Wetlands cover 7 per cent, grassland 57 per cent (tall grass 52% and short grass 5%), sand 7 per cent and woodland (semi-evergreen forest) 29 per cent of the erstwhile area of the park (Kushwaha and Madhavan Unni, 1986). Kushwaha *et al.* (2001) reported a landmass loss of 20.8 km^2 between 1967 and 1997 due to river erosion. The area under beels in Kaziranga also reduced from 36.6 km^2 to 27.4 km^2 during this period.

3.2 Flora and Fauna

The vegetation of the KNP consists of extensive alluvial grasslands, with tall and short grasses, interspersed by semi-evergreen forests. The grasslands have been classified as Eastern Wet Alluvial Grasslands (4D/2S2) by Champion and Seth (1968). *Erianthus ravennae*, *Phragmites karka*, *Arundo donax*, *Imperata cylindrica* and *Saccharum procerum* are the main tall grass species. The herb *Alpina allughas* grows abundantly as most common associate of these species, especially in the damp areas. The forest is dominated by trees such as *Aphanamixis polystachya*, *Talauma hodgsonii*, *Dillenia indica*, *Garcinia tinctoria*, *Ficus* sp., *Cinnamomum bejolghota*, *Syzygium* sp. etc. In contrast to tall grasses,

short grasses, which grow only around beels are of high forage value. The short grass species are: *Hemarthia compressa*, *Cynodon dactylon*, *Cenchrus ciliaris*, *Crysopogon aciculate* and *Andropogon* sp.

The KNP is also endowed with rich fauna with about 15 mammal, 490 bird and 25 reptile species. The main mammals are: Indian one-horned rhino (*Rhinocerous unicornis*), tiger (*Panthera tigris*), elephant (*Elephas maximus*), hog deer (*Axis porcinus*), sambar (*Cervus unicolor*), Hoolock gibbon (*Hylobates hoolock*) wild boar (*Sus scrofa*), capped langur (*Trachypithecus pileatus*) and rhesus maccaca (*Macaca mulatta*), sloth bear (*Melursus ursinus*), otters (*Lutra lutra and L. perspicillata*), Gangetic dolphin (*Plantanista gangetica*), barking deer (*Muntiacus muntjak*) and Malayan giant squirrel (*Ratufa bicolor*). Kaziranga is home for largest population of one-horned rhino in the world. It also has highest ecological density of royal Bengal tiger, largest population of Asiatic wild buffaloes since 2001, largest population of eastern swamp deer and more than 1000 Asiatic elephants (Sahgal, 2005).

3.3 Avifauna

Barua and Sharma (1999) have reported more than 478 bird species in KNP. While it is not possible to describe status and distribution of each threatened species, it is worth mentioning that Kaziranga is one of the outstanding IBAs, especially for birds of the tall, wet grasslands of the Assam Plains Endemic Bird Area and Biome-12. Out of the 478 bird species listed by Barua and Sharma (1999), 197 are residents, 165 are migrants, 46 are local migrants. The status of the remaining species is uncertain (Islam and Rahmani, 2004). The notable resident species with significant population are: spot-billed pelican (*Pelecanus philippensis*), lesser adjutant (*Leptoptilos javanicus*), swamp francolin (*Francolinus gularis*), Bengal florican (*Houbaropsis bengalensis*), pallas's fish-eagle (*Haliaetus leucoryphus*), greater grey-headed fish-eagle (*Ichthyophaga ichthyaetus*), white-bellied heron (*Ardea insignis*), black-necked stork (*Ephippiorhynchus asiaticus*), bristled grass-wabler (*Chaetornis striatus*), marsh babbler (*Pellorneum palustre*), black-breasted parrotbill (*Paradoxornis flavirostris*) and Finn's weaver (*Ploceus megarhynchus*).

3.4 Terrain, Geology and Soil

The terrain of the Kaziranga National Park is flat with gentle almost imperceptible slope from east to west and from north to south. It is bounded by the Karbi Anglong hills in the south. The Kukurakata Reserve Forest is hilly and the Panbari Reserve Forest is flat with hilly slopes along Karbi Anglong boundary. From the geological and geo-morphological mapping of the Kaziranga area (Surendranath and Sharma, 1991), it is seen that the area of the KNP predominantly comprises of recent composite alluvial plains and floodplains. The channels and point bars, back swamps deposits are quite conspicuous in the active flood plain of the park area. Lithologically, the Kaziranga formation is represented by grey silt and fine to medium sands which form the recent composite flood plain with numerous meander scars and scrolls, palaeochannels and abandoned channels belonging to Holocene period of quaternary ages. The Brahmaputra river flowing along the northern boundary of the park exhibits braiding pattern with numerous river islands.

Two types of chaporis i.e. stable and unstable chaporis are encountered. The stable chaporis have large areal extent and have tall grass cover whereas unstable islands are devoid of grass cover. The left bank of the Brahmaputra river, which formed the erstwhile boundary of the national park is very steep and its height varies from 3 to 7m. Due to the changing pattern of the river, the left bank of the river erodes away considerable stretch of the land along its banks, severely affecting the park landmass. The soil overlying the sandy deposits at places is very deep while at some places it is shallow and devoid of organic matter. As such the soil at various places varies from sandy soil, sandy loam, clayey loam to pure clayey soil.

3.5 Climate

The climate of Kaziranga is typical subtropical monsoonic type. There are three distinct seasons. The dry and windy simmer runs from mid-February to May with an average maximum temperature of 35°C. The rainy season extends from May to September with average annual rainfall ranging between 1500 to 2500 mm. This period is humid and hot. The mild winter with average maximum

temperature of 25°C and an average minimum temperature of 10°C extends from November to mid-February. This period is normally rainless except for a few winter showers.

3.6 Settlements

There is no village inside the originally notified KNP. However, there exist different kinds of human disturbances in the Addition areas. An area of about 1 km^2 in the 1^{st} Addition area is occupied by graziers besides the stable chaporis of 6^{th} Addition area, which is also encroached by graziers and cultivators. Other than these, there are 150 revenue villages and tea estate settlement in the zone of influence. However, present situation of the villages located on the zone of influence on the northern boundary of the 6^{th} Addition has not been assessed so far. The main communities in these villages are Assamese including Miching, Karbi, Nepali, tribes working in tea gardens and Muslims. These communities are mainly dependent on agriculture for subsistence.

The Miching community is the major tribal community in the area. Agriculture is their principal activity and they rear livestock like buffaloes and pigs to supplement their income. Miching community is poor. There are Karbi villages in the western part of the zone of influence and their livelihood too is agriculture oriented. They also collect herbs and building material from reserve forests. The tea garden labourers of this area are engaged in tea industry. The Nepali community consists of mainly graziers and their occupation has considerable impact on the protected area. Majority of the Muslims are agriculturists. Some of them also resort to illegal fishing, which is of major concern to the park managers.

Frequent floods, poaching, erosion, weeds and siltation of waterbodies are major threats to the habitat at kaziranga. Nontheless, Kaziranga still remains as best managed national park in India, and with its amazing variety of the wildlife (Johnsingh, 2005), it will always remain a much sought after destination for the wildlife enthusiasts. Fig. 2 – 11 gives some illustrations of Kaziranga conservation area.

Fig.2: Elephant festival is celebrated at Kaziranga from time to time.

Fig.3: Cattle grazing is a major problem in Eastern Range.

Fig. 4: Wetland is favourite habitat of the Great Indian One-Horned Rhino.

Fig.5: Sambars in Kaziranga National Park.

Fig. 6: Beels are an essential component of the rhino habitat.

Fig. 7: Poaching of rhino for its horn is the greatest menace in Kariranga.

Fig. 8: Elephants are the third largest wild animal group in Kaziranga.

Fig. 9 : Spot-billed pelicans are a common sight in Kaziranga.

Fig. 10: Kaziranga has nearly 70% of global one-horned rhino population.

Fig. 11: Wild buffaloes are the second largest wild animal group in Kaziranga.

4.1 Data

The Resourcesat-1 LISS-IV imagery (Fig. 12) was procured from National Remote Sensing Centre, Hyderabad for mapping of the land cover in KNP. The image quality was not satisfactory and hence, not used in the study. Fortunately, cloud-free ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) data (Fig. 13) was available and the same was used for this purpose in absence of good quality LISS-IV data. Table 1 shows the path and row and date of acquisition of the imagery. ASTER images are acquired simultaneously at three resolutions. Each ASTER scene consists of 15 bands of data including one band, which points backwards to create parallax. The three bands in the visible and near-infrared (VNIR) have 15m resolution. The six bands in the short wave (SWIR) have 30m resolution. The remaining 6 thermal infrared (TIR) bands have 90m resolution. The two ASTER images were geo-referenced using WGS84 datum and LCC (Lambert conformal conical) projection. The KNP boundary was digitized using National Atlas and Thematic Mapping Organization (NATMO) map. The Assam Remote Sensing Application Centre (ARSAC), Guwahati helped in finalization of the KNP boundary and the field work.

Table 1: Satellite data procured.

Sensor	Path-Row	Date of Pass
IRS P6 LISS-IV	111-53	29th December 2005
IRS P6 LISS-IV	112-53	15th December 2004
IRS P6 LISS-IV	111-53	11th November 2005
ASTER	136-41	16th October 2005
ASTER	136-41	29th October 2005

The Survey of India (SOI) topographic maps on 1:25,000 and 1:50,000 scales were used as ancillary data. The management plan of Kaziranga National Park provided by Directorate of KNP, Bokakhat was also referred.

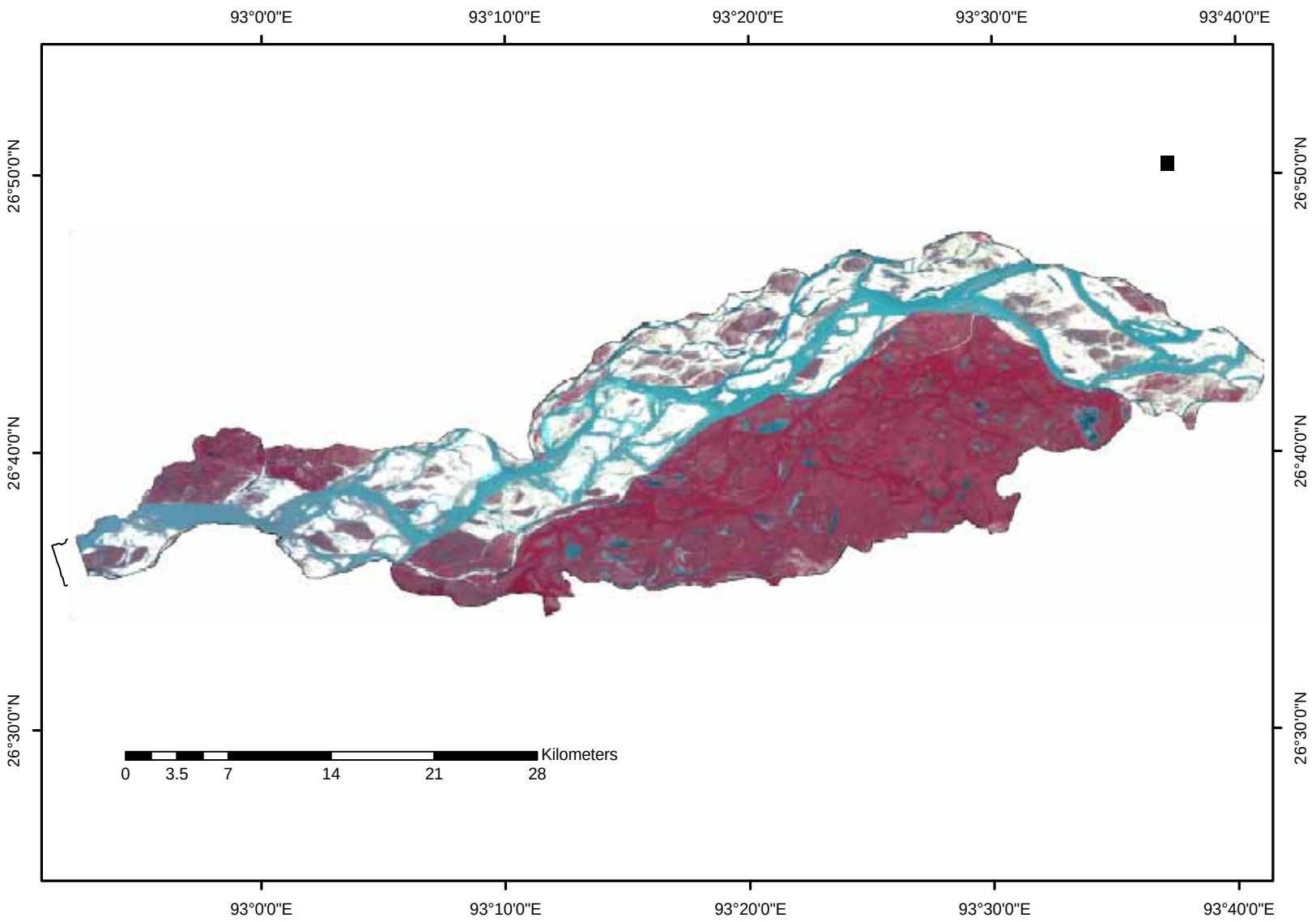


Fig. 12: IRS P6 LISS-IV FCC.

