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RESEARCH ARTICLE

Habitat Suitability Assessment of *Ardeotis nigriceps* (Vigors) in Great Indian Bustard Sanctuary, Maharashtra (India) Using Remote Sensing and GIS

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Abstract *Ardeotis nigriceps*, commonly known as Great Indian Bustard (GIB), is a Critically Endangered, Evolutionary Distinct and Globally Threatened (EDGE) and endemic species to the Indian subcontinent. GIB is under tremendous threat in its last strongholds and sliding inextricably towards extinction. The GIB sanctuary in Maharashtra (India) is one of the last refuges of the bird constituting an area of 8496 km^2 spread over in seven talukas of Solapur and Ahemednagar districts. Major portion of the sanctuary (94.3 %) consists of privately owned lands under a variety of economic vocations and large number of villages and townships. In view of the legal restrictions relating to Protected Area under the Wildlife (Protection) Act of India 1972, the inhabitants of villages and townships faced a very difficult situation regarding use of their lands, development of properties and deriving benefits from planned local and regional development. This created conflict between local people and the forest department over the use of land, which necessitated the rationalization of the sanctuary. The objective of the present study was to map the suitable habitat of GIB in GIB Wildlife Sanctuary as an input for the realignment of the GIB Sanctuary by identifying areas that are important for the GIB. Main parameters considered for the habitat suitability assessments are, habit and habitat of GIB, slope, minimum patch size and disturbance sources. Based on the criteria derived for the ecological and biological requirements of GIB, binary deductive habitat suitability modeling has been done using remote sensing and GIS and prioritized the potential habitats of GIB. The net area of important suitable habitat of GIB in GIB sanctuary is 2304.99 km^2 out of 8496.44 km^2. The output of the present study has been used as an input by the committee (set by Honorable Supreme court of India) on rationalization of the GIB Sanctuary and the sanctuary has been rationalized with an area of 1222 km^2.

Keywords Habitat suitability assessment · Deductive · Great Indian Bustard · Remote sensing · GIS

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Introduction

GIB is a Critically Endangered species under the IUCN red Data (IUCN 2014) and Birdlife International Listing (2001). It is also an EDGE species with a rank of 69 in the birds list (Jetz et al. 2014). The species is included under Appendix I of the CITES3 and under Schedule I, Part I of the Wildlife (Protection) Act, 1972 (1993). Formerly, bustards were widely distributed in Indian semi-arid grassy plains and open scrubs is now restricted to few pockets with fragmented and apparently decreasing population. The increasing rarity of the species is attributed to rapidly increasing disturbance and destruction of its habitat. The species has been described as resident and seasonally nomadic. During the early 1900s, flocks of 10 to 12 birds were common. By 1950, the average flock size had dropped to 1–3 birds (Anon 2007). The species was globally listed in 1966 as threatened. During the period of the past decade or so the population has crashed in many areas. A global population of about 300 birds is further fragmented into eight populations in the states of Rajasthan (shared with Pakistan), Maharashtra, Andhra Pradesh, Gujarat, Karnataka, and Madhya Pradesh in India. The largest population of 100–125 birds exists in Jaisalmer, Barmer, and Bikaner districts of Rajasthan and remaining population number less than 35 birds each (Dutta et al. 2012). Threats include expansion of farm lands including those under intensive cultivation, irrigation, rapidly increasing population of livestock, and factors of disturbance associated with local and regional processes of development (Rahmani et al. 1997). The Great Indian Bustard Sanctuary is the only protected area in Maharashtra State of India which is solely dedicated to the conservation of GIB, the flagship species of the sanctuary. The sanctuary area form mosaic of different types of land use. The size of sanctuary was irrational and impractical for field conservation as more than 94.3 % percent land was private and offered no control over land use practices inside the sanctuary. There are rainfed agricultural areas, intensive canal irrigated croplands, wastelands, fuel wood plantations and new industrial belts.

The associated species of the GIB in this sanctuary are Blackbuck (*Antilope cervicapra*), Chinkara (*Gazella bennettii*), Indian Gray Wolf (*Canis lupus pallipes*) and Lesser Florican (*Sypheotides indica*) all are placed in Schedule I of the Wildlife (Protection) Act 1972. Lesser Florican is also a critically endangered (IUCN 2014) and listed as an EDGE species like GIB. The main objective of this study was to prioritize the potential habitats of wildlife values of GIB using remote sensing and GIS as inputs for the rationalization of GIB Sanctuary boundary. In order to link all implications and features of the proposed rationalization (realignment) of boundaries of the GIB Wildlife Sanctuary, habitat suitability assessment of GIB has been adopted in this study by modeling in Geographic Information System (GIS).

