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Identification of Swamp Deer (*Cervus duvauceli duvauceli* Cuvier) Potential Habitat in Jhilmil Jheel Conservation Reserve, Uttarakhand, India Using Multi-Criteria Analysis

S. Nandy · S. P. S. Kushwaha · Priyanka Gaur

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Abstract The present study aims to identify the potential habitat for swamp deer (*Cervus duvauceli duvauceli* Cuvier) in Jhilmil Jheel Conservation Reserve in the Uttarakhand province of India using multi-criteria analysis. The study area represents one of the last remnant habitats of the flagship species, the swamp deer in Uttarakhand, which is considered as vulnerable. The study showed that only 6.08% of the study area (225 km^2) was highly suitable to suitable for the swamp deer. An area of 135.52 km^2 (60.23%) turned out to be moderately suitable. Within the officially designated Conservation Reserve (area 37.84 km^2), 10.91% (4.13 km^2) area was found highly suitable to suitable, while 74.19% (28.07 km^2) happens to be moderately suitable. Only 14 km^2 area, which was found as suitable habitat for swamp deer falls short of the space required by a population of 134 animals. The problem could be mitigated if the agricultural land (2.47 km^2) adjacent to the Jhilmil Jheel is brought under the Reserve management. This would provide additional area to meet the fodder requirement. The study brings out a particularly grim situation with limited options for conservation and management of the swamp deer in the Indo-Gangetic plains. It also emphasizes the role of geospatial techniques in quick appraisal of habitat attributes and identification of potential sites for protected areas.

Keywords Swamp deer · Habitat · Suitability · Conservation · Geospatial techniques · AHP

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Introduction

Wilderness areas and the wildlife habitats throughout the world are shrinking due to ever-increasing pressure from anthropogenic activities. The unprecedented growth of human population and the resultant commercial exploitation has been a prime cause of the decline of the wildlife in India (Alfred and others 2001; Kushwaha and Roy 2002). With the passage of time, the human influence on habitats is alarming. The cases of encroachment of habitats and activities like poaching and grazing are threatening the majority of wildlife species and their habitats in India. Species are said to be a product of their habitat (Smith 1974) and, hence, maintenance of appropriate habitat is vital to wildlife management (Thomas and others 1979). Habitat evaluation is the first step towards meaningful wildlife conservation and management. Evaluation of any habitat for its suitability or unsuitability for a particular species requires information on a host of parameters including food, water and shelter. The last one is related to the physical conditions of the habitat like type of vegetation cover, slope and aspect (Panwar 1991). Much interest has been shown in recent years towards protection and conservation of wildlife at various levels (Kushwaha and Roy 2002). The work on conservation and management of wildlife is often hampered due to non-availability of data on species presence and habitats occupied (Kushwaha and Roy 2002).

There has been emphasis on the use of standardized procedures for identification of potential habitat, both for economical and ecological reasons among various organizations and professionals. This emphasis on standardization of inventories and evaluations was one of the reasons why the habitat evaluation procedure (HEP) was developed (initially by the U.S. Fish and Wildlife Service) for use in

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the evaluation of water and related land resources development projects (Anonymous 1980). The U.S. Fish and Wildlife Service has developed several habitat suitability models for a large number of fish and wildlife species, which is the most comprehensive database anywhere in the world (Anonymous 1981).

The quickest, most cost-effective and accurate way for identification of potential/suitable habitat is through the application of geospatial technologies, which include remote sensing and geographic information system (GIS) combined with the global positioning system (GPS). Ground methods, derived through intensive ground surveys, have been used since time immemorial to evaluate the habitats using various indices (Lamprey 1963). The ground-based methods have a specific limitation in that the whole targeted area cannot be traversed and the information collected may not be accurate and adequate. While ground surveys such as counting animals, trapping, collection of droppings, investigations of feeding sites as well as ground mapping of habitats (Giles 1978; Lamprey 1963) are useful, the geospatial technology can supplement or circumvent tedious ground survey methods. The geospatial technology has been used as an invaluable tool in wildlife studies ranging from habitat evaluation (George and others 1977; Bright 1984; Hill and Kelly 1987; Kushwaha and others 2001; Kushwaha and Hazarika 2004), suitability analysis (Kushwaha and others 2000; Beier and others 2008), human-animal conflict (Musavi and others 2006), and wildlife corridor monitoring (Khanna and others 2001; Nandy and others 2007). Potential habitat identification is a tool for predicting the suitability of habitat for a given species based on the known affinities with habitat characteristics. One of the techniques used for this purpose is Habitat Suitability Index (HSI) modeling. A suitability index provides a probability that the habitat is suitable for the species, and hence a probability that the species will occur where that habitat occurs. If the value of the index is high on a particular location, then the chance of species occurrence is greater. HSI models use geo-statistics (Kushwaha and others 2004; Habib and others 2010), logistic regression (Zarri and others 2008; Imam and others 2009), refined logistic regression (Singh and Kushwaha 2011), multi-criteria analysis using analytical hierarchy process (AHP) (Nekhaya and others 2009; Goswami 2010) and other data integration techniques to calculate an index of species occurrence (Clark and others 1999; Brown and others 2000) and provide an efficient and inexpensive method for determining habitat quality (Schamberger and Krohn 1982).