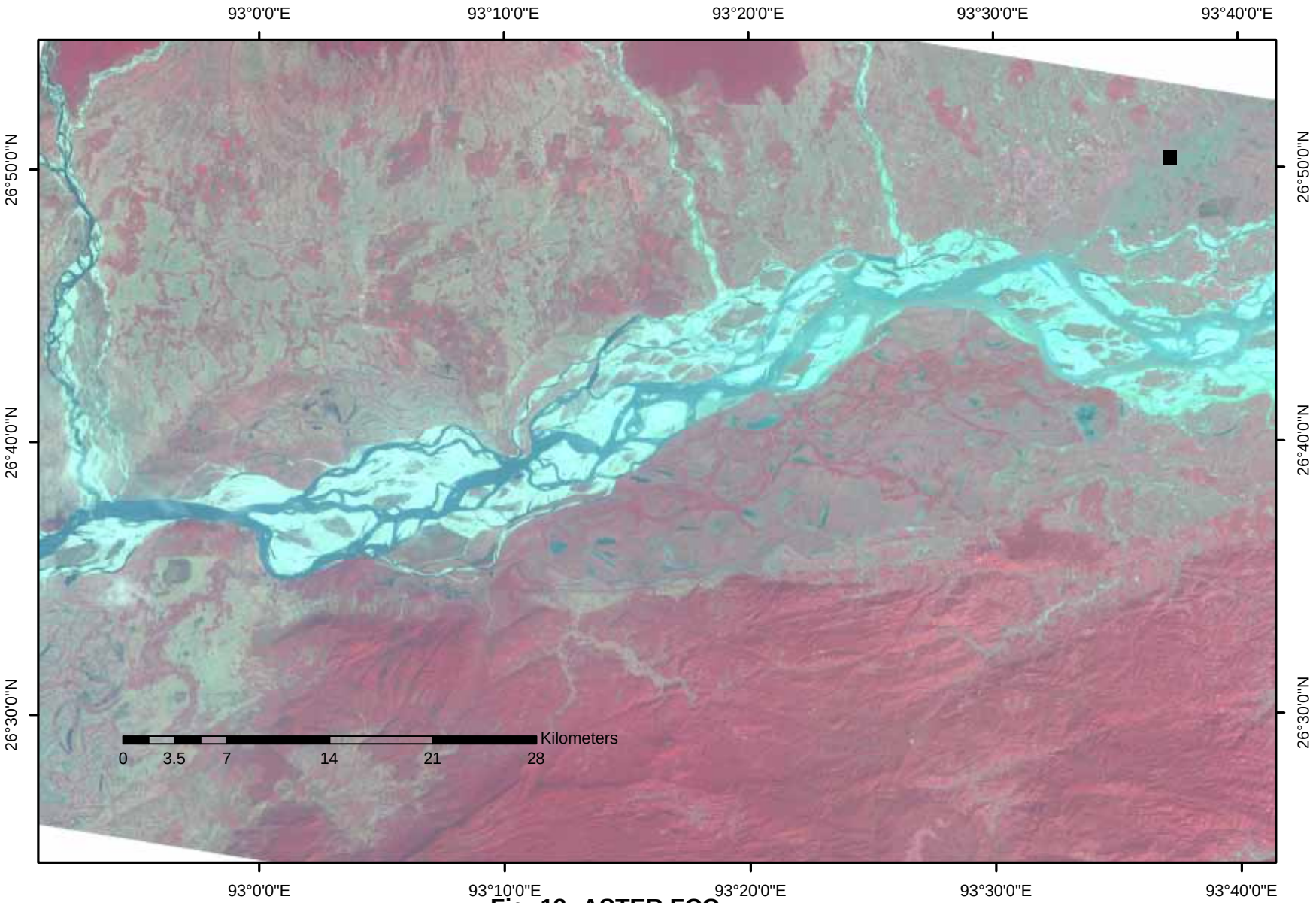


Fig. 13: ASTER FCC.

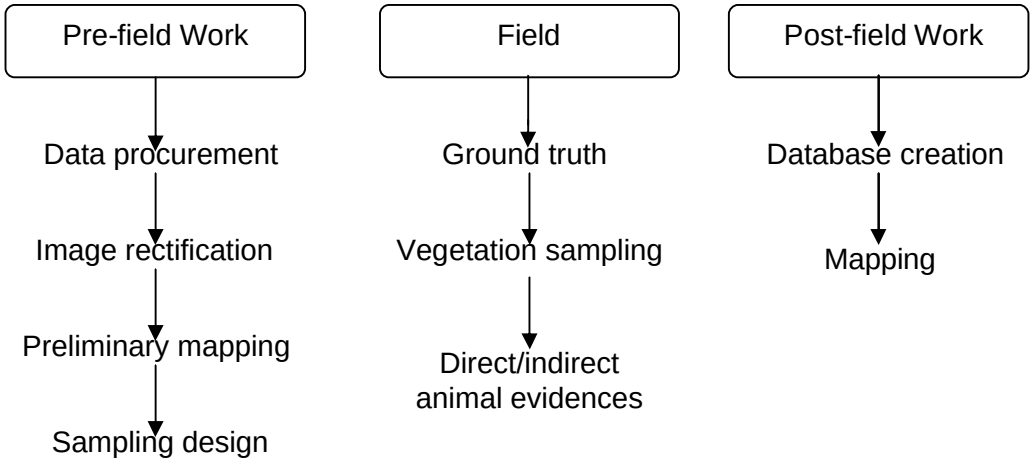
4.2 Equipment, Hardware and Software

- Magnetic compass
- Measuring tape
- *Garmin-12* GPS
- *ERDAS Imagine 9.0*
- *ArcView 3.2a*
- *ARC/INFO 8.0*

The image processing was carried out on a Pentium-IV PC with adequate RAM and hard disk space and loaded with software such as *ERDAS Imagine, ARC/INFO, ArcView, ArcGIS* etc.

4.3 Methods

The entire was scheduled into three major phases: the pre-field work, field work and the post-field work as mentioned below:



4.3.1 Pre-field work

The pre-field work is genesis of the foundation of the entire methodology followed. The most important task to start a project is to collect literature and data of the previous studies related to the project area. Hence, first fifteen days were spent in the library for collection of the literature. During this period, the literature related on Kaziranga was collected. The base map for the field work was derived form the Survey of India topographic maps as well as NATMO map.

Image to map registration: The raw digital images usually contain geometric distortions so significant that they can not be used as maps. The sources of these distortions range from variation in the altitude and the velocity of the sensor platform to factors such as panoramic distortion, earth curvature, atmospheric refraction, relief displacement and non-linearity in the sweep of a sensor's instantaneous field of view (IFOV). The intent of geometric correction is to compensate for the distortions introduced by these factors, so that the corrected image will have the geometric integrity of map. Images were registered geometrically using SOI topographic maps on 1:50,000 scale. Larger scale Topographic maps were not available by this time. The evenly distributed ground control points (GCPs) were used with root mean square error of less than one pixel and the image was re-sampled using nearest neighbour sampling.

Image to image registration: Image to image registration is a translation and rotation alignment process by which two images of like geometry belonging to the same geographic area are positioned coincident with respect to one another so that the corresponding elements of the same ground area appear in the same place on the registered images. This type of geometric correction is used when it is not necessary to have pixel assigned in to a unique x,y coordinate system in a map projection.

Land cover mapping: Supervised digital classification technique was used to extract the thematic information. The identity and location of some of the land cover types, such as settlements, agricultural land and grasslands were known *a priori* from previous work. The same was, however, updated using latest satellite imagery. The training sites were identified in field and spectral characteristics of these sites were used to train the classification algorithm for land cover mapping of the remaining image. Every pixel, both within and outside these training sites, is then evaluated and assigned to the class of which it has the maximum likelihood. In addition, the on-screen visual interpretation of the satellite imagery was also taken up and vectors of various classes were generated using ArcView 3.2a software. A combination of both digital and visual methods was finally used to map the land cover classes. An overall classification accuracy of 91.08 per

cent (Kappa statistic – 0.88) could be achieved after several iterations. The stratified random sampling technique was used for sampling the plant and animal species. The satellite image derived strata sizes were used following probability proportional to size (PPS) principles to determine the number of plots to be sampled in the park.

4.3.2 Field work

The sample plots were approached on ground using GPS and bearings on SOI topographic maps. On reaching the desired location, the sample plots of 20m x 20m (in case of trees), 5m x 5m in case of shrubs and 5m x 5m in case of herbs were laid. The individuals with =30cm cbh were considered as trees. At each site, the plant and animal (mammals) species present within the quadrat were recorded. In case of trees, the cbh was also measured. In case of animals, both direct sightings and indirect evidences such as pallet group and hoof marks, pug marks etc. were taken in to account. The field work was carried out between December 2006 and February 2007 and a total of 140 plots were studied.

4.3.3 Post-field work

The plots were recoded in decimal degrees (geographic lat/long) and re-projected using LCC projection. The tiger census map provided by KNP was digitized to prepare the compartment map of the study area. Boundary shown on the NATMO map was used to extract the KNP area. No other map showing KNP boundary was officially available. The protection camps map was generated from the geo-coordinates of the protection camps recorded in field using GPS. The GPS points were re-projected from original, universal transverse mercator (UTM) to LCC and modified Everest datum.

5.1 Land Cover

The eleven categories of the land cover types (Fig. 14) could be mapped using ASTER imagery and extensive ground truthing. The largest cover class happened to be river sand (38.67%), followed by river water (20.09), tall grass (19.99%), semi-evergreen forest (11.77%), short grass (3.08%) and water bodies/beels (5.14%) (Table 2). The area of the park worked out to be 993.27 km^2, which should at best be considered as approximate area. The exact area of the park (old park area plus additions) could only be determined when an authenticated park boundary is officially available on sufficiently large scale either from park directorate or from Survey of India. The new 1:25,000 scale maps provided by Survey of India did not depict any park boundary. The only forest type of Kaziranga i.e. semi-evergreen forest was categorised in to three canopy density classes *viz.*, 10-40% (open), 40-70% (medium dense) and >70% (dense) based on visual interpretation of the satellite imagery. The exercise revealed that 55.40 per cent forest had dense canopy (55.40%), 24.62 per cent had medium dense canopy and 19.97 per cent had open canopy (Table 3).

Table 2: Area under different land cover categories.

S. No.	Category	Area (km^2)	% Area
1.	River sand	384.06	38.666
2.	River	199.51	20.086
3.	Tall grass	198.63	19.997
4.	Semi-evergreen forest >70%	67.00	6.746
5.	Semi-evergreen forest 40-70%	29.78	2.998
6.	Semi-evergreen forest 10-40%	24.17	2.433
7.	Short grass	30.63	3.084
8.	Water body	51.06	5.141
9.	Agriculture	8.02	0.807
10.	Fallow land	0.38	0.038
11.	Tea garden	0.03	0.003
Total		993.27	100.00