Models predicting species and environment relationship have been the central concern in ecology (Guisan and Zimmermann 2000) and have been used to wildlife management issues. For many species it will be possible to develop habitat models that can be predict expected distributions of species. Such models can be developed by combining observations of species with diverse kind of spatial information, like spectral set from satellite image, topography, soil types, mesic conditions etc (Varghese et al. 2010). Over time, the availability of better spatial data has made habitat evaluation and management more scientific and realistic (Kushwaha and Roy 2000). With the advent of high-resolution (5.8 m) multispectral data of Linear Imaging Self Scanner (LISS IV) of Indian Remote Sensing Satellite (IRS) Resourcesat-1, the textural and spectral information can be better utilized in generating detailed forest type classification (Varghese and Menon 1999; Varghese and Krishna Murthy 2006).

In general, two modeling approaches are distinguished: inductive and deductive approaches (Corsi et al. 2000). Deductive or theoretical approaches are based on accepted theories on relationships between phenomena (Vogiatzakis 2003). It uses known species ecological requirements to extrapolate suitable areas from the environmental variable layers available in the GIS database. Once the preferences are identified overlay operation are used to merge the different environmental layers to yield the combined effect of all environmental variables (Corsi et al. 2000). Deductive modeling has some severe drawbacks in wildlife ecology as for many species knowledge of habitat requirements simply does not exist. For limited number of species models have been developed for one particular area, however the validity elsewhere remains unknown. Inductive modeling has been advertised to overcome these problems (de Leeuw and Albricht 1996). Inductive or empirical approaches are based on the analysis of field data collected based on presence/absence or presence data only. In situations where a recorded absence may in fact represent a failure to detect what is actually there (a false zero) erroneous inferences may result with naïve application of procedures such as logistic regression (MacKenzie and Kendall 2002; Tyre et al. 2003; Wintle et al. 2004). Moreover these models are often based on coarse scaled landscape and species information allowing coarse habitat inferences and predictions. Sometimes they may overlook biological details important for species conservation. Many of the studies undertaken in Indian subcontinent are based on inductive modeling (Kushwaha et al. 2004; Zarri et al. 2008; Nandy et al. 2012; Imam et al. 2013).

Considering the nature of the requirement and the availability of knowledge of habitat requirements of the concerned species, deductive habitat suitability assessment was used in the present study. More over biological details important for GIB conservation and variability in terms of different opinions of experts can be introduced in deductive method which will take into account of the range of acceptability of all environmental variables measured.

Study Area

The GIB sanctuary is located in two portions, the smaller of the two, Newasa taluka, falls between Latitudes 19° 13′ 25″ N to 19° 40′ 50″ N and Longitudes 74° 46′ 00″ E to 75° 12′ 34″ E. The larger part with 6 talukas is located between Latitudes 17° 22′ 17″ N to 18° 54′ 42″ N and Longitudes 74° 23′ 34 E to 76°15′ 01″ E (Fig.1). Solapur and Ahmednagar districts are semi-arid and drought prone, with average annual precipitation of 744 mm in Solapur district and 550 mm in Ahmednagar district. Rainfall is erratic and poorly distributed with year-to-year fluctuations. In Ahmednagar the number of rainy days is about 35–40. The maximum temperature varies from 25.2 °C in winter to 42.5 °C in summer. The year can be divided into three seasons. Winter (November–January), summer (February–June) and Monsoon (July–October). The sanctuary area includes reserved forests, Gairan lands (grazing land), other Govt. lands and private lands. The reserved forest areas partly rest with the forest department and partly with the