The present study attempts to use the geospatial technologies for identification of potential habitat of swamp deer (*Cervus duvauceli duvauceli* Cuvier) in Jhilmil Jheel Conservation Reserve in Haridwar district of Uttarakhand province of India. Once abundant throughout the tall and wet grasslands of the north Indian *terai*, the Brahamaputra flood plain, and the central Indian grasslands bordering sal (*Shorea robusta* Roxb. ex Gaertn.f.) forests, the swamp deer is now classified as vulnerable by IUCN (2004). Three sub-species of swamp deer viz., *C. duvauceli duvauceli*, *Cervus duvauceli branderi* (Pocock 1943) and *Cervus duvauceli ranjitsinhii* (Groves 1982) have been identified. Schaller (1967) reported swamp deer from fifteen localities in India of which eleven were in Uttar Pradesh, three in Assam and one in West Bengal provinces. At present, the swamp deer exists in six localities in Uttar Pradesh, two in Assam and nil in West Bengal. Schaller (1967) and Qureshi and others (1995) reported the distribution of swamp deer in India. Presently, *duvauceli* is restricted to Jhilmil Jheel Wildlife Conservation Reserve in Haridwar, Hastinapur Wildlife Sanctuary, Pilibhit Forest Division, Kishanpur Wildlife Sanctuary, Dudhwa National Park, Katerniaghat Wildlife Sanctuary in Uttar Pradesh in India and Sukla Phanta Wildlife Reserve and Karnali-Bardia Reserve in Nepal. Schaff (1978) studied the population size, structure and habitat relations of the *duvauceli* in Sukla Phanta Wildlife Reserve, Nepal. The *ranjitsinhii*, at present, is found only in Assam; populations persist in Kaziranga National Park though the status in Manas Tiger Reserve is uncertain. The *branderi*, at present, is found only in Kanha Tiger Reserve in Madhya Pradesh (Anonymous 2005). Martin (1977) studied the status and ecology of *branderi* in Kanha National Park, India. The species largely feeds on grasses and the aquatic plants. It is mostly found in marshy and swampy areas such as reed beds, marshes and also along the rivers. With the destructions of much of its original habitat, the species is now seen in isolated protected forests, the habitat islands. The Jhilmil Jheel was declared as Swamp Deer Conservation Reserve by Uttarakhand Forest Department in 2005. Approximately 134 individuals of *C. duvauceli duvauceli* were reported during a census in Jhilmil Jheel Wildlife Conservation Reserve in 2007 (R. Tewari, pers. comm.). Declaration of Jhilmil Jheel as a Conservation Reserve for swamp deer not only provides a focused approach to protect the species but also allows effective management and conservation of the habitat. The area represents one of the last remnants of *terai* habitat and its representative fauna, especially the swamp deer as a flagship species.

Materials and Methods

Study Area

An area of 15 km × 15 km (225 km^2) (29°32'–29°50'N and 78°00'–78°15'E) with Jhilmil Jheel at its centre

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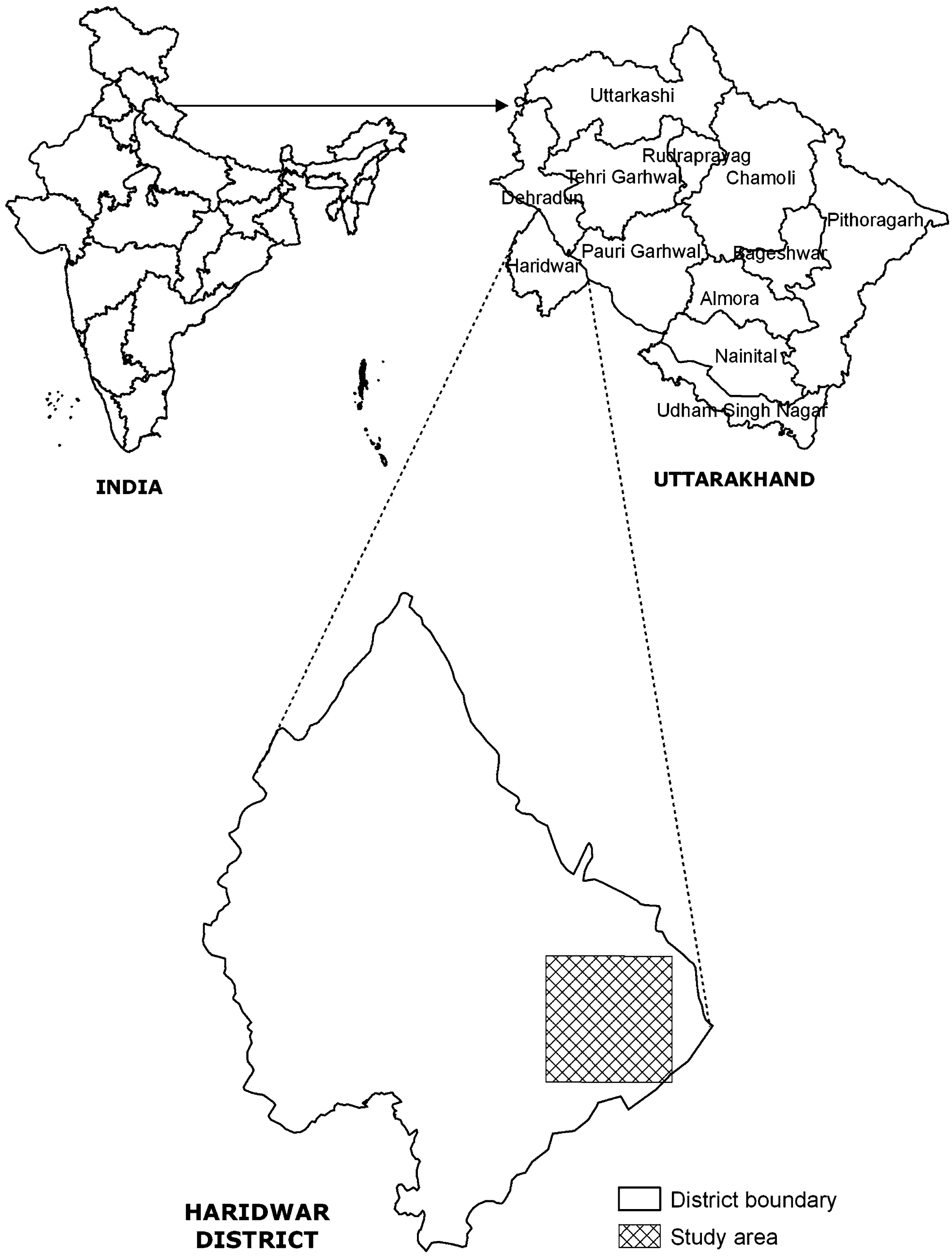

Fig. 1 Location of Jhilmil Jheel Conservation Reserve in India

(Fig. 1) was used for this study. Jhilmil Jheel, a saucer-shaped wetland situated on the left bank of the river Ganga, is located between the Haridwar–Nazibabad Highway and the natural course of river Ganga in Chidiyapur Range of Haridwar Forest Division, Uttarakhand. Jhilmil Jheel receives water from the northerly formations of the Shiwaliks of Chidiyapur Range or even further beyond as underground streams (sub-surface flow), as well as from the floods of the river Ganga. A tributary of Ganga named Rawasan river directly drains the area. The Jheel area drains directly into the Ganga. The altitude in the area varies from 200 to 300 m above m.s.l. Thirty-one villages are located within the study area. The nearest village, Dudhia Diyalwala (Tatwala), is adjacent to Jhilmil Jheel. It consists of 130 households, mostly comprising migrant farmers from Punjab, Himachal Pradesh and Garhwal. The Jhilmil Jheel Conservation Reserve is divided into three blocks viz. Nalowala, Ganga and Amsot, which are further divided into fourteen compartments (Fig. 2).