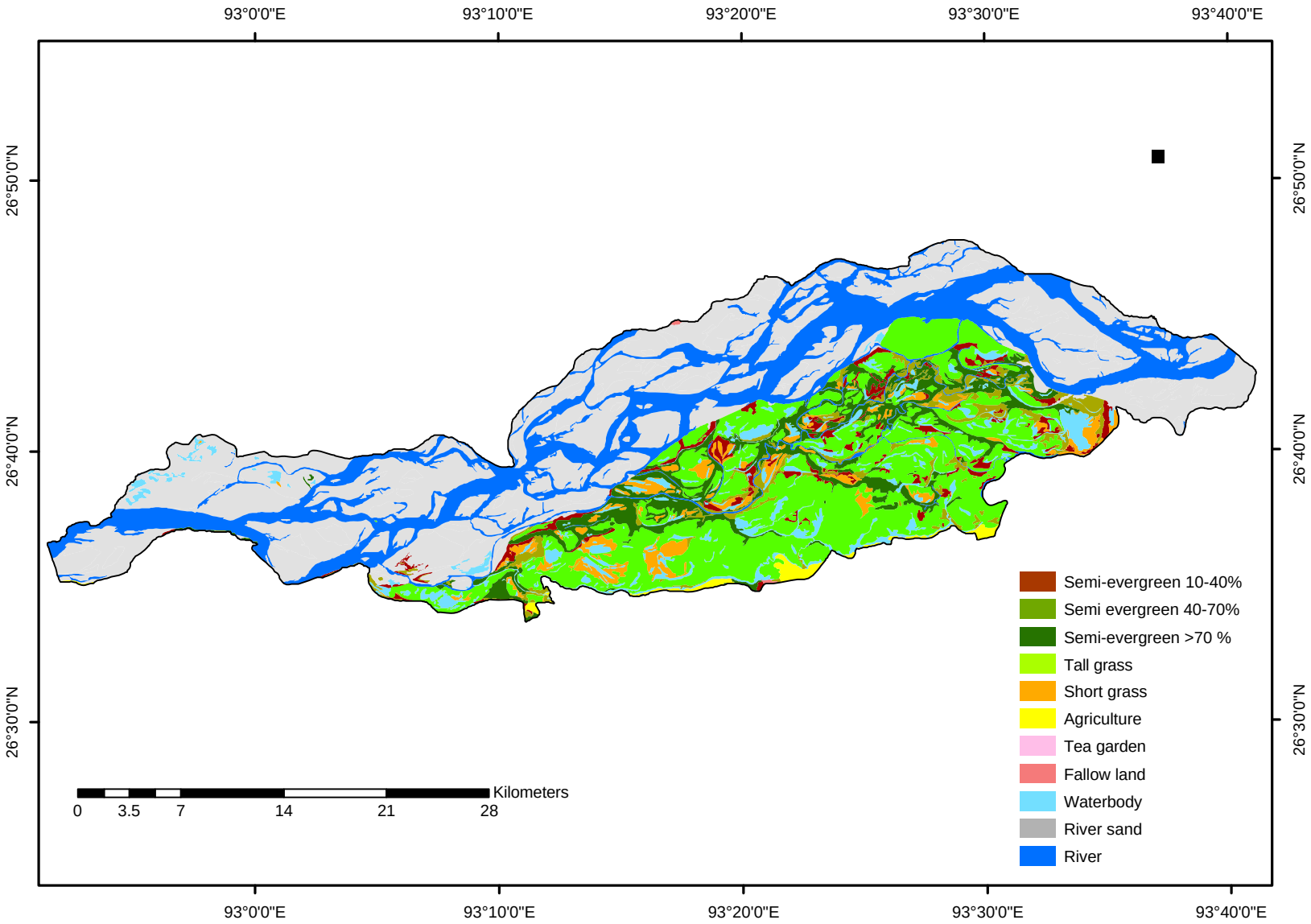


Fig. 14: Forest / land cover map.

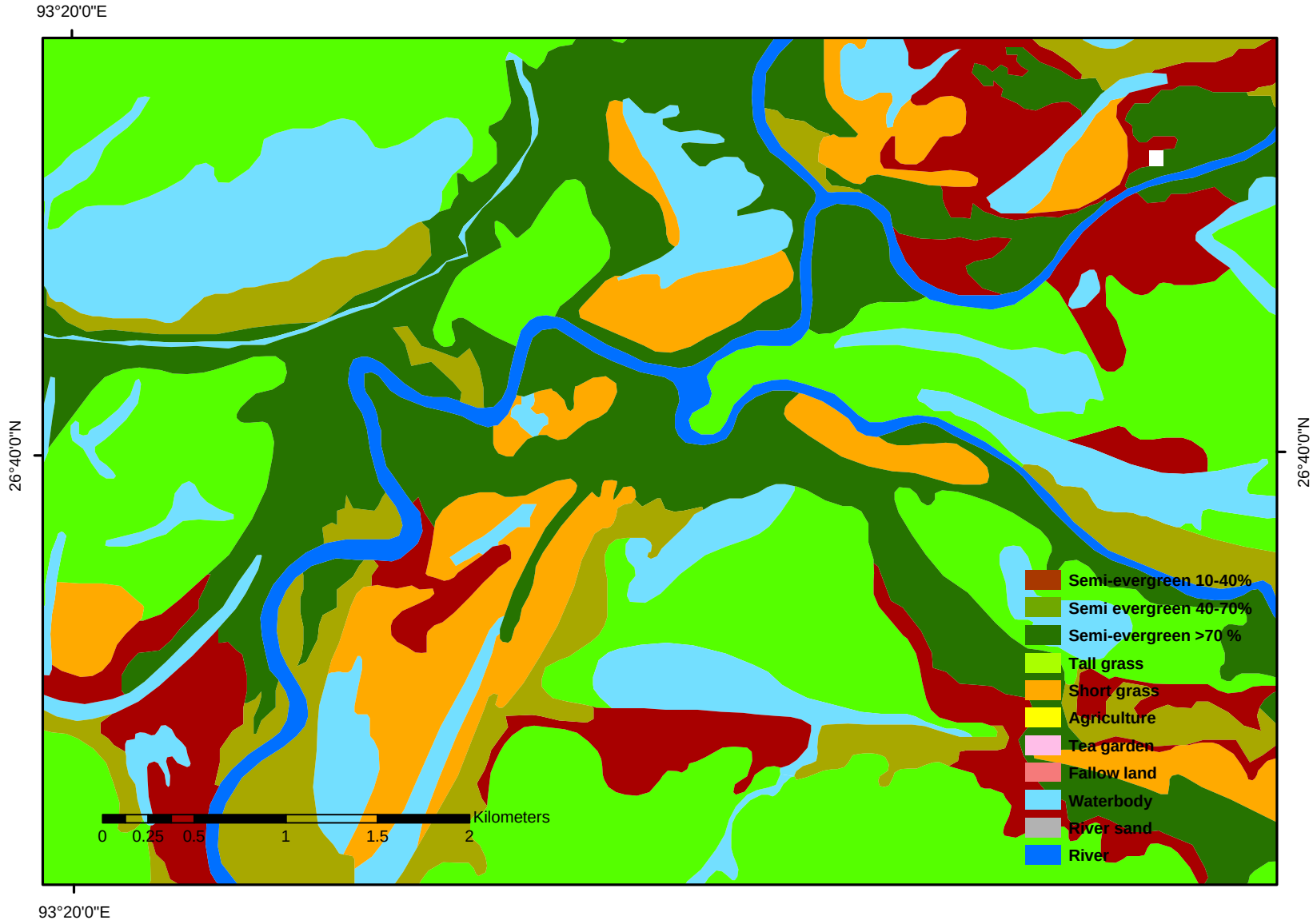


Fig. 15: Forest / land cover map (a part on 1:25,000 scale).

Table 3: Area under three densities of semi-evergreen forest.

Forest Type and Density	Area (km^2)	% Area
Semi-evergreen forest 10-40%	24.17	19.98
Semi-evergreen forest 40-70%	29.78	24.62
Semi-evergreen forest >70%	67.00	55.40
Total	120.95	100.00

5.2 Tiger Compartments

Kaziranga is divided in to 28 tiger compartments, of which 10 compartments are large (area >18 km^2) and the remaining are smaller. The largest compartment covers 20.80 km^2 area while smallest compartment occupies 8.21 km^2 (Fig. 16 and Table 4). No other compartment map was officially available.

Table 4: Tiger compartments.

Compartment	Area (km^2)	Area (%)
River	551.52	55.53
TE1	18.91	1.90
TE2	16.90	1.70
TE3	13.77	1.39
TC4	18.54	1.87
TEC5	11.85	1.19
TE6	14.98	1.51
TE7	14.22	1.43
TEC8	16.45	1.66
TC9	14.67	1.48
TC10	8.21	0.83
TC11	16.15	1.63
TC12	10.00	1.01
TC13	13.26	1.34
TC14	15.34	1.54
TC15	20.89	2.10
TCW16	20.45	2.06
TCW17	14.07	1.42
TC18	14.33	1.44
TC19	15.84	1.60
TC20	20.21	2.03
TCW21	20.58	2.07
TW22	18.68	1.88
TW23	20.77	2.09
TW24	13.80	1.39
TW25	9.30	0.94
TW26	18.41	1.85
TBR27	10.57	1.06
TBR28	20.59	2.07
Total	993.27	100.00

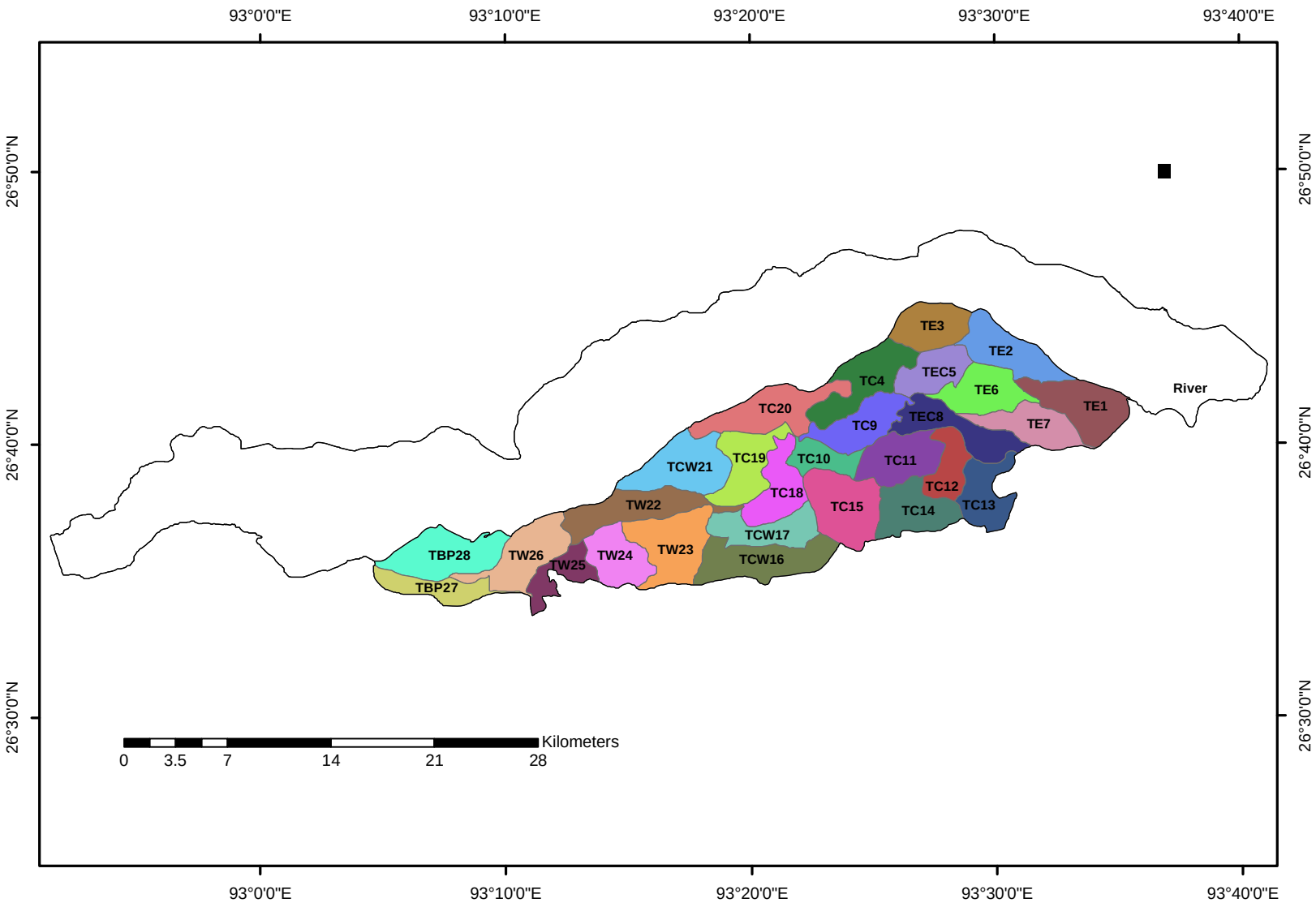


Fig. 16: Tiger compartment map.

5.3 Protection Camps

Kaziranga has 122 protection camps inside the park and they are more or less quite evenly distributed within the park area (Fig. 28). Twenty five more camps are proposed for an effective anti-poaching strategy. With 147 camps in place, Kaziranga will have nearly one camp for every 7 km^2. This must be the highest density of protection arrangements for any national park in India.

5.4 Animal Distribution

The field survey indicated that wild animals are more or less evenly distributed in KNP, more so in western and eastern ranges because of the higher availability of the fodder from short grasses. Very few animals were noticed in compartment number 11 and 15 while compartment number 1,7,17 and 24 had high density (up to 83). Large number of animals could be noticed (even from road) in the area west of Baguri in Burapahar range. The most abundant animals noticed during the field work were rhino, wild buffalo, hog deer, elephant and the sambar in that order. Others were in smaller numbers. Fig. 17 illustrates the relative density of the animals in the park; it indicates high density of animals in eastern most area in Agoratoli range tourist entry area and in the Baguri range. The numbers intercepted during field survey, however, does not indicate the total number of mammal/animals present in the Kaziranga National Park, which are given in Table 5.

Table 5: Number of wild animals.