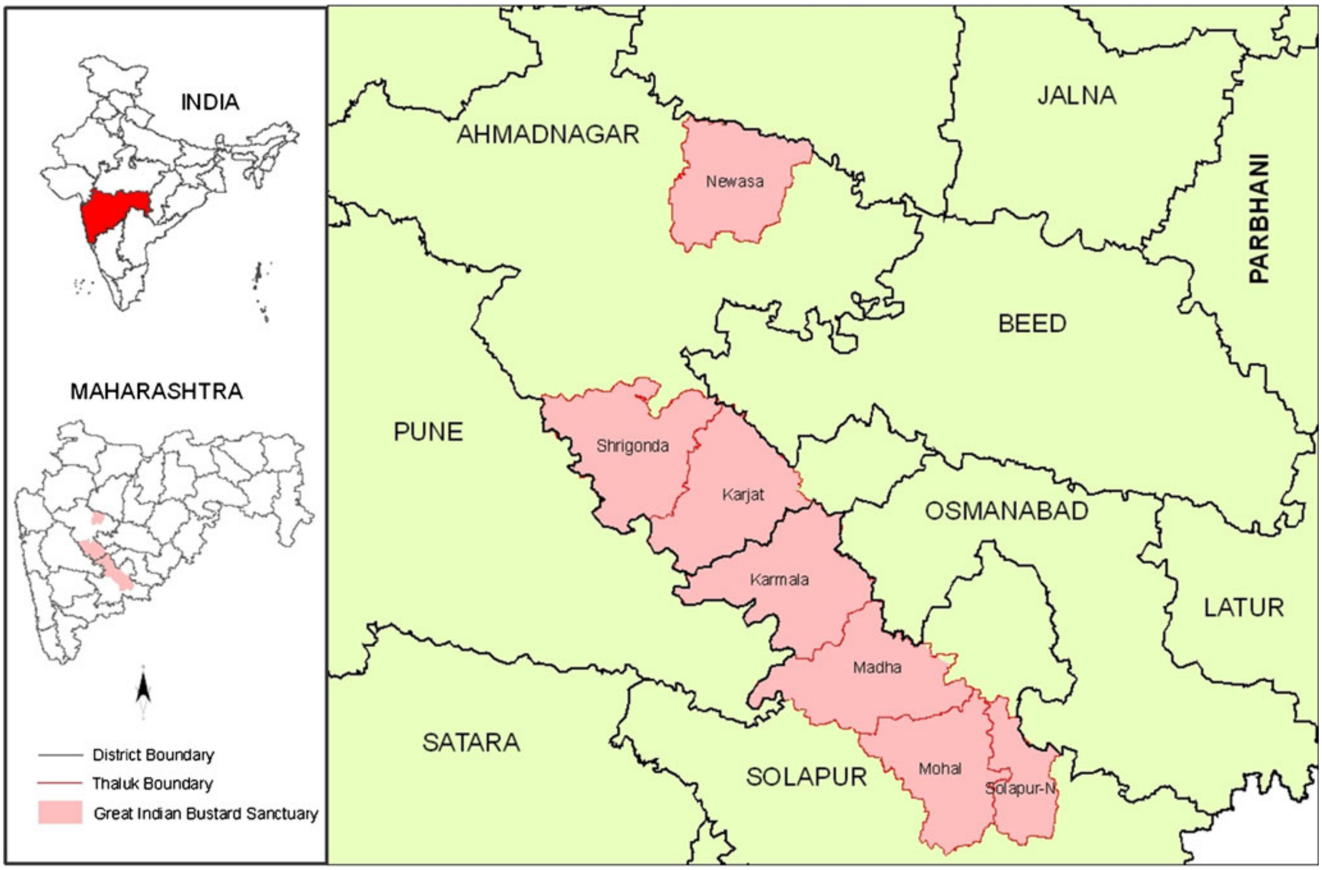

Fig. 1 Location map of GIB wildlife sanctuary

revenue department. Most of the reserved forest areas and Gairan lands which come under revenue department are distributed to the landless people.

The forest of the sanctuary can be classified into Southern Tropical Thorn Forest (Champion and Seth 1968). However, the natural vegetation has more or less disappeared. Open grasslands are seen in poor soil (Shendre 2002) with few young *Acacia nilotica* trees and *Cassia auriculata* bushes. Prominent grasses are *Aristida funiculate*, *Aristida stocksii*, *Chrysopogon fulvus*, *Heteropogon contortus*, *Lodhopogon tridentatus*, *Melanocenchris jacquemontii*. The Forests are almost entirely limited in areas to those lands, which were found to be unsuitable for cultivation owing to their physical nature. This too is not concentrated in compact blocks but is scattered in strips and patches all over the sanctuary area. The pressure of human and cattle population on the forests has affected the composition and condition of the vegetation to such an extent that nowhere it has remained in its natural form.