The conservation area is located at the junction of the *bhabhar* and *terai* formations extending up to the Ganga. The floodplain of the Ganga is characterized by deep sandy loam soils consisting of coarse sand and stones in shallow patches. The texture of the soil varies from fine sand to clayey loam. The central reserve area is a wetland, which gets submerged during the monsoon months (July–September). A number of

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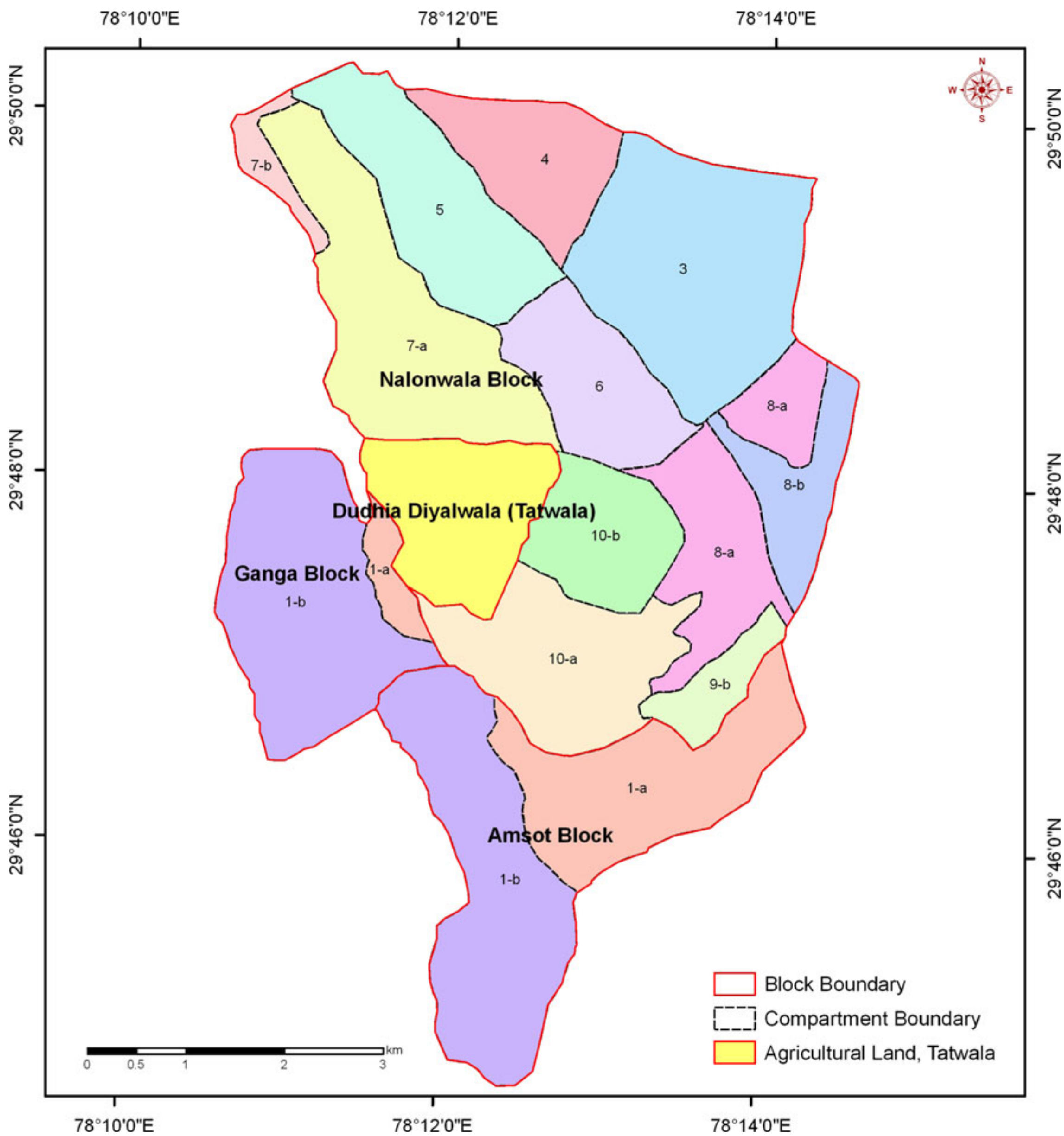

Fig. 2 Jhilmil Jheel Conservation Reserve map

small rivulets emerge from the surrounding forests and discharge into Jhilmil Jheel. The area experiences subtropical climate, coldest month being January when temperature dips as low as 2°C. Summer is hot and humid, when temperature soars up to 44°C, often accompanied by frequent dust storms. Average annual rainfall in the area is 1,800 mm and most of the rain falls between July and September.

No detailed floristic studies have been conducted in the Jhilmil Jheel area and its adjoining forests. The swampy Jhilmil Jheel area shows the dominance of *Typha elephantina* Roxb., *T. angustifolia* Watt and *Phragmites karka* Trin. ex Steud., typical of upper Gangetic flood plain habitat. A few grassy patches dominated by *Cynodon dactylon* Pers. and *Imperata cylindrica* Beauv. form the regular grazing ground for local livestock. The borders of swamp have tree species viz., *Emblica officinalis* Gaertn., *Ficus bengalensis* Linn., *Azadirachta indica* A. Juss., *Anogeissus latifolia* Wall. ex Bedd., *Streblus asper* Lour., *Adina cordifolia* Benth. & Hook.f., *Acacia catechu* Willd., *Dalbergia sissoo* Roxb. and *Ziziphus nummularia* (Burm.f.) Wight & Arn.. The dominant land cover types include grassland, moist deciduous forest, khair–shisham forest, scrub, and various types of forest plantations.

The area is rich in faunal diversity including five species of deer viz. spotted deer (*Axis axis* Erxl.), sambar (*Rusa*

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unicolor Kerr), barking deer (*Muntiacus muntjak* Raf.), hog deer (*Axis porcinus* Zimm.), swamp deer, elephant (*Elephas maximus* L.), nilgai (*Boselaphus tragocamelus* Pallas) and wild boar (*Sus scrofa* L.). Common leopard (*Panthera pardus* L.) and occasionally tiger (*Panthera tigris* L.) are also seen in the area. Avifauna includes a large number of resident and winter migratory birds. The shallow water with swampy habitat in Jhilmil Jheel also attracts a variety of water fowls. More than 30 species of both migratory and resident birds have been recorded in this area. The forest edge around Jhilmil Jheel is extremely rich in fauna, especially the python and the entomofauna. Another striking feature of the area is the presence of very high concentration of honeybees (Anonymous 2005).