Species	1991	1993	1999	2000	2001	2005	2006	2007	2008
Rhino	1129	1164	1552	-	-	-	1855	-	-
Elephant	515	1094	882	-	-	1246	-	-	1293
Tiger	50	72	80	86	-	-	-		-
Wild Buffalo	1008	1034	1192	-	1431	-	-	-	1943
Swamp deer	559	427	398	468	-	-	-	681	-
Sambar	55	34	58	-	-	-	-	-	-
Wild boar	555	140	431	-	-	-	-	-	-

(Source: Kaziranga National Park, Bokakhat, Assam)

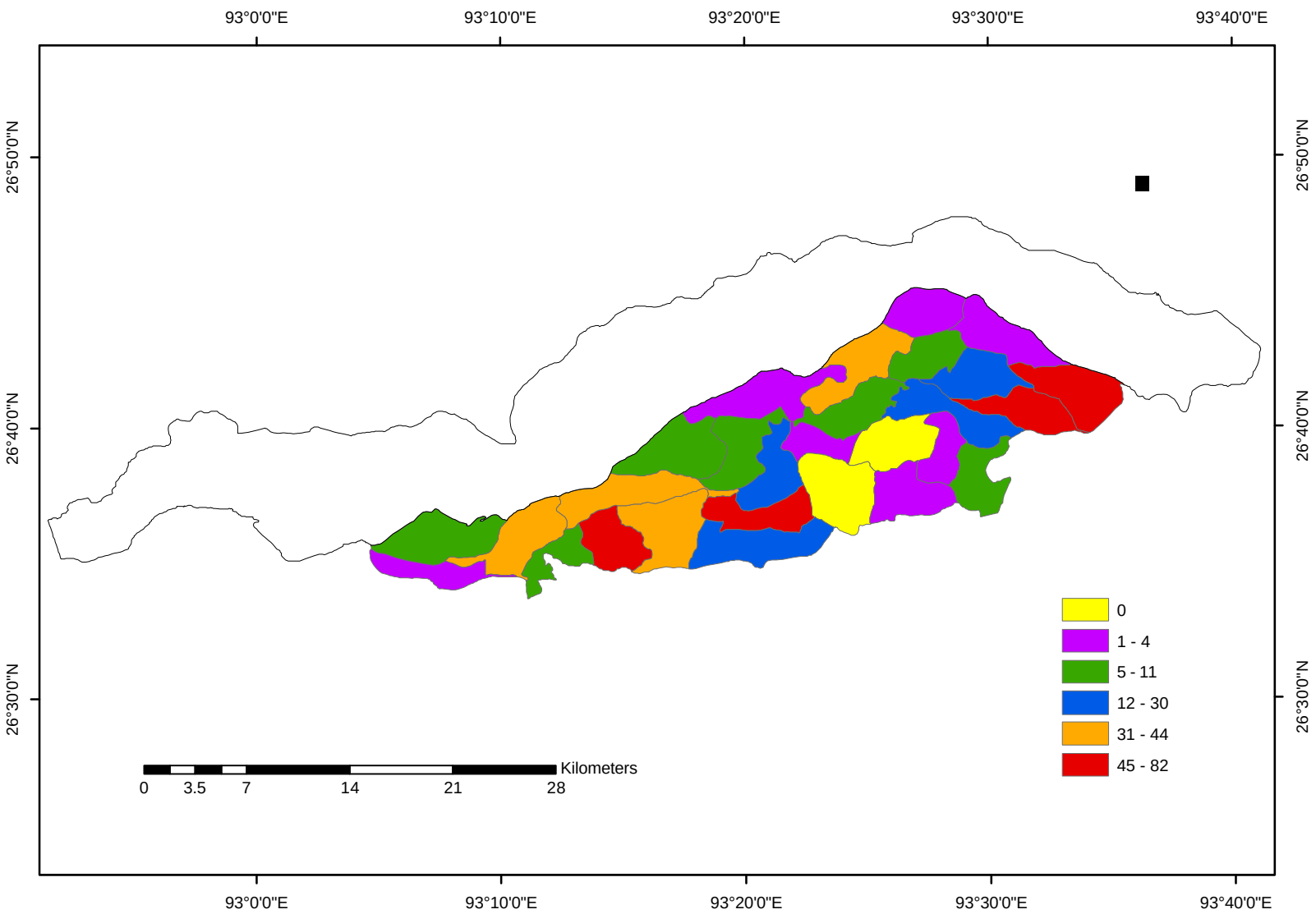


Fig. 17: Animal density encountered during field survey.

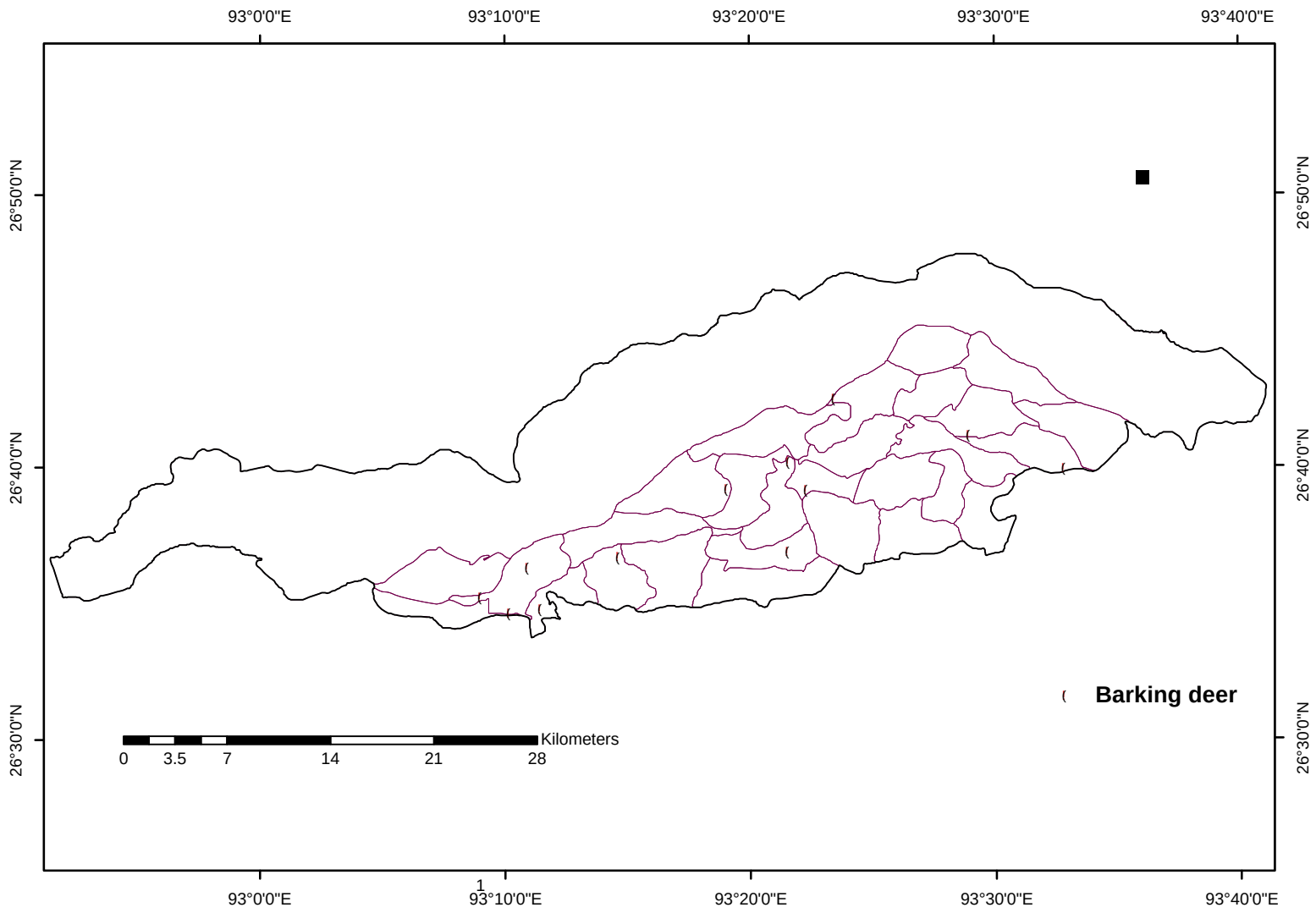


Fig. 18: Barking deer distribution.

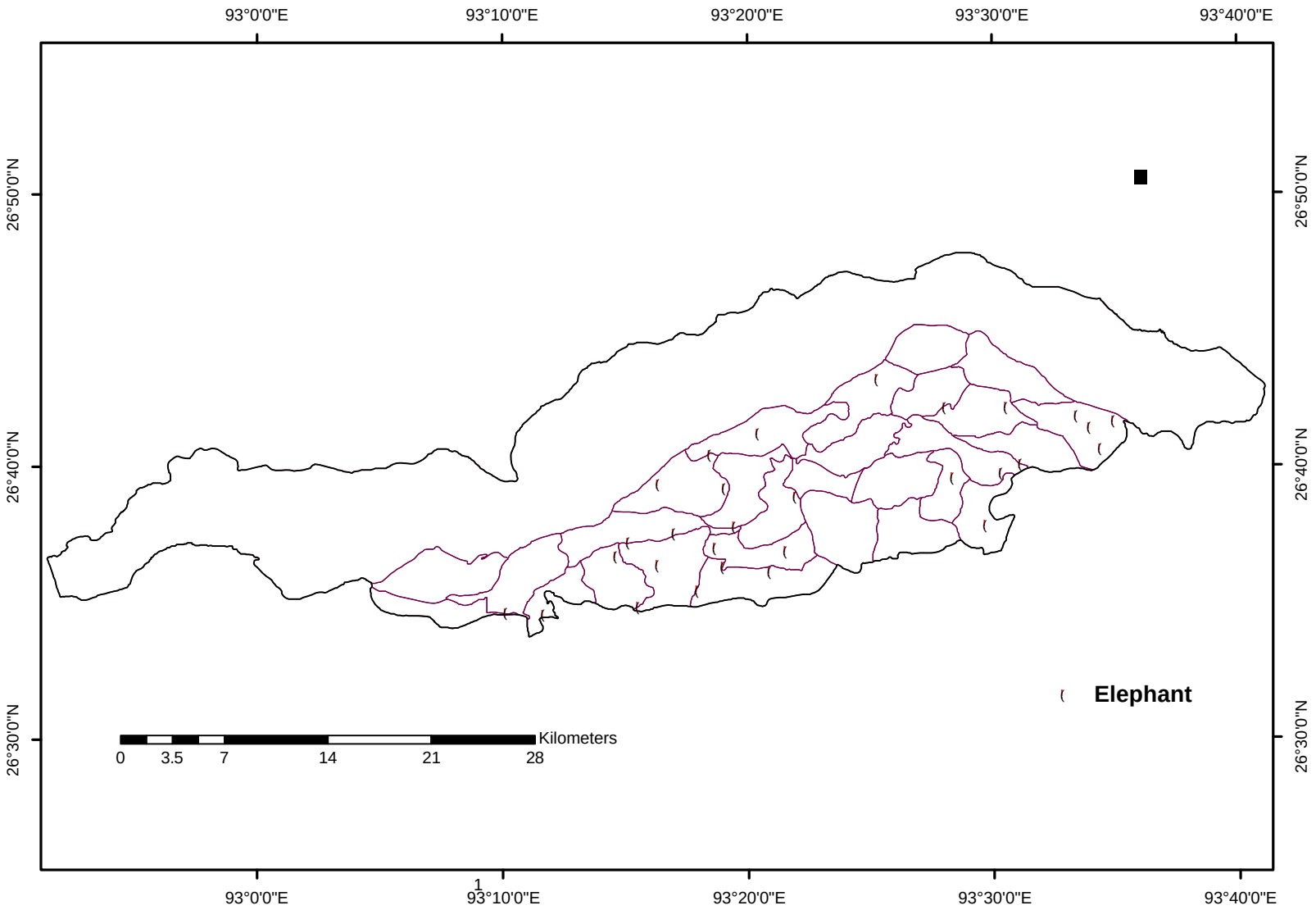


Fig. 19: Elephant distribution.