Materials and Method

A vector based deductive binary model was used for the present study. Main parameters considered for the habitat suitability assessments of GIB are, habitat requirements, habit, slope, minimum patch size, and disturbance sources (Fig. 2). The inputs for modeling were generated from remote sensing data

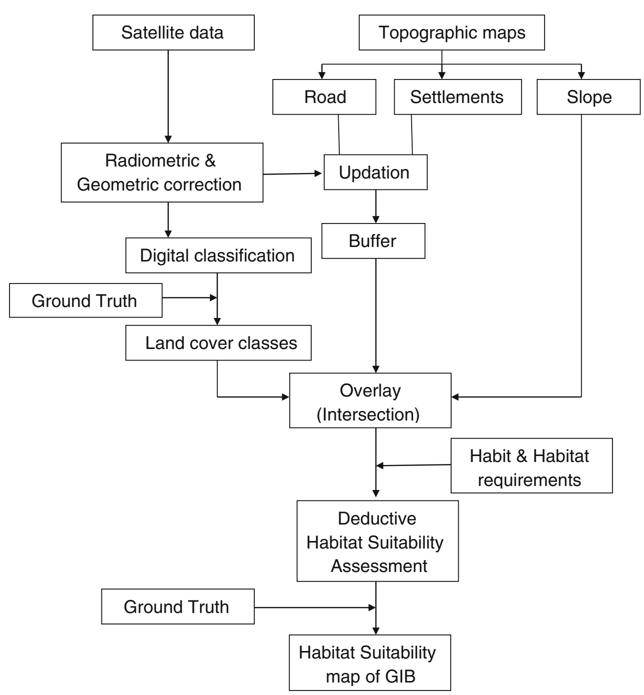

Fig. 2 Methodology flow chart

and knowledge of the habitat requirement of GIB has been given by the expert committee set for the rationalization of the sanctuary.

Parameters Considered

Habitat Requirements

Semi-arid grasslands sparsely dotted with scattered trees with occasional low knolls, scrubland and stony wasteland are the habitats used by GIB (Figs. 3 & 4). GIB actively avoids damp and waterlogged areas and certain crop fields such as sugarcane and standing wheat field. The habitat is characterized by erratic low rainfall, droughts, scattered dry land agriculture and sparsely distributed sources of water.

Habit

For day roost, bustards prefer to sit or stand in the shade of small trees or shrubs while for night roost, they prefer bare ground (Rahmani 1986). The bustards prefer to nest in open areas with moderate to short grass/vegetation (about 50 cm in height) or well-drained stony grounds (Bhatia 1986). During the breeding season, adult males are solitary, territorial and exhibit nest site fidelity. Eggs are laid on plain to slightly rising ground enabling the incubating bird a clear line of sight over the surrounding area. The preference of substrate varies from stony ground to fallow fields and scrubland to sparse, or no cover. The clutch size is of one or two eggs. The young normally remains with the mother till the following breeding season (Rahmani 1989).

Topography and Disturbances

The bird is not sighted above 20° slope areas as well as wet regions of the sanctuary like sugarcane fields and other water bodies. Minimum patch size selected for the inclusion in the boundary area was 20 ha and above. Main sources of disturbance to GIB are from anthropogenic and livestock disturbances from settlements, roads, transmission lines.

Remote Sensing and Other Auxiliary Data

The following data were used in the present study to translate the above mentioned requirements to GIS. IRS Resourcesat LISS III Images of 2007; IRS Resourcesat LISS IV Images (2006 and 2007); Survey of India topographical maps in the scale 1: 25,000; Infrastructure maps digitized from SOI toposheet and updated using IRS LISS IV scenes; Spatial data characterizing terrain (slope, drainage) and Ground truth data collected during the field visits with GPS handsets. For the land cover type generation IRS LISS IV scenes were used with unsupervised classification techniques to derive various land cover classes as per the habit and habitat requirements of GIB. All LISS IV scenes pertain to the study area were classified separately using unsupervised classification technique. Unsupervised classification method which divide the scenes into more or less pure spectral clusters, typically constrained by pre-defined parameters characterizing the statistical properties of these clusters and the interrelationships among adjacent clusters (Jenson 2014). The assignment of land cover labels to individual spectral clusters is made subsequently on the basis of ground information, obtained in the locations indicated by the resulting clusters. The large number of clusters then reduced to the required level of classes through merging process and subsequently reconciles the classes across the mosaic. The following classes are identified in the sanctuary like cropland, fallow land, grassland, land with scrub, land without scrub, settlements, Barren Rocky/Stony waste/Sheet Rock, waterlogged areas and water bodies. Classification accuracy was assessed with reference sample information collected from field compared with the classification output. The relationship between these two sets of information was examined in the error matrix. An error matrix is a square array of numbers laid out in rows and columns that express the number of sample units assigned to a particular class relative to actual class as verified in the field. An error matrix is a very effective way to represent accuracy because the accuracy of each category is clearly described, along with both the errors of inclusion (commission errors) and exclusion (omission errors) (Jenson 2014). Disturbances sources like settlements, roads, transmission lines etc were digitized from LISS IV data and given appropriate buffer zone to exclude from the suitable areas.