Methods

The methodology adopted for the present study is shown in Fig. 3. The IRS P6 LISS-4 false colour composite (FCC) satellite imagery of 26 February 2005 with a spatial resolution of 5.8 m (Fig. 4) and ancillary data viz., Survey of India topographic maps and forest management maps were used. Radiometric correction of the satellite imagery was done using dark pixel subtraction technique (Lillesand and Kiefer 2000). Images were then geometrically corrected using topographic maps. The common uniformly distributed ground control points (GCPs) were taken with root mean square error of less than one pixel and the image was resampled using cubic convolution method in Universal Transverse Mercator (UTM) projection and WGS 84 datum. A 15 km $\times$ 15 km study area was taken up keeping Jhilmil Jheel as centre. The study area FCC was then extracted from satellite imagery. The FCC was taken to the field to relate the image characteristics with the ground features. Information on the pattern and distribution of vegetation, its composition etc. was also collected during field work. The image was on-screen visually interpreted for vegetation types/land uses using image elements viz.

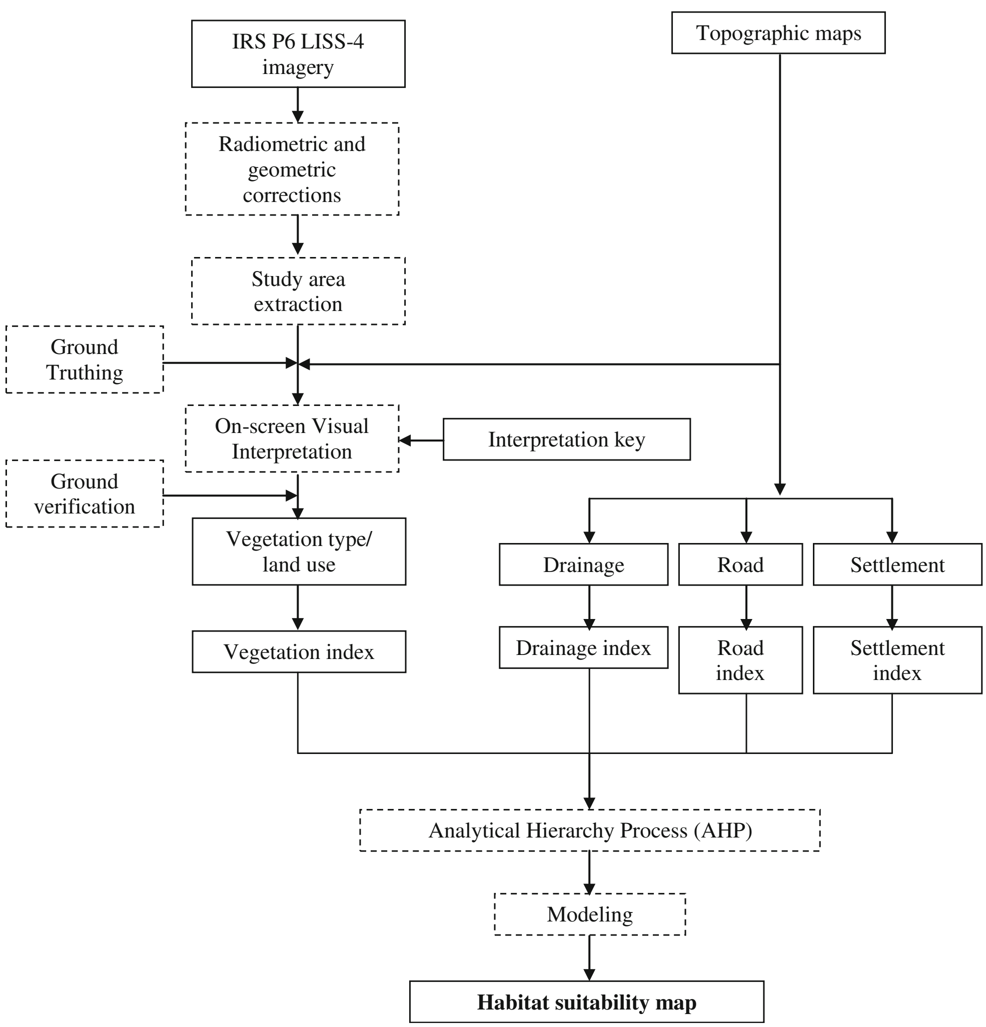

Fig. 3 Paradigm of the study