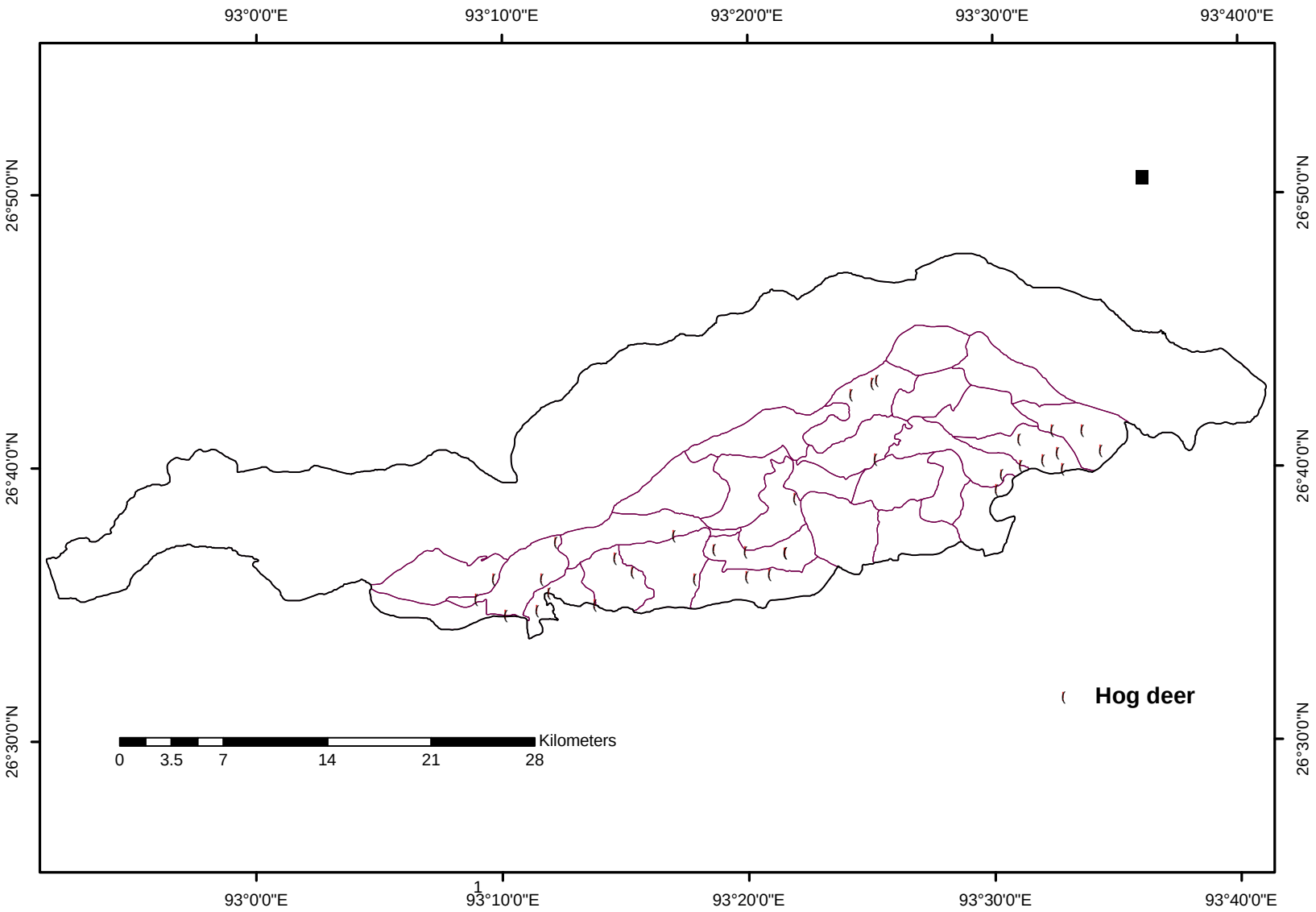


Fig. 20: Hog deer distribution.

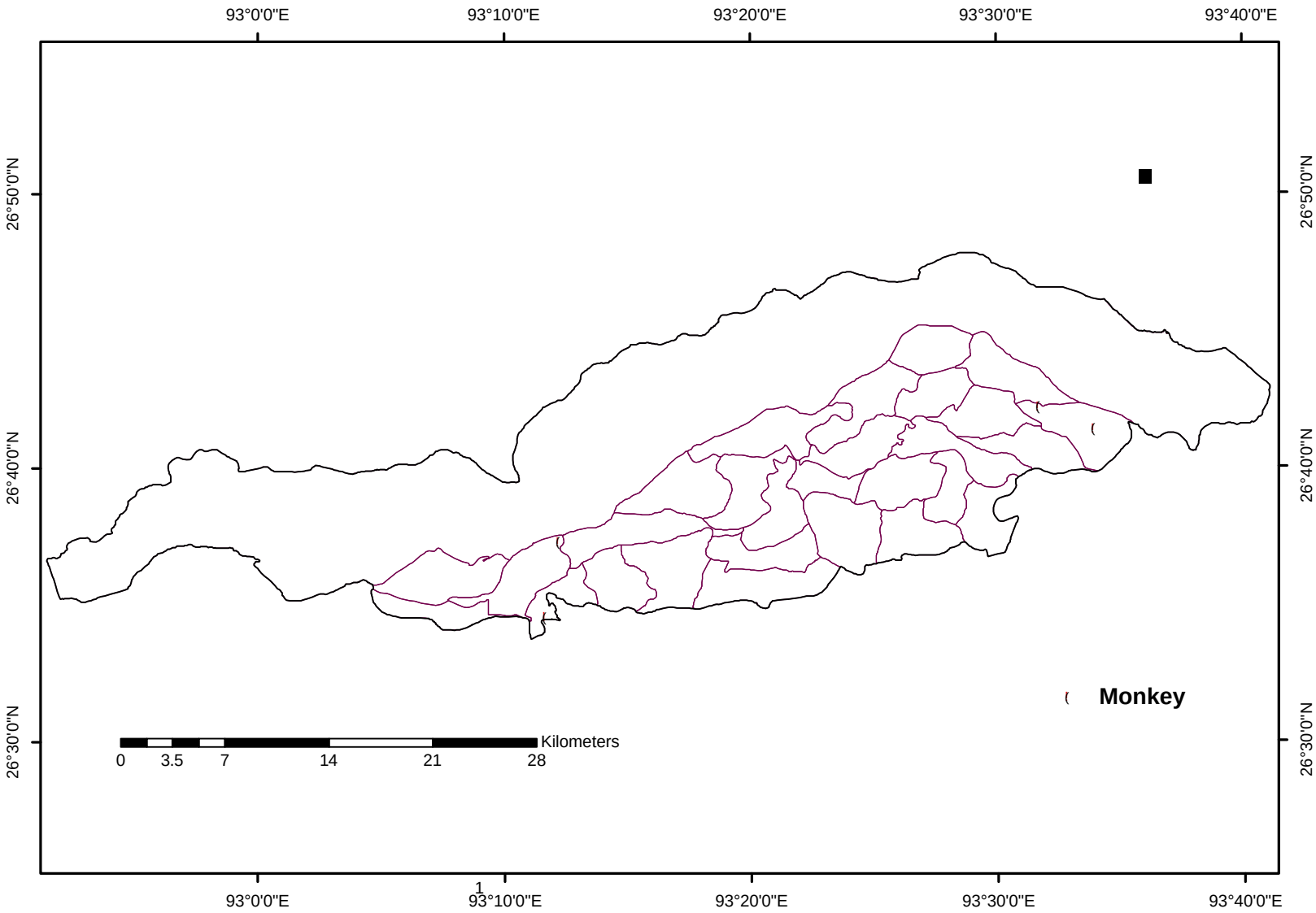


Fig. 21: Monkey distribution.

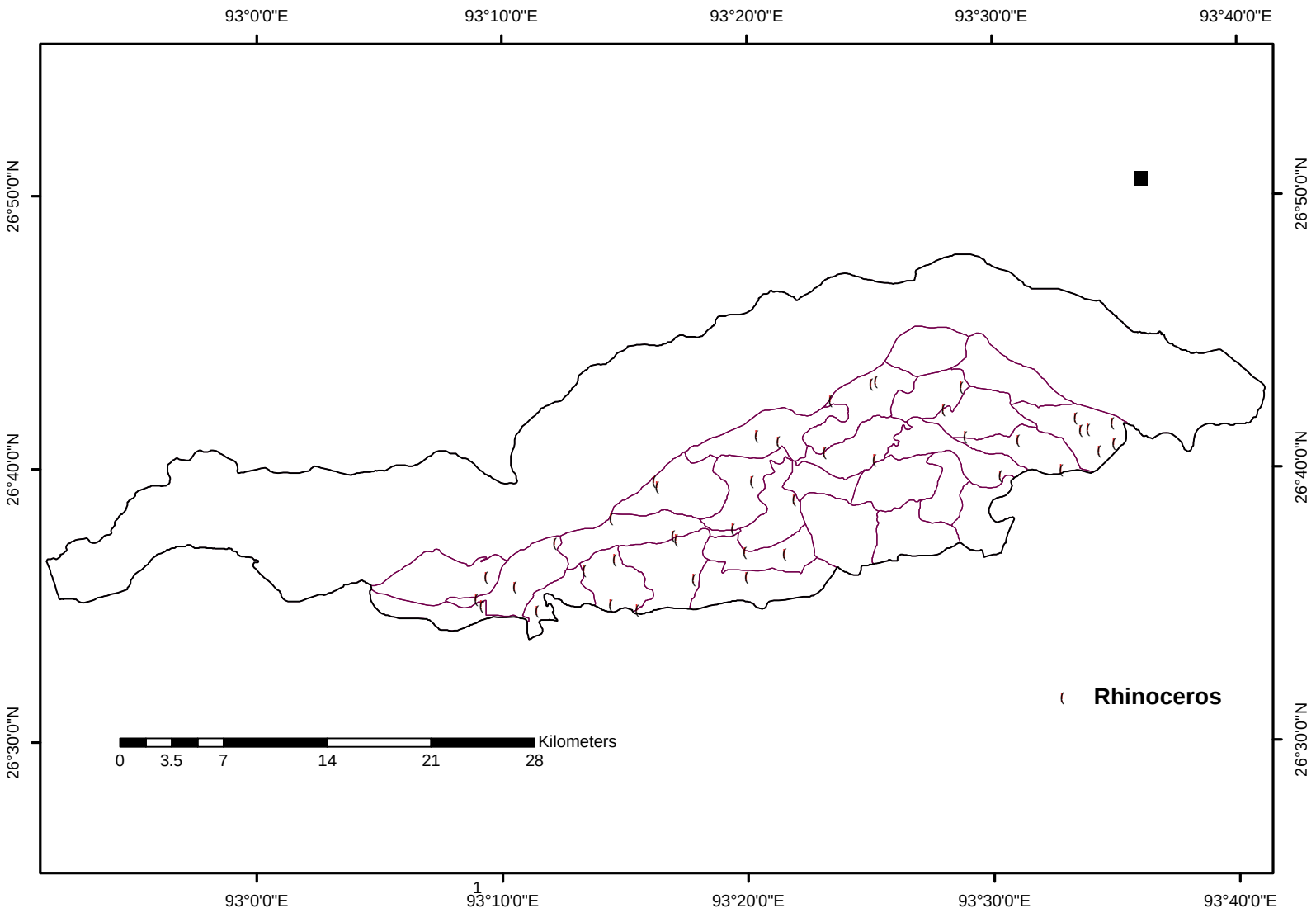


Fig. 22: Rhinoceros distribution.

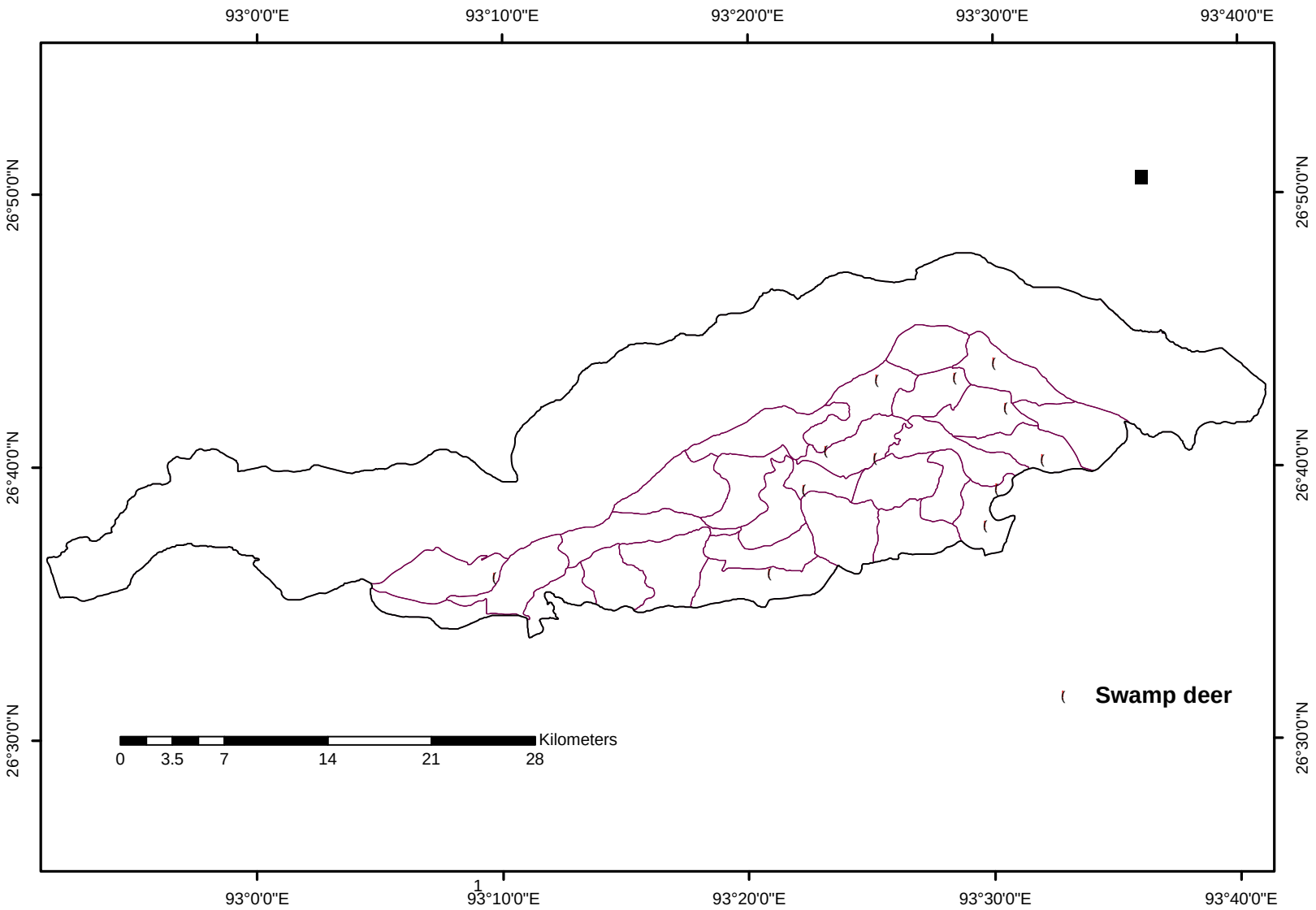


Fig. 23: Swamp deer distribution.