Suitability Assessment

Based on the criteria derived for the habitats of GIB, deductive binary habitat suitability modeling has been done in GIS and prioritized the potential habitats of GIB. Overlay operation with intersect was used to combine geometries and attributes of all data layers generated for the study to make composite feature layer. By using logical expressions based on the habitat requirement of GIB, the habitat suitability map was generated. The deductive approach uses known species ecological requirements to extrapolate suitable areas from the variable layers in the GIS database. Based on the criteria set for GIB, optimum set of topographic, edaphic and biological conditions were derived from the integrated layers. From practical point of view small isolated non forest patches are difficult to manage, hence, all such individual patches standing alone having an area less than 20 ha were excluded to derive the overall suitable habitat for GIB.

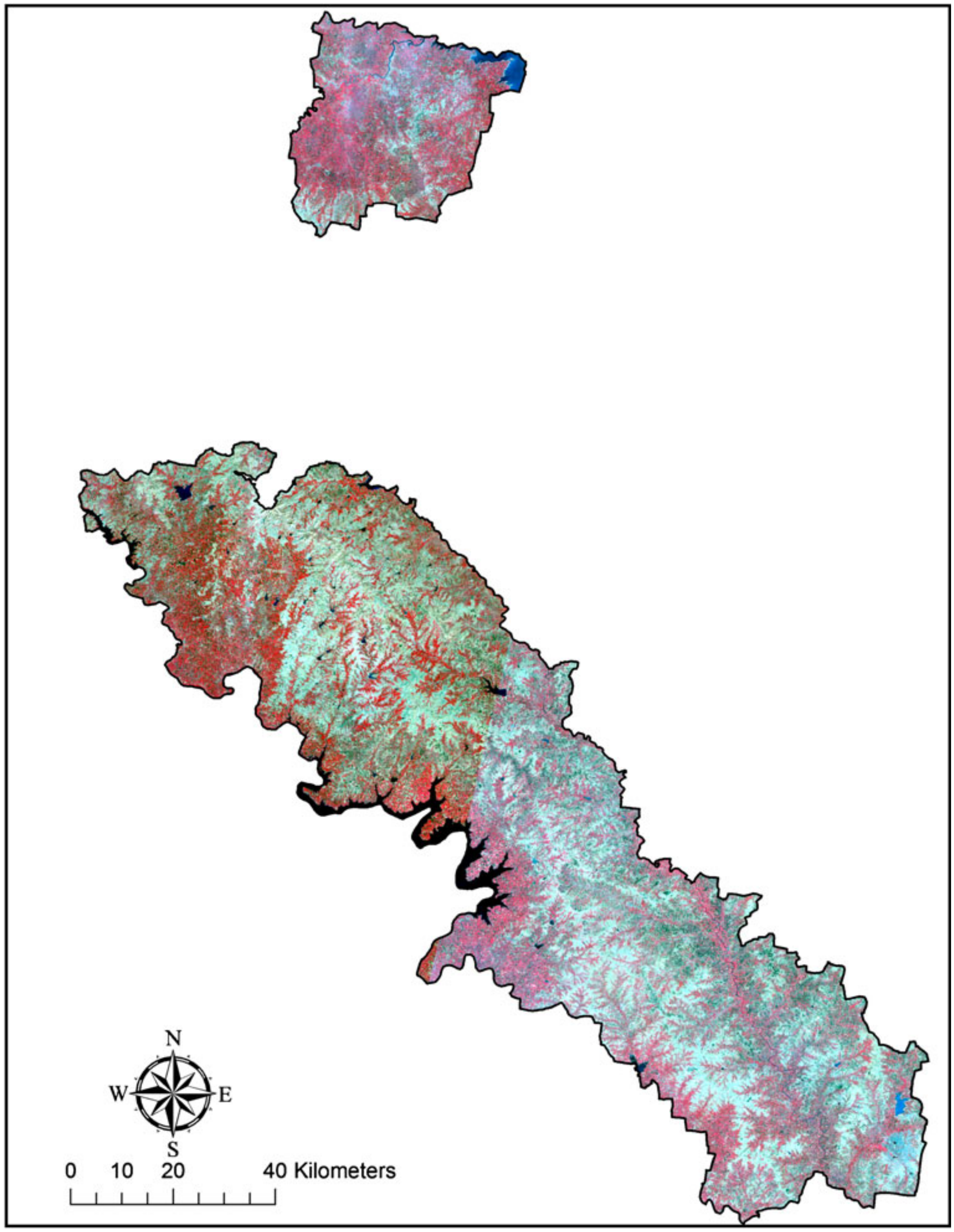

Fig. 3 GIB sanctuary as seen by IRS LISS III image

Results and Discussion

Biological diversity is assessed, measured and managed at six levels of biological organizations, namely, genes, species, communities, populations, ecosystems and landscapes. The most visible and convenient levels for addressing the future of native species of wild plants and animals is by species, communities and populations since these can be measured by means of techniques with which wildlife managers are familiar (Sawarkar 2005; Rodgers et al. 1991). The last four can be expressed spatially, though none have a definite size. The largest spatial scale is represented by the landscape which is defined as 'a tract of land that has a mosaic of interacting land uses, usually many hundreds to thousands of square kilometers in extent.' Conservation actions at this scale are governed by the principles of Landscape Ecology that consider people and the impacts of their activities as the corner stone of its science (Decker et al. 1991; Mathur et al. 2002). At this point the principles of two other powerful and applied streams of ecology intersect with those of the Landscape Ecology. These are, Insular or Island Biogeography (Harris 1984) that deals with land locked isolated populations located in a matrix of hostile land uses in other words, fragmented habitats and Conservation Biology that represents the science of rarity (Hunter 1990; Morrison et al. 1998). The vagrant nature of GIB reduces the benevolent effect of small protected areas,