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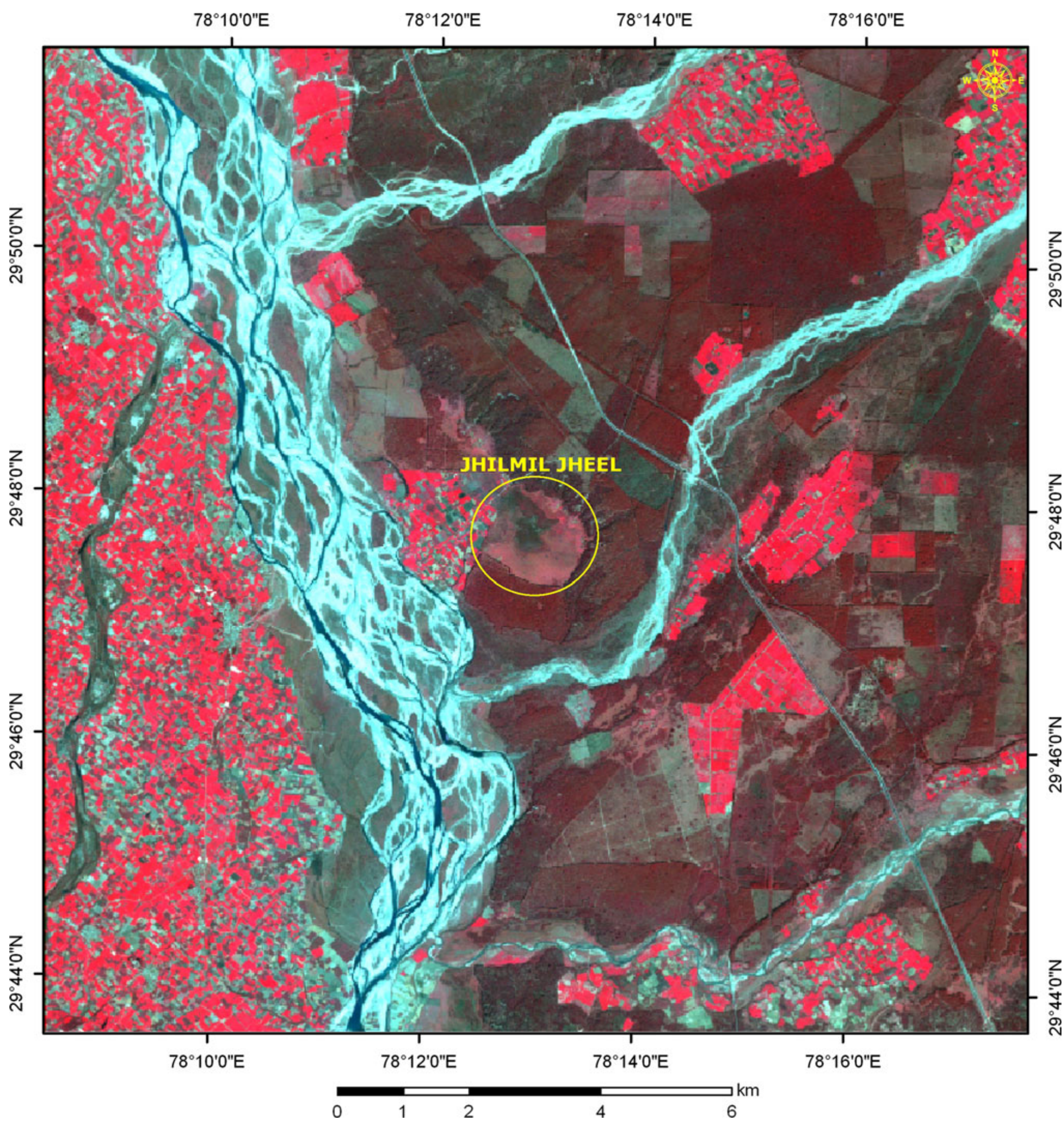

Fig. 4 IRS P6 LISS-4 FCC of 26 February 2005 of the study area

tone, texture, pattern, shape, size, shadow, location and association. The interpreted image was field-verified for classification accuracy assessment. A GPS receiver was used during the fieldwork to mark the locations of various features including presence of swamp deer. Digital database of vegetation types/land uses, drainage, settlement, road etc., was prepared in GIS environment. Different categories of thematic layers were rated into habitat values by assigning habitat quality rating (HQR) based on their suitability on a scale of 1–4 in decreasing order of suitability (value 1 was assigned to highly suitable habitat while four to least suitable). Buffer maps were prepared for drainage and settlement and HQR was assigned to different buffers. After rating all thematic layers into four suitability classes, a linear additive model was run to evaluate the potential habitats for swamp deer. Weights assigned to different layers were derived using AHP, a decision-aiding tool developed by Saaty (1980).

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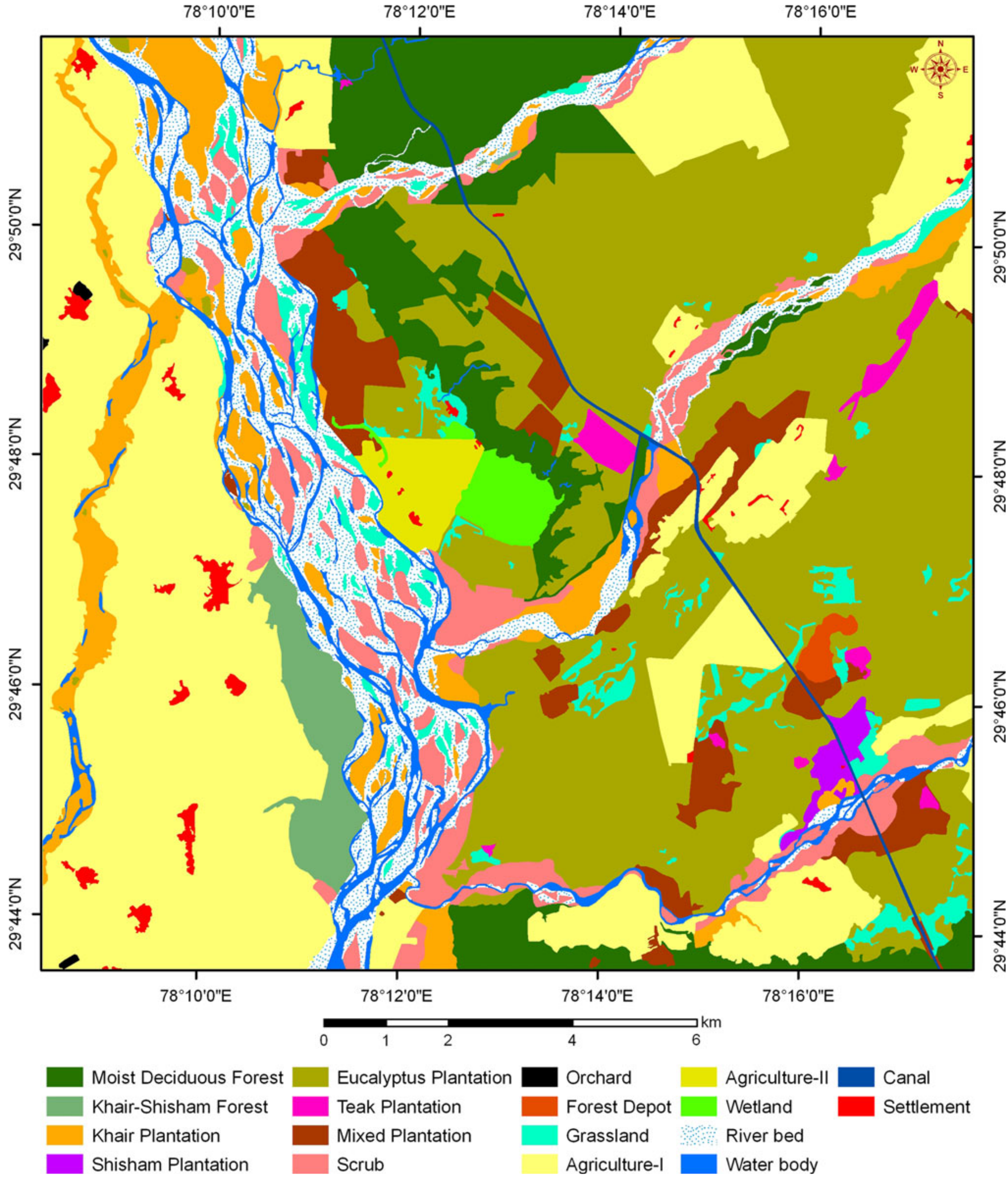