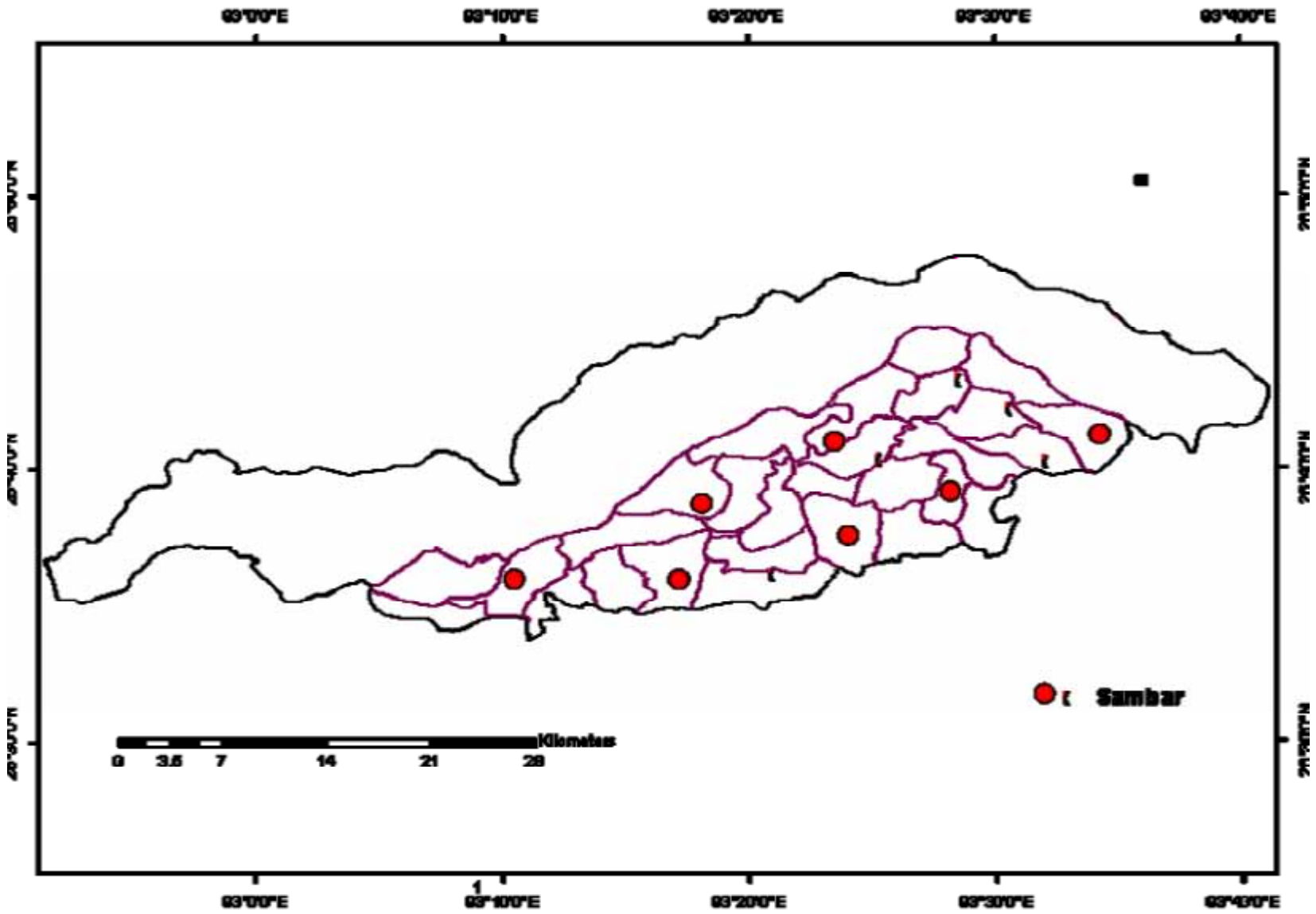


Fig. 24: Sambar distribution.

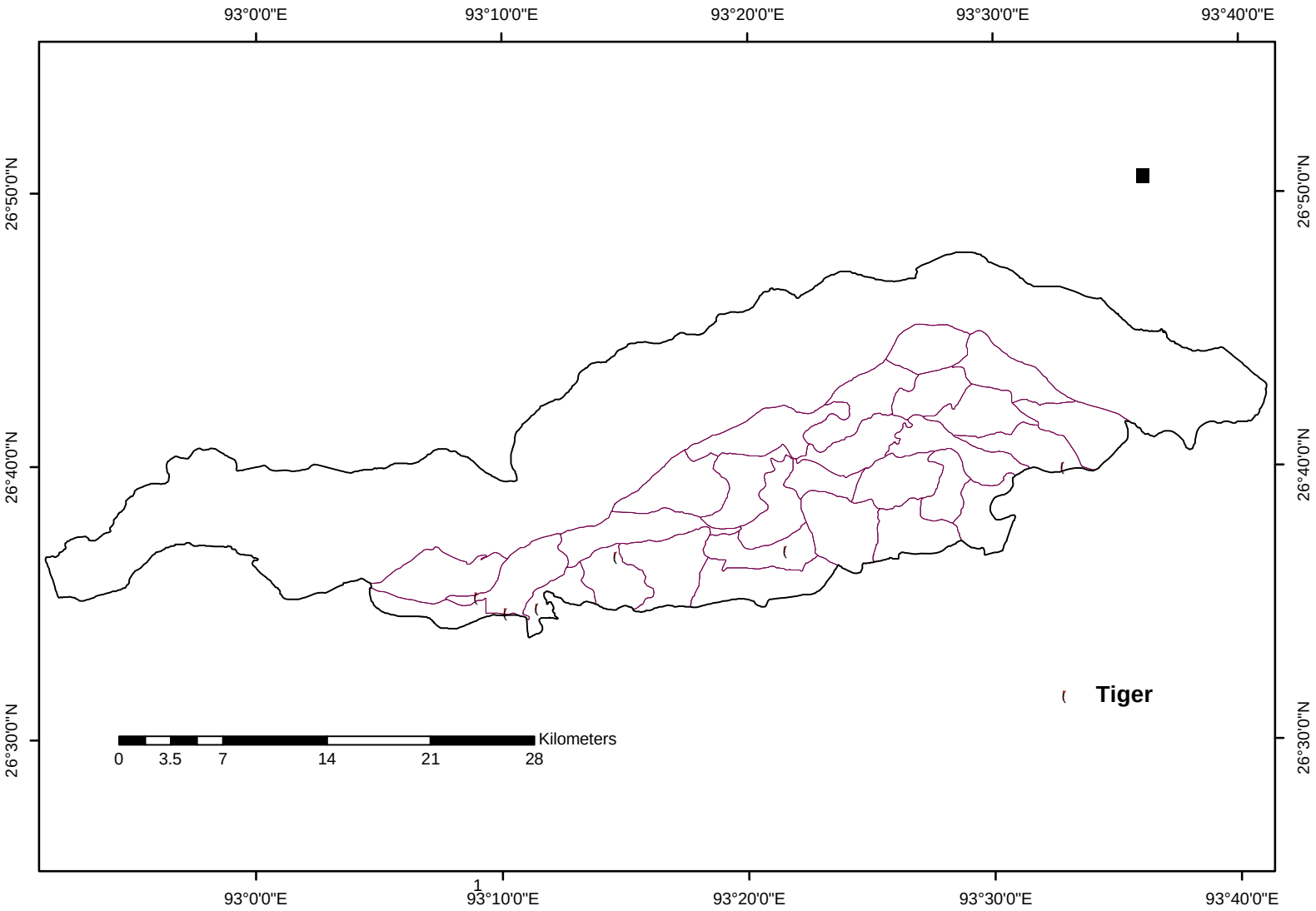


Fig. 25: Tiger distribution.

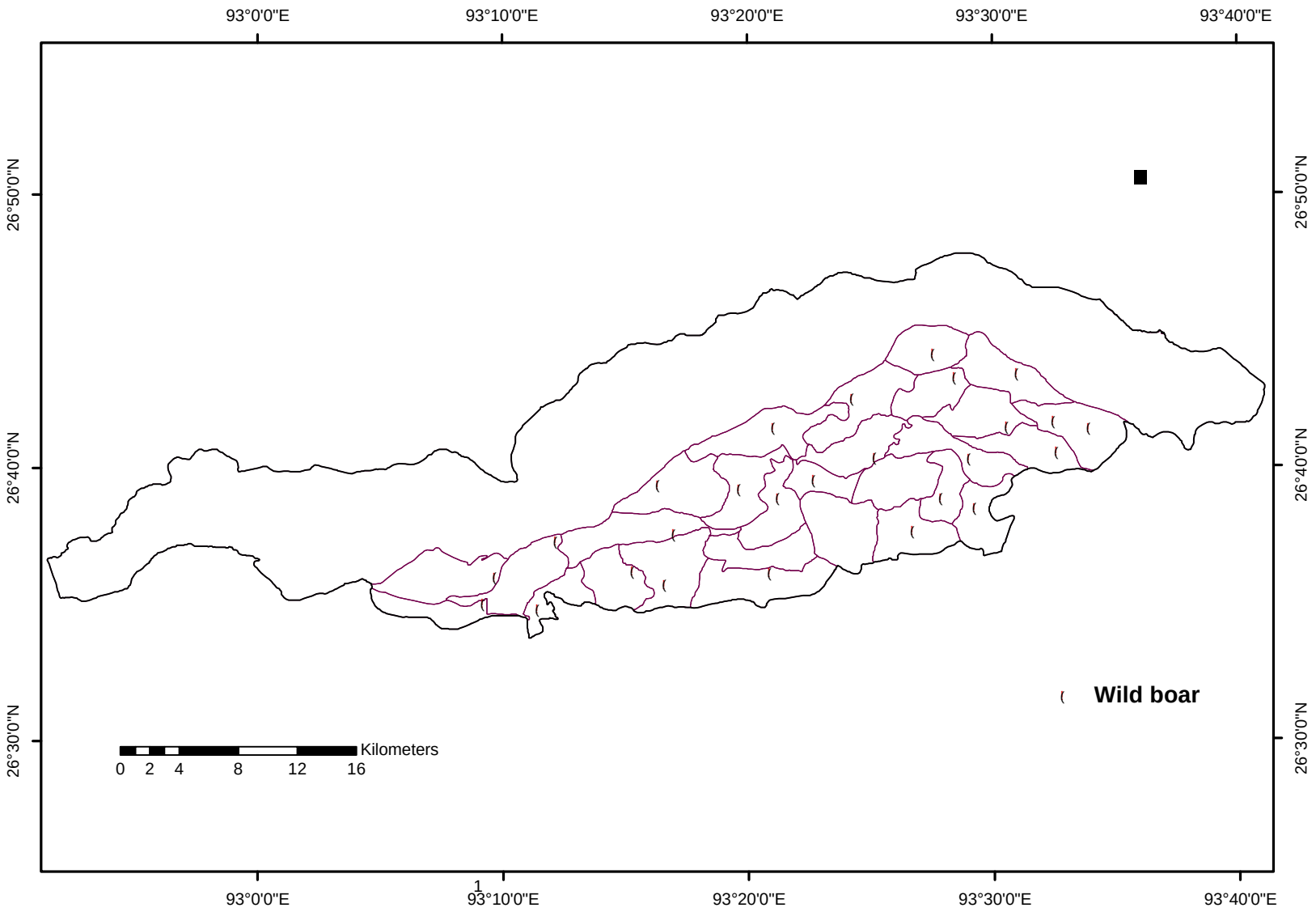


Fig. 26: Wild boar distribution.