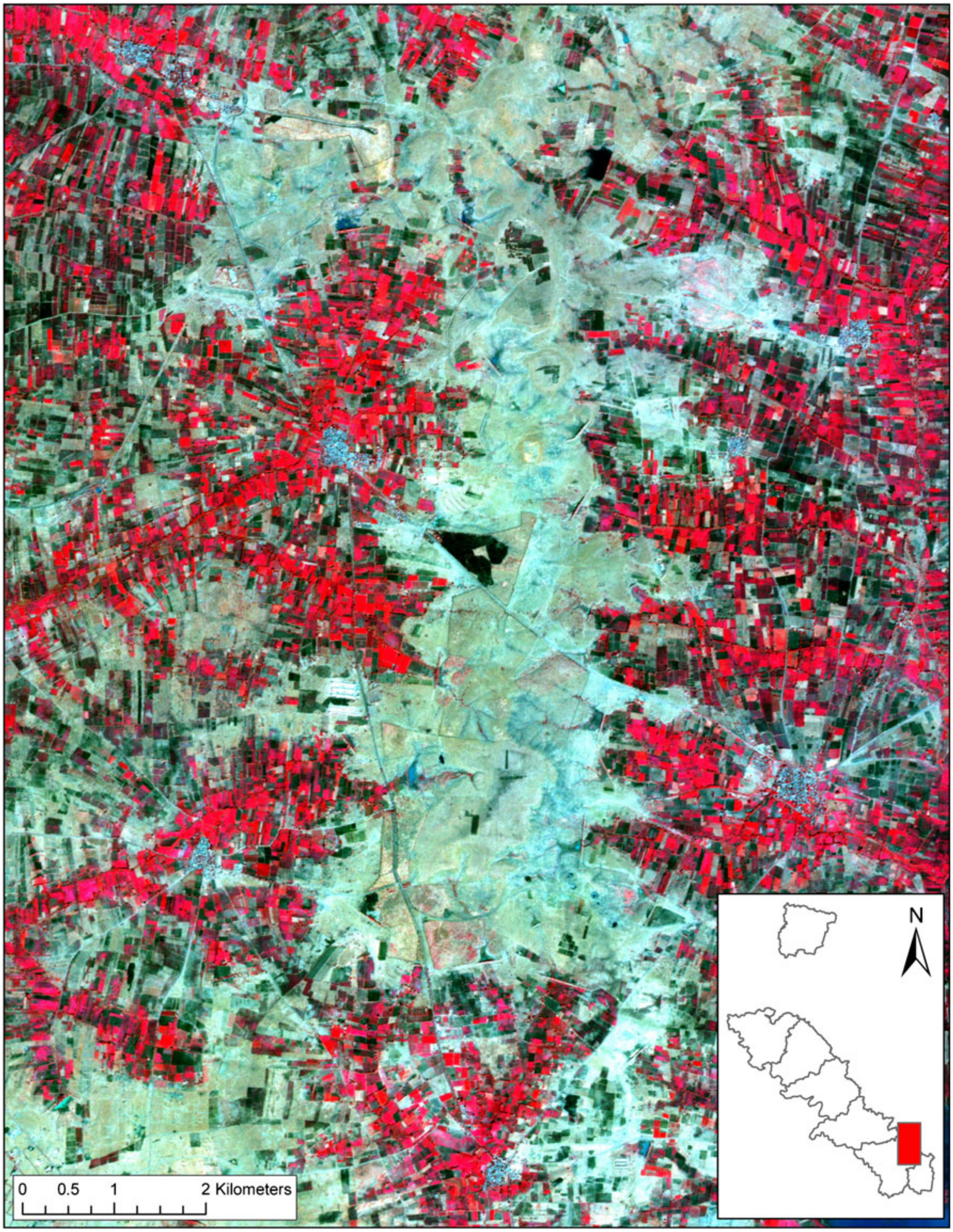

Fig. 4 Grasslands of GIB sanctuary as seen by IRS LISS IV data of 2007

while large reserves alienate people by curbing legitimate subsistence rights through strict legislation.

The land cover classification results show an area of 498.78 km^2 is occupied by grassland in this sanctuary. Land with scrub; land without scrub and Barren Rocky/Stony waste/Sheet Rock registered 174.43, 149.07 and 98.52 km^2 respectively. Agriculture land occupies major share of the sanctuary with an area of 6331.80 km^2. Of this, an area of 226.24 km^2 comes under sugarcane/waterlogged area. Dense and open forests, which are coming under notified forest occupies 8.71 and 1.36 km^2 respectively. Remaining areas are classified in to water body (1043.20), settlements (142.75) and mining/industrial waste. Accuracy of the digitally classified and final mosaic output was checked through error matrix. Twenty five reference points were collected randomly from each Taluka and cross checked with the classified output for the classification accuracy and the overall accuracy was found to be 95 %. Spectral mixing of the classes mainly happened between scrub land and grassland and that has been fine tuned in the classification stage to achieve this accuracy.

The Great Indian Bustard occur on isolated patches of habitats located in a matrix of hostile land uses such as agriculture,