Fig. 5 Vegetation type/land use map of the study area

The various vegetation types/land uses are shown in Fig. 5. Table 1 shows the area under different vegetation types/land uses categories. The overall accuracy of the vegetation type/land use map worked out to be 91.22%. Five types of forest plantations were found in the study area viz. *Eucalyptus* plantation, khair (*A. catechu* Willd.), shisham (*D. sissoo* Roxb.), teak (*Tectona grandis* L.f.) and mixed plantation. The *Eucalyptus* plantations were found

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to be the dominant vegetation in the area followed by agricultural land and the moist deciduous forest. About 30.47% area was classified as *Eucalyptus* plantations (differently aged) and 27.29% area as agriculture-I (agricultural area away from the Jheel proper). There are two types of forests in the study area viz., moist deciduous forest and khair–shisham forest having 8.27 and 1.74 per cent of the area respectively, former being close to Jhilmil Jheel while the latter near rivulets. An area of 3.12% is covered by waterbody while 7.75% of the area is covered by riverbed; canal and forest depot covered 0.40 and 0.24% of the area respectively. The area under wetland category was found to be 1.82 km^2 i.e. 0.81% of the total study area while the area under agriculture-II (part of swamp area adjacent to Jheel, currently under agriculture) was 2.39 km^2.

A rapid field survey was conducted to collect the presence data of the swamp deer. The systematic random sampling method was followed for placing sampling transects. The survey design was based on the a priori information obtained by interviewing with the forest personnel followed by a pilot survey in the Dudhia Diyalwala (Tatwala) village. The survey revealed that apparent densities of the target species were most abundant in the wetlands and swampy areas followed by grasslands, riverbed, scrub and the forests. In the light of this information, eight linear transects were laid radiating out from the center of the Conservation Reserve. The first transect was oriented towards north. The remaining seven transects were laid in 45° increments to the first. All transects were ~6 km long. This arrangement ensured uniform sampling across all the vegetation types/land uses. In each transect, sampling locations were marked at ~500 m intervals. A 10 m radius circular plot was placed at each sampling location and the area was searched intensively for pellets. In all cases, plots were rejected if pellets were found in advanced stages of decay. Presence of pellet groups and actual sightings of the species were considered as direct evidence of habitat use, and were recorded using a Trimble

Table 1 Area under different vegetation types/land uses

S. no.	Vegetation/land cover type	Area (km^2)	Area (%)
1.	Moist-deciduous forest	18.61	8.27
2.	Khair–Shisham forest	3.92	1.74
3.	Eucalyptus plantation	68.56	30.47
4.	Khair plantation	12.30	5.47
5.	Shisham plantation	0.90	0.40
6.	Teak plantation	1.49	0.66
7.	Mixed plantation	9.29	4.13
8.	Scrub	10.47	4.65
9.	Grassland	6.20	2.75
10.	Orchard	0.11	0.05
11.	Forest depot	0.53	0.24
12.	Agriculture-I	61.40	27.29
13.	Agriculture-II	2.39	1.06
14.	Wetland	1.82	0.81
15.	Waterbody	7.01	3.12
16.	Riverbed	17.45	7.75
17.	Canal	0.90	0.40
18.	Settlement	1.64	0.73
Total		225.00	100.00

Table 2 HQR for vegetation types/land uses, distance to drainage, road and settlement

S. no.	Vegetation type/land use	HQR
1.	Moist deciduous forest	3
2.	Khair–Shisham forest	3
3.	Eucalyptus plantation	3
4.	Khair plantation	3
5.	Shisham plantation	3
6.	Teak plantation	4
7.	Mixed plantation	3
8.	Scrub	3
9.	Orchard	4
10.	Agriculture-I	3
11.	Agriculture-II	1
12.	Wetland	1
13.	Waterbody	3
14.	Grassland	2
15.	Forest depot	4
16.	Canal	4
17.	Settlement	4
18.	Riverbed	3
S. no.	Distance to drainage (m)	HQR
1.	<1,000	1
2.	1,000–2,000	2
3.	2,000–3,000	3
4.	3,000–4,000	4
S. no.	Distance to road (m)	HQR
1.	<1,000	4
2.	1,000–2,000	3
3.	2,000–3,000	2
4.	3,000–4,000	1
S. no.	Distance to settlement (m)	HQR
1.	<1,000	4
2.	1,000–2,000	3
3.	2,000–3,000	2
4.	3,000–4,000	1

1 highly suitable, *2* suitable, *3* moderately suitable, *4* least suitable)

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Juno-SB GPS receiver. At each location, the vegetation type/land use and general terrain characteristics were noted (in a field form). Of a total of 97 surveyed locations, confirmed presence of swamp deer were collected from 46 locations.

Based on the field data, HQR for various vegetation types/land uses was given (Table 2). The areas classified as wetland and agriculture-II, which is adjacent to Jheel, was rated as highly suitable habitat for swamp deer. It was observed that the maximum number of swamp deer was found in marshy/swampy habitats. However, as swamp deer utilizes a variety of habitat types including open forests with grasses, grassland was also considered as potential habitat. Areas classified as waterbody, riverbed, scrub, khair plantation and khair–shisham forests were rated as moderately suitable habitats. The animals were seen also visiting the nearby forests to meet their fodder requirements and hence, moist deciduous forests were considered as moderately suitable habitat. The categories like agricultural land and plantations (except the teak plantation) were considered as being only moderately suitable, as very few presences were recorded from these areas. The land uses like, orchard, forest depot, canal and settlement were rated as least suitable habitats for the swamp deer. This category also included teak plantations; teak plantations do not support understorey vegetation and hence happen to be least suitable habitats.

Four buffer layers, each 1,000 m wide, were generated for drainage, roads and settlements and HQRs were assigned to them. The area close to drainage was considered to be highly suitable (Table 2) as swamp deer is usually found along river or close to the source of water. Swamp deer, on an average, moves only 2–3 km (straight line) daily. In case of road and settlement buffers, the areas near the road and settlement were considered as least suitable area due to high human interference. Being away from road and settlement is considered better (Table 2). After rating all thematic layers into four suitability classes, AHP-derived weights were generated for each layer.