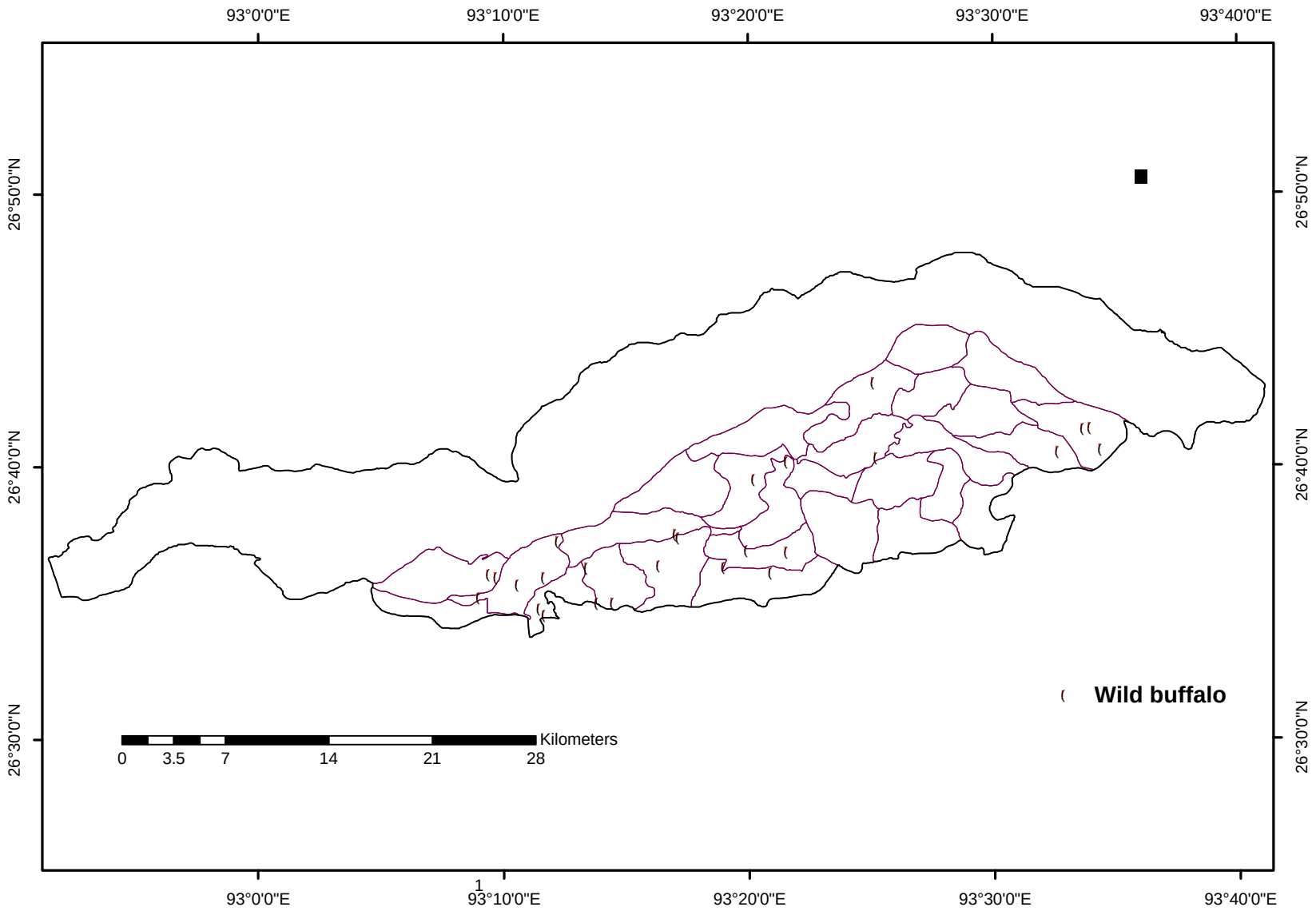


Fig. 27: Wild buffalo distribution.

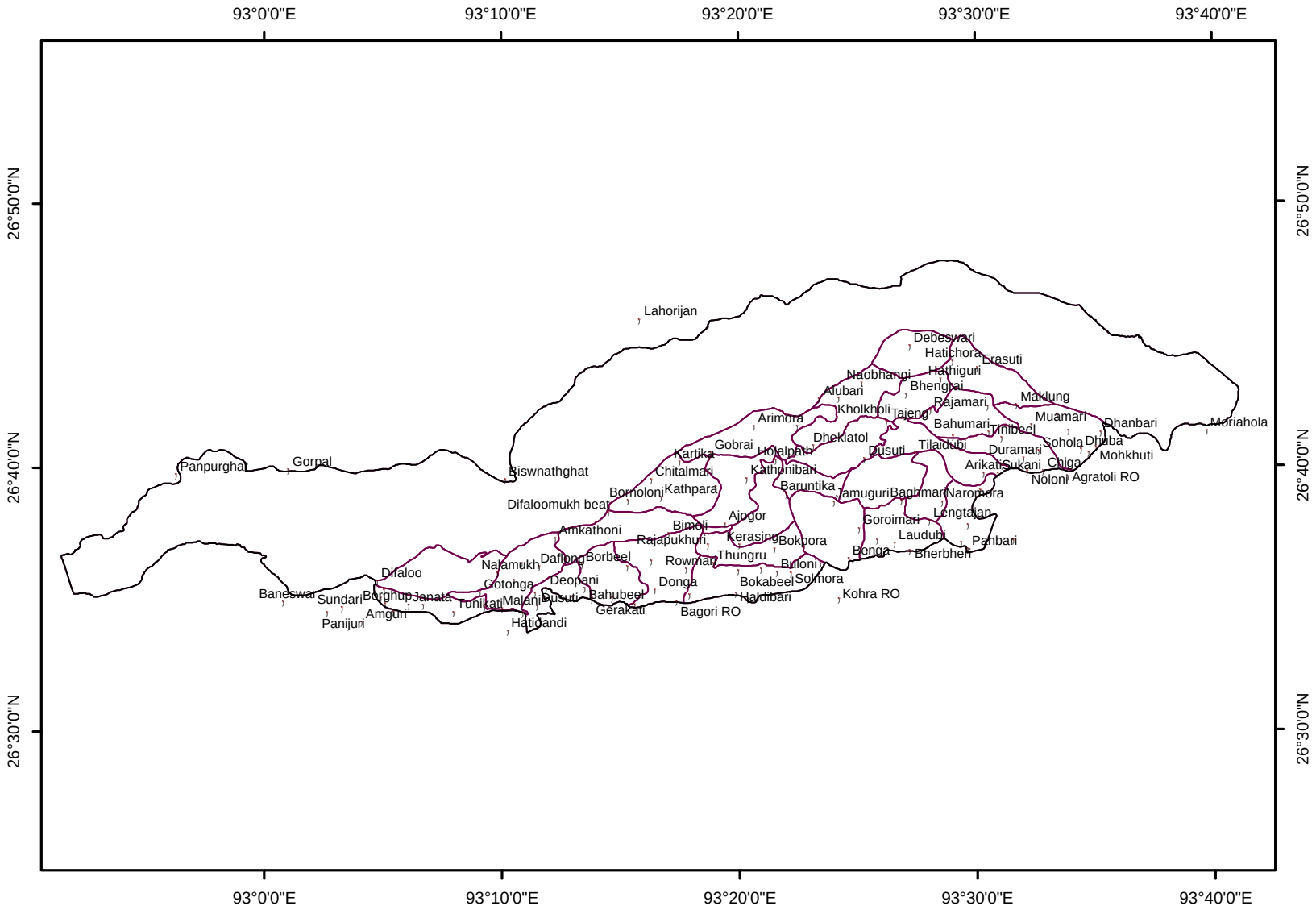


Fig. 28: Protection camps.

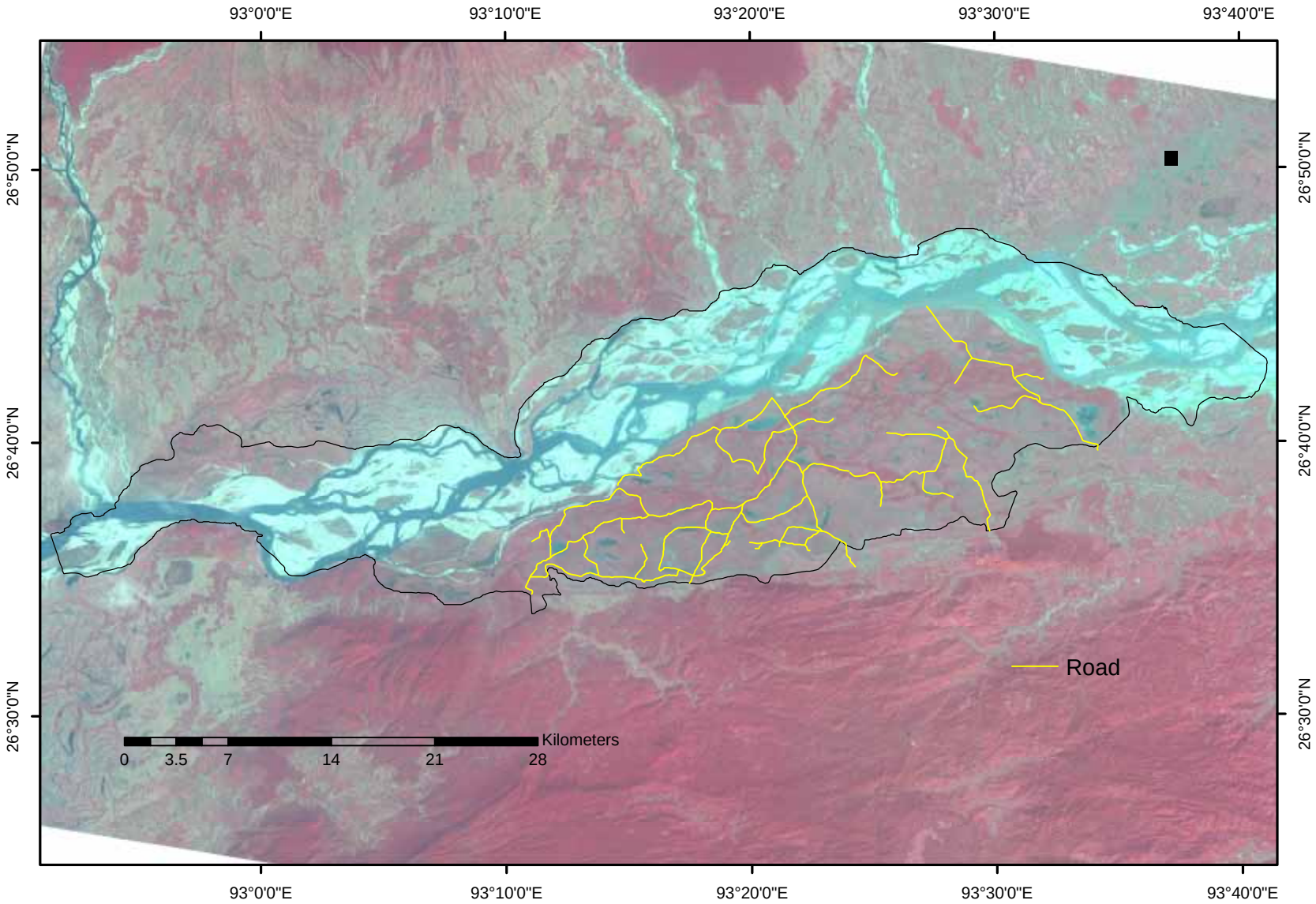


Fig. 29: Jeepable roads (source: SOI).

Fig. 18 to 27 illustrate the distribution of individual wild animal species in the park analysed using data collected in field. The rhino, elephants, hog deer and wild buffalo showed relatively uniform distribution throughout the park except for compartment number 11, 14 and southern part of the compartment 9. The uniform distribution could be attributed to the higher availability of the fodder and higher density of water bodies in the area.

The small number of barking deer was found to be sporadically distributed along southern boundary of Brahmaputra river. Most of them were sited in the central portion than elsewhere. The sambar was noticed more in the elevated areas having intermittent grasses and forests in Agoratoli and Kaziranga ranges compared to Baguri range. The wild boar was noticed throughout the national park while tiger was spotted more in Kaziranga and Baguri ranges.