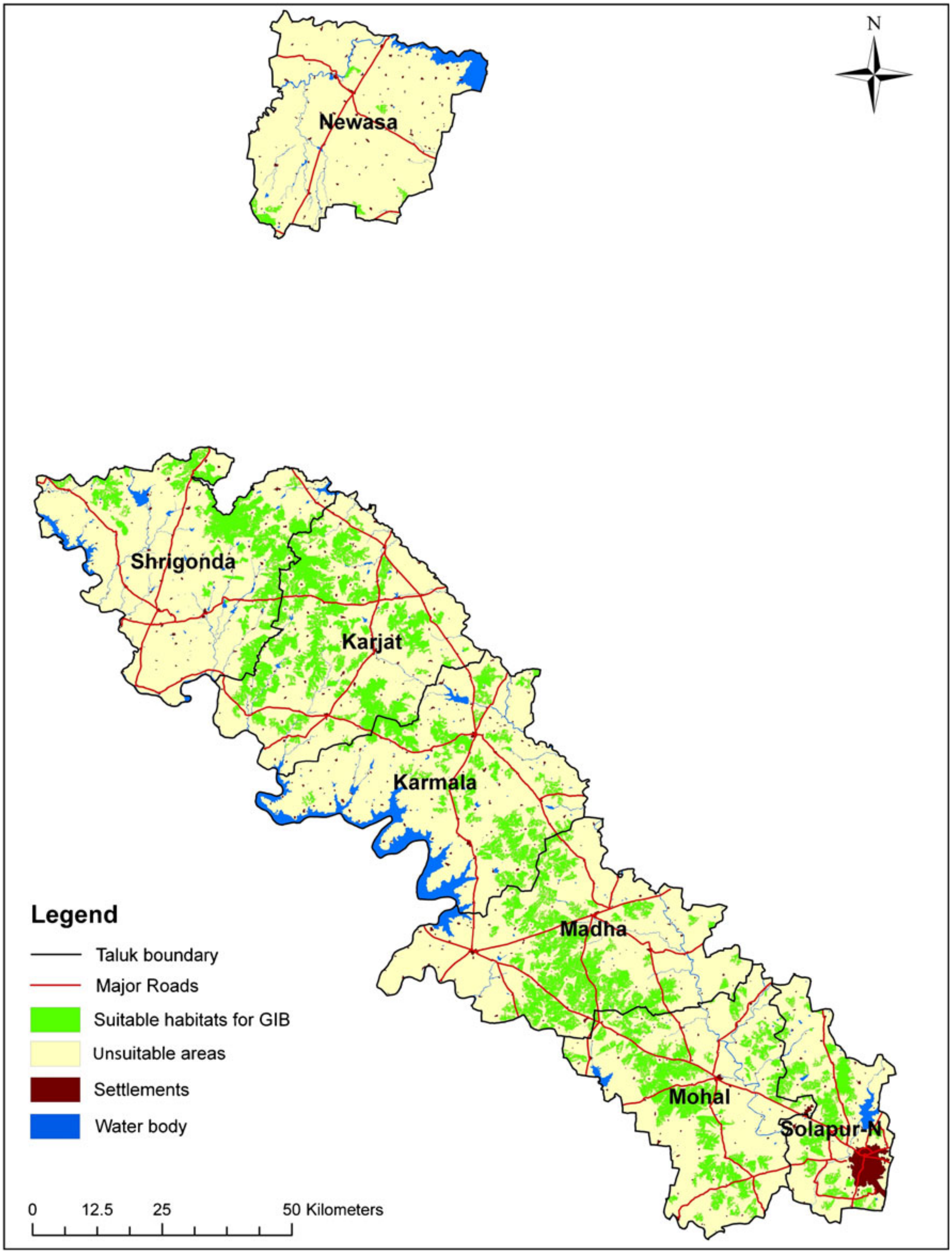

Fig. 5 Suitable habitats of GIB in GIB wildlife sanctuary

the pressure of grazing of livestock and of a large number of other land based economic activities of local communities. Irrational distribution and size of the GIB sanctuary is the major culprit for the suffering of both community and wildlife. It has created anti-bustard environment in the region. So there is a need to delete areas that are not important for the GIB. Keeping this view, the sanctuary cannot have one single compact area. Such composition and structure is unique to this sanctuary and cannot be interpreted as a precedent for any other protected areas that currently exist in Maharashtra or may be created in future.

The net area of suitable habitat for GIB in the sanctuary is 2304.99 km^2, which has an irregular shape, with scattered patches (Fig. 5). Out of 123 villages in the Newas Taluka of Ahmednagar district only 31 villages are notified in the GIB sanctuary. Geographically this taluka is not in contiguity with the other six talukas included in the notified GIB sanctuary. The identified suitable habitat areas in these 31 villages of Newasa taluka do not meet the criteria set forth to categorize them under important habitats for GIB. There is lot of fragmentation within the suitable areas. Hence it was decided to exclude the entire 31 villages from the important suitable habitats proposed for the GIB wildlife sanctuary. The suitable habitats, which include private and government lands then, cross checked on field by stratified random sampling method. Twenty five samples from each Taluka has been selected and cross checked with the suitable habitats for the accuracy and it was found to be 95 %.

Adequate care has been exercised to effectively meld the call of science with practicability of defining and sustaining the boundaries on the ground.