The first step in AHP is the generation of a pair-wise comparison matrix of the different variables. Pair-wise comparison matrix of four variables viz. vegetation type/land use, drainage, road and settlement is shown in Table 3. The pair-wise comparison matrix was then synthesized by dividing each element of the matrix by its column total (Table 4). The priority vector in Table 4 can be obtained by finding the row averages. The weighted sum matrix was calculated following Saaty (1980), the consistency ratio was found out to be 0.025 which is less than 0.1, indicating that the calculation is acceptable according to Saaty's principle. The weights of different variables, obtained from the above analysis, were used in following linear additive model to arrive at the potential habitats for swamp deer:

$$\mathrm{HSI} = 0.563 \times \mathrm{VTI} + 0.267 \times \mathrm{DI} + 0.108 \times \mathrm{RI} + 0.062 \times \mathrm{SI}$$

where, HSI is the Habitat Suitability Index, VTI is the Vegetation Type Index, DI is the Drainage Index, RI is the Road Index, SI is the Settlement Index

Results

Habitat suitability map generated from the above analysis is shown in Fig. 6. An area of 4.63 km^2 (2.06%) was found to be highly suitable while 9.04, 135.52 and 75.81 km^2 areas worked out to be suitable, moderately suitable and least suitable respectively. The 60.23% (135.52 km^2) of the study area was found to be moderately suitable while 33.69% (75.81 km^2) worked out to be least suitable. Only 5.44% (2.06 km^2) of the area of the Conservation Reserve, i.e. Jhilmil Jheel, turned out to be highly suitable habitat for swamp deer while most of the area (74.19%) was found to be moderately suitable (Table 5).

Table 3 Pair-wise comparison matrix

Class	Vegetation type/land use	Drainage	Road	Settlement
Vegetation type/land use	1	3	5	7
Drainage	1/3	1	3	5
Road	1/5	1/3	1	2
Settlement	1/7	1/5	1/2	1
Total	1.676	4.533	9.50	15.00

Table 4 The synthesized matrix

Class	Vegetation type/land use	Drainage	Road	Settlement	Priority vector
Vegetation type/land use	0.597	0.662	0.526	0.467	0.563
Drainage	0.199	0.221	0.316	0.333	0.267
Road	0.119	0.074	0.105	0.133	0.108
Settlement	0.085	0.044	0.053	0.067	0.062
					$\sum = 1.000$

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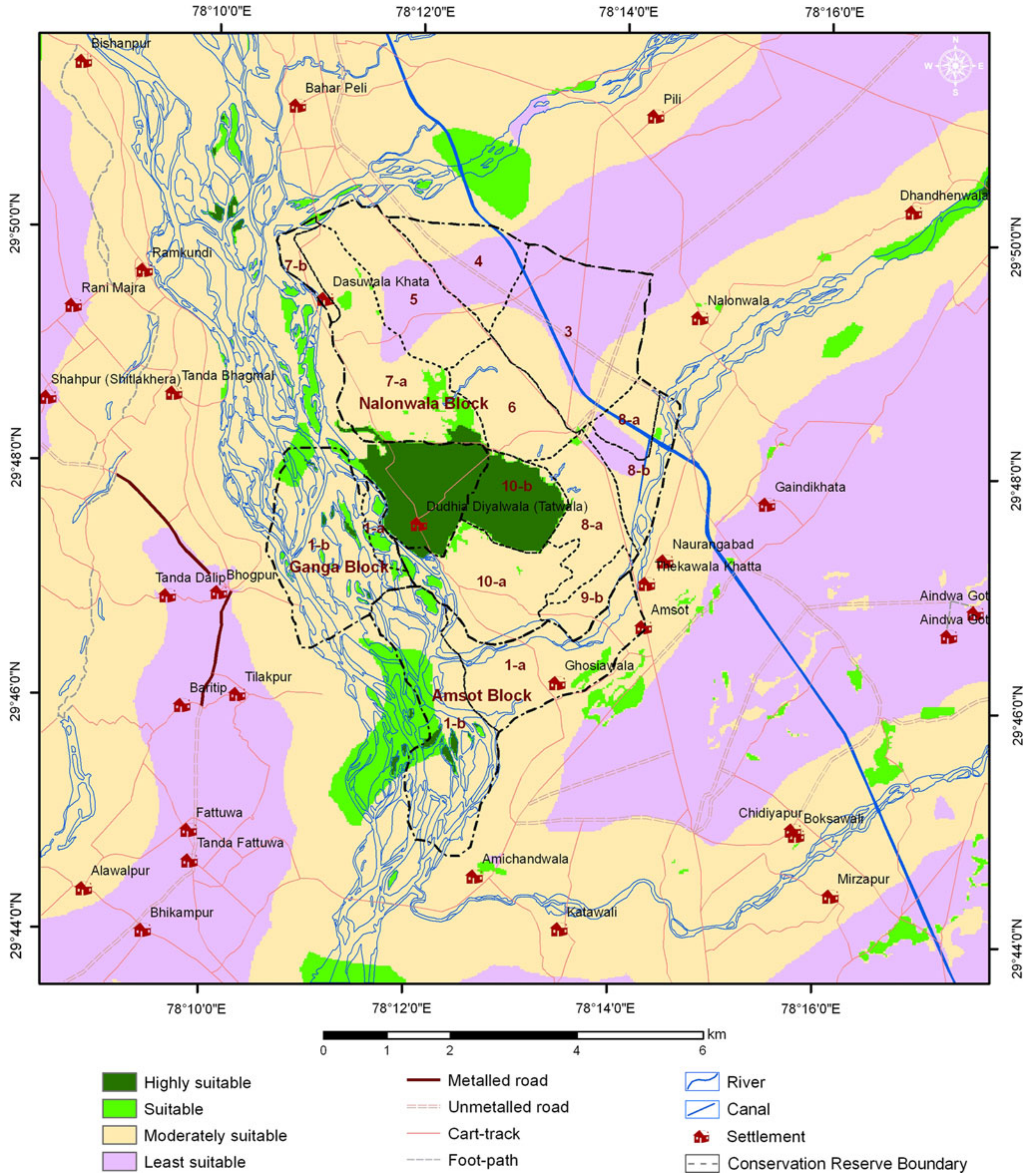

Fig. 6 Potential habitat map of swamp deer in Jhilmil Jheel Conservation Reserve

Block- and compartment-wise habitat suitability status is shown in Table 6. Amsot block makes only 0.35% of the highly suitable area. Similar case is with Ganga block, where only 0.18% of the area within this block worked out as highly suitable habitat. An area equivalent to 6.45% in Nalonwala block was estimated to be highly suitable.