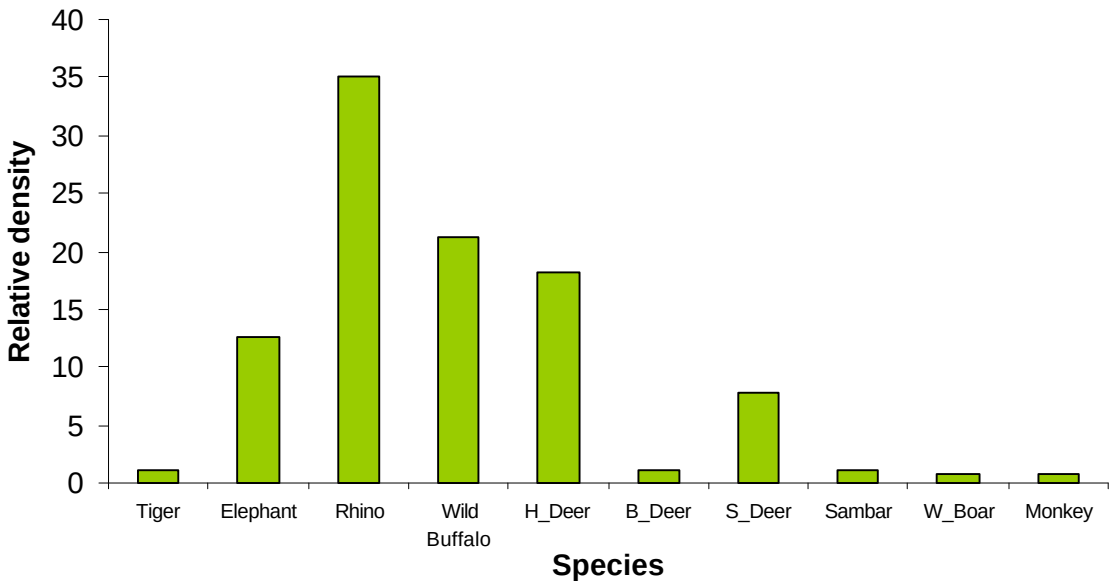


Fig. 30: Relative density of different species.

5.5 Plant Distribution

The density, frequency and importance value index (IVI) of *Crysopogon aciculata* grass was found to be highest followed by *Cynodon dactylon* and *Chenpodium album* in short grass areas. While *Polygonum orientalis* and *Eclipta prostrata* were two most common associates of the above species, the frequency of the former was noticed to be high. A total of eight species were recorded from the short grass areas. The field

inventory was carried out in December month and this is expected to result in somewhat under estimation of species number, density and the frequency.

Table 6: The IVI values of different short grass species.

S.No.	Name of species	Frequency	Abundance	Density	IVI
1.	*Chenopodium album*	100	63.40	63.40	44.37
2.	*Cynodon dactylon*	100	123.00	123.00	67.29
3.	*Polygonum orientalis*	80	8.25	6.60	18.85
4.	*Eclipta prostrata*	60	16.33	9.80	16.99
5.	*Matikundari*	20	13.00	2.60	6.95
6.	*Chrysopogon aciculata*	100	301.60	301.60	135.95
7.	*Lantana camara*	20	4.00	0.80	4.91
8.	*Mikania micrantha*	20	3.00	0.60	4.68

Table 7: Density, frequency, dominance and IVI of tree species.

S.No	Name of species	Frequency	Density	Dominance	IVI
1.	*Bischofia javanica*	46.15	2.00	0.08	23.47
2.	*Lagerstroemia flos-reginae*	53.85	6.15	0.08	39.25
3.	*Albizzia Lebbek*	53.85	1.46	0.24	38.76
4.	*Bombx ceiba*	38.46	1.46	0.11	23.56
5.	*Lagerstroemia parviflora*	7.69	0.23	0.01	2.77
6.	*Dalenia pulchera*	7.69	0.08	0.00	1.89
7.	*Ficus benjamina*	15.38	0.85	0.03	8.65
8.	*Chikrassia velutina*	23.08	1.00	0.06	13.68
9.	*Ficus geniculata*	46.15	1.38	0.06	19.15
10.	*Ficus lepidosa*	15.38	0.38	0.01	5.14
11.	*Cryptocarya amygdalina*	38.46	2.38	0.03	18.12
12.	*Mesua ferrea*	15.38	0.23	0.01	4.35
13.	*Albizzia procera*	23.08	0.77	0.04	11.16
14.	*Mangifera sylvatica*	15.38	0.23	0.01	4.40
15.	*Duabanga sonneratioides*	15.38	0.31	0.02	6.22
16.	*Emblica officinalis*	15.38	0.15	0.00	3.65
17.	*Tetrameles nudiflora*	61.54	6.38	0.15	49.12
18.	*Dillenia indica*	15.38	0.31	0.01	4.68
19.	*Alstonia scholaris*	7.69	2.54	0.01	10.79
20.	*Dalbergia sissoo*	7.69	0.62	0.06	9.71

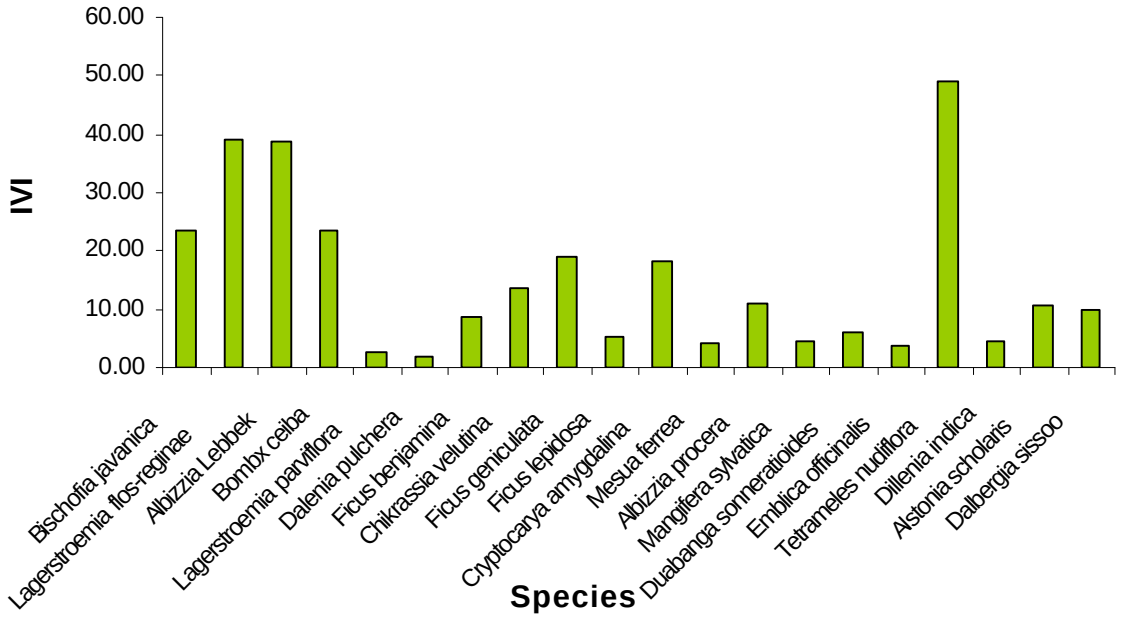


Fig. 31: The IVI values of different tree species.

A total of 20 tree species were encountered in Kaziranga National Park. The *Lagerstroemia flos-reginae* and *Tetrameles nudiflora* had highest density while *Albizia lebbek* had highest basal cover. *T. nudiflora* had highest frequency (61.54%). The other species were *Bischofia javanica, Bombax ceiba, Lagerstroemia parviflora, Dalenia pulcherra, Ficus benjamina, Chikrassia velutina, Ficus geniculata, Ficus lepidos, Cryptocaria amygdalina, Mesua ferrea, Albizzia procera, Mangifera sylvatica, Duabanga sonneratioides, Emblica officinalis*, *Dillenia indica*, *Alstonia scholaris* and *Darbergia sissoo*. The importance value index worked out to be the highest for *T. nudiflora*, while least IVI was noticed in case of *Dalenia pulchera*. The trees in moist area were often noticed having profuse growth of cane.

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ANNEXURE-1

Protection camps in Kaziranga National Park:

Sl. No.	Range	Name of the Camp
1.	KR	Mihimukh
2.	KR	Benga
3.	KR	Goroimari
4.	KR	Bordoloni
5.	KR	Laudubi
6.	KR	Teteliguri
7.	KR	Jamuguri
8.	KR	Dusuti
9.	KR	Tajeng
10.	KR	Bhengrai
11.	KR	Holalpath
12.	KR	Baruntika
13.	KR	Solmora
14.	KR	Hatikhuli Borbeel
15.	KR	Bokabeel
16.	KR	Haldibari East
17.	KR	Haldibari
18.	KR	Sildubi
19.	KR	Haldibari pahar
20.	KR	Arimora
21.	KR	Hanuman Langurgur
22.	KR	Gobrai
23.	KR	Kartika
24.	KR	Ajogor
25.	KR	Dhekiatoli
26.	KR	Methunmari
27.	KR	Naobhangi
28.	KR	Naste
29.	KR	Thungru
30.	KR	Kholkholi
31.	KR	Hawk Float
32.	KR	Kaziranga Beat
33.	KR	Lengtajan
34.	KR	Baghmari
35.	KR	Tilaidubi
36.	KR	Panbari
37.	KR	Bherbheri
38.	KR	Naromora
39.	KR	Bheroni
40.	KR	Mikirjan
41.	KR	Moderjuri
42.	KR	Naharkathoni
43.	KR	Bejbejia
44.	KR	Korne
45.	KR	Alubari
46.	KR	Bokpora
47.	KR	Kerasing
48.	KR	Buloni
49.	WR	Harmoti No.1
50.	WR	Gerakati
51.	WR	Deopani
52.	WR	Borbeel
53.	WR	Bimoli
54.	WR	Gendamari
55.	WR	Baghmari
56.	WR	Murphuloni
57.	WR	Bhaisamari
58.	WR	Rowmari
59.	WR	Difaloomukh beat
60.	WR	Bornoloni
61.	WR	Kathpara
62.	WR	Chitalmari
63.	WR	Rowmari
64.	WR	Amkathoni
65.	WR	Murkhowa
66.	WR	Samrat
67.	WR	Gotonga
68.	WR	Lohoroni
69.	WR	Kawaimari
70.	WR	Nalamukh
71.	WR	Daflong
72.	WR	Bherbheri
73.	WR	Dusuti
74.	WR	Kanchanjuri
75.	WR	Hatidandi
76.	WR	Burapahar Beat
77.	WR	Rajapukhuri
78.	WR	Bholukajan
79.	WR	Donga
80.	WR	Malani
81.	WR	Ajarkathoni
82.	WR	S.C. Rowmari
83.	WR	Borakata
84.	ER	Tinibeel
85.	ER	Duramari
86.	ER	Muamari
87.	ER	Turturani
88.	ER	Dhuba
89.	ER	Mohkhuti

Sl. No.	Range	Name of the Camp
90.	ER	Dhanbari
91.	ER	Balipukhuri
92.	ER	Mohpora
93.	ER	Maklung
94.	ER	Tamulipathar Beat
95.	ER	Arikati
96.	ER	Demow
97.	ER	Natun Beel
98.	ER	Bor Beel
99.	ER	Bahumari
100.	ER	Rangamatia Beat
101.	ER	Naloni
102.	ER	Rajamari
103.	ER	Ahotguri
104.	ER	Erasuti
105.	ER	Belipara
106.	ER	Debeswari

Sl. No.	Range	Name of the Camp
107.	ER	Hatichora
108.	ER	Chiga
109.	ER	Sohola
110.	ER	Gerela
111.	ER	Thute
112.	ER	Noloni
113.	BR	Tunikati
114.	BR	Baneswar
115.	BR	Gorakati
116.	BR	Borghup
117.	BR	Diphlu
118.	BR	Kathalchang
119.	BR	Chirang
120.	BR	Lohoroni
121.	BKT	Moriahola
122.	6th Addn.	Biswanathghat

Proposed protection camps:

Sl. No.	Range	Name of the Camp
1.	KR	Bihdia
2.	KR	Behena
3.	KR	Kachu Kathoni
4.	KR	Dolamora
5.	KR	Jhalki
6.	KR	Magurmari
7.	KR	Halwa
8.	KR	Kathalguri
9.	KR	Englengpathar
10.	WR	Hermoti No.2
11.	WR	Sukani
12.	WR	Dherapara
13.	WR	Pengajan
14.	WR	Bahubeel

Sl. No.	Range	Name of the Camp
15.	WR	Rotikhowa
16.	WR	Soisola
14.	ER	Modarjuri
15.	BR	Natun Danga
16.	BKT. Beat	Borbhata
17.	BKT. Beat	Lokhowjan
18.	6th Addn.	Panpurghat
19.	6th Addn.	Garhpal
20.	6th Addn.	Tiwaripal
21.	6th Addn.	Chitalmari
22.	6th Addn.	Bholakata
23.	6th Addn.	Kathanibari
24.	6th Addn.	Monabari
25.	6th Addn.	Laletapu

KR - Kaziranga Range, Kohora
WR - Western Range, Baguri
ER - Eastern Range, Agratoli
BR - Burapahar Range, Ghorakat
BKT - Bokakhat