The existing GIB boundary was notified in the gazette, considering the villages as the minimum units of demarcation. Due to such criteria the gross geographic area of the village were considered as sanctuary. Declaration of gross geographic area as sanctuary is one of the main factors which have been causing unnecessary hardship to the local people. To resolve this problem, it is recommended to rationalize the sanctuary by specifying the relevant gat number as the basic unit for demarcation in each village. For this the geo-referenced digital cadastral maps available at Maharashtra Remote Sensing Application Center can be used.

A landscape conservation strategy using conservation/community reserve concept that includes controlled traditional land uses with GIB-friendly infrastructural development is needed in this sanctuary. There are matching habitats for the GIB in some other districts in Maharashtra such as Usmanabad, Beed, Nasik and Aurangabad etc. Similar studies may be undertaken to create new protected areas in the same biogeographic zone for GIB.

Conclusion

The suitable habits (2304.99 km^2) derived through remote sensing and GIS has been submitted to the expert committee for the realignment GIB sanctuary. The expert committee, after considering the landscape metrics (Contagion, Fragmentation and Juxtaposition) and the habitat requirements of associated species, realigned the GIB sanctuary and submitted to Honorable Supreme Court of India (Sawarkar et al. 2008). Honorable Supreme Court of India accepted the realigned boundary after seeking the opinion of National Board for Wildlife (NBWL) and the Committee on Rationalization of boundaries of National Parks and Sanctuaries**.** As a result of rationalization of the GIB sanctuary boundaries, the size of the GIBWLS is reduced to 1222.61 km^2 from the previous extent of 8496.44 km^2**.** The private land, which is coming under the community reserve, would get the necessary incentive for protecting the bird or its nest. This study demonstrated that satellite imageries, a range of maps created in the GIS environment and the database generated from these would be the most useful companions for planners, managers and decision makers.

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