This study covered 225 km^2 while the Conservation Reserve area happens to be 37.84 km^2, indicating that an

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Table 5 Habitat suitability status

S. no.	Suitability class	Suitability status					
		Total area		Inside Conservation Reserve		Outside Conservation Reserve	
		Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
1.	Highly suitable	4.63	2.06	2.06	5.44	2.57	1.38
2.	Suitable	9.04	4.02	2.07	5.47	6.97	3.72
3.	Moderately suitable	135.52	60.23	28.07	74.19	107.45	57.41
4.	Least suitable	75.81	33.69	5.64	14.89	70.17	37.49
Total		225.00	100.00	37.84	100.00	187.16	100

Table 6 Block and compartment-wise habitat suitability in the Conservation Reserve area

S. no.	Block	Compartment no.	Suitability class	Area (km^2)	Area (%)
1.	Amsot	1-a	Moderately suitable	3.16	8.34
2.	Amsot	1-a	Suitable	0.11	0.28
3.	Amsot	1-b	Highly suitable	0.13	0.35
4.	Amsot	1-b	Moderately suitable	3.51	9.28
5.	Amsot	1-b	Suitable	0.64	1.68
6.	Ganga	1-a	Moderately suitable	0.30	0.79
7.	Ganga	1-a	Suitable	0.14	0.37
8.	Ganga	1-b	Highly suitable	0.07	0.18
9.	Ganga	1-b	Moderately suitable	3.64	9.62
10.	Ganga	1-b	Suitable	0.45	1.18
11.	Nalonwala	3	Least suitable	2.76	7.82
12.	Nalonwala	3	Moderately suitable	1.92	5.07
13.	Nalonwala	3	Suitable	0.01	0.02
14.	Nalonwala	4	Least suitable	1.12	2.15
15.	Nalonwala	4	Moderately suitable	0.82	2.96
16.	Nalonwala	5	Least suitable	1.07	2.83
17.	Nalonwala	5	Moderately suitable	1.79	4.73
18.	Nalonwala	5	Suitable	0.02	0.04
19.	Nalonwala	6	Moderately suitable	2.03	5.38
20.	Nalonwala	6	Suitable	0.01	0.02
21.	Nalonwala	7-a	Highly suitable	0.17	0.44
22.	Nalonwala	7-a	Least suitable	0.16	0.43
23.	Nalonwala	7-a	Moderately suitable	3.33	8.81
24.	Nalonwala	7-a	Suitable	0.48	1.27
25.	Nalonwala	7-b	Moderately suitable	0.41	1.10
26.	Nalonwala	7-b	Suitable	0.01	0.04
27.	Nalonwala	8-a	Least suitable	0.21	0.56
28.	Nalonwala	8-a	Moderately suitable	0.58	1.53
29.	Nalonwala	8-b	Least suitable	0.27	0.72
30.	Nalonwala	8-b	Moderately suitable	1.02	2.70
31.	Nalonwala	8-b	Suitable	0.02	0.06
32.	Nalonwala	9-a	Highly suitable	0.01	0.02
33.	Nalonwala	9-a	Least suitable	0.04	0.12
34.	Nalonwala	9-a	Moderately suitable	1.94	5.12
35.	Nalonwala	9-a	Suitable	0.02	0.05

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Table 6 continued

S. no.	Block	Compartment no.	Suitability class	Area (km^2)	Area (%)
36.	Nalonwala	9-b	Moderately suitable	0.75	1.99
37.	Nalonwala	10-a	Highly suitable	0.05	0.14
38.	Nalonwala	10-a	Moderately suitable	2.74	7.24
39.	Nalonwala	10-a	Suitable	0.17	0.46
40.	Nalonwala	10-b	Highly suitable	1.64	4.32
41.	Nalonwala	10-b	Moderately suitable	0.13	0.34

area of 187.16 km^2 lies outside the Reserve. An area of 2.57 km^2 (1.37%) outside the Conservation Reserve is considered to be highly suitable habitat for swamp deer (Table 5). This area included some grasslands, agricultural lands and Tatwala village. This village, which is excluded from the Conservation Reserve, has high potential to serve as extended home range for increasing population of the swamp deer.

Discussion

It is clear from the study that only 6.08% of the study area (225 km^2) happens to be highly suitable to suitable for the swamp deer. An area of 60.23% (135.52 km^2) turned out to be moderately suitable. Much of the moderately suitable area happens to be the river course, which is not suitable during rainy season due to flood. Within the officially designated Conservation Reserve (area 37.84 km^2), 10.91% (4.13 km^2) was found to be highly suitable to suitable, while 74.19% (28.07 km^2) happens to be moderately suitable. Among the Nalonwala, Ganga and Amsot forest blocks, the highest suitability (6.78%) was noticed in Nalonwala followed by the Amsot (2.31%) and the Ganga (1.73%). The fact that only about 6.08% (14 km^2) area is fit for the swamp deer is somewhat disappointing from conservation point of view. The Jhilmil Jheel Conservation Reserve has a population of 134 swamp deers. The 14 km^2 area found suitable for the animal certainly falls short of the habitat needs of a large population. Efforts, therefore, must be made to bring additional suitable areas under Reserve for a viable population. The problem could be mitigated if the agricultural land adjacent to the Jhilmil Jheel, presently cultivated by Tatwala farmers, mainly for paddy, sugarcane, potato and wheat crops, is brought under the Reserve. This would provide an additional habitat area of 2.47 km^2 for the swamp deer to meet their requirement of fooder and space. For that, the cooperation of the local community is imperative, since village would need to be located somewhere else. There is also need for reducing the overall anthropogenic pressure including grazing of cattle and other livestock in the Reserve area and beyond for long-term survival of the swamp deer population. Fires are yet another problem in the study area, endangering the swamp deer habitat significantly. Efforts, therefore, are needed to save the forests and forest plantations from the fire between February and June every year. In past, the species was distributed nearly continuously from Jhilmil Jheel to Hastinapur Wildlife Sanctuary in Meerut, Uttar Pradesh in the floodplains along the river Ganga. Over time, however, the habitats have fragmented tremendously due to ever-increasing anthropogenic pressures, especially reclamation of these areas for agriculture, resulting in the isolated remnant populations in a few habitat islands. The study brings out a particularly grim situation with limited options towards conservation and management of the swamp deer in the Indo-Gangetic plains, currently falling under the jurisdiction of two provinces viz., Uttarakhand and the Uttar Pradesh.

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