Asian Journal of Conservation Biology, December 2024. Vol. 13 No. 2, pp. 208–214 AJCB: FP0255/86114
ISSN 2278-7666 ©TCRP Foundation 2024 https://doi.org/10.53562/ajcb.86114

Research Article

Geospatial Analysis of Land Use Change and Grassland Degradation in Pune's Urban Hills

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(Received: August 26, 2024; Revised: December 14, 2024; Accepted: December 15, 2024)

ABSTRACT

Urbanization is a widespread phenomenon worldwide, and it is particularly intense in South Asian developing countries like India. This study focuses on the land use and land cover (LULC) changes in the hills of the Pune metropolitan region, one of India's fastest-growing metropolises. The study utilized Landsat 8 satellite data and analysed it in QGIS software using a semi-automatic classification plugin. The land use maps were categorized into four classes: built-up, tree cover, savanna, and water. We also conducted field surveys to identify and record human activities that negatively affect grassland vegetation. The hilly region of Pune is facing significant pressure from urban growth. The original savanna vegetation on these hills is diminishing due to the introduction of exotic plantations and other human activities. Safeguarding Pune's savannas requires a multi-pronged approach, with public awareness campaigns at the forefront. Educating citizens, naturalists, conservationists, and policymakers is essential for their preservation. Building public understanding and fostering community engagement is fundamental for these critical areas' long-term protection and sustainable management. Through highlighting current trends and challenges, this study aims to provide valuable insights for sustainable land-use planning in Pune's urban hills, ensuring the preservation of these natural habitats for the future.

Key words: Anthropogenic activities, Built-up, Exotic plantations, Grassland-Scrub, Slums, Urban sprawl

INTRODUCTION

Urbanization rates have significantly risen in recent decades, particularly in developing countries, due to rapid economic growth (ESSAP, 2020). Urban areas in these countries are rapidly expanding in both size and population. India, the world's second most populous country, is home to 17.7% of the global population, occupying just over 2.4% of the land. India is experiencing a substantial increase in its urban population (Jensen, 1990) and according to a survey (United Nations, 2019); it is expected to have the world's largest urban population by 2050. The leading causes of urban sprawl in Indian cities include high urbanization rates, low land prices outside city limits, unplanned land development, lower taxes, and available uncultivated land (Lata *et al.*, 2007). Urban sprawl is a significant threat to natural habitats worldwide, and grasslands are no exception. The increasing concentration of people in cities leads to a demand for more land. This expansion significantly alters land use, replacing agricultural lands and grasslands with urban infrastructure (Zubair *et al.*, 2019). Kapuria (2021) highlights a substantial decrease in grasslands across India, including urban areas. Between 2005 and 2015 alone, the country lost 31% (5.65 million hectares) of its grassland cover. Grasslands are vital for urban environments due to their multifaceted benefits. They support biodiversity, enhance ecosystem services, improve air and water quality, provide recreational and educational opportunities, and contribute to urban areas' overall resilience and sustainability. Understanding the specific impacts of urbanization on these grasslands is essential for sustainable urban planning and conservation efforts. Pune is the seventh most populous city in India. It is located on the Deccan plateau, and large industries have flourished here due to the underlying basalt rock. The growth of various industries in Pune, particularly IT and manufacturing, has created many job opportunities. This economic pull factor attracts people from surrounding rural areas and other parts of India seeking better career prospects and a higher standard of living. The influx of people has caused Pune to expand beyond its urban boundary, putting pressure on natural resources, vegetation, and agricultural land (Dixit *et al.*, 2001; Ingalhalikar *et al.*, 2001; Khare *et al.*, 2016).

Hills are prominent natural landmarks that contribute significantly to the Pune city's ecological and recreational landscape. These hills support a diverse range of flora, including native species like *Azadirachta indica*, *Acacia catechu*, *Terminalia arjuna*, *Carissa carandas*, *Ziziphus mauritiana* and the grassland vegetation 'savanna'. Pune has a rich history of tree plantation efforts, especially in its urban hills. The city's urban hills, including Durga Tekadi, Pashan-Baner Hill, Vetal Hill Complex, Pachgaon-Parvati Hill, Ramtekadi and others, have been the focus of various tree plantation initiatives aimed at promoting green cover, biodiversity conservation and environmental sustainability. Unplanned plantation programmes of exotic species, fires, and changing land use are some of the threats that these hills currently face (Choudaj & Wankhade, 2021; Nerlekar & Kulkarni, 2015). The native vegetation on these hills was once a thriving savanna (Ratnam *et al.*, 2016). However, the introduction of non-native plants has transformed the landscape. The once-widespread savanna has been fragmented, with only scattered pockets remaining (Choudaj & Wankhade, 2021). Previous studies on land use in Pune have explored a range of topics, including urban sprawl (Aithal *et al.*, 2014; Kantakumar *et al.*,

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2011; 2016), the impact of land-use change on water resources (Kumar & Dhorde, 2021; Samal & Gedam, 2015), and the effect on city temperatures (Gohain *et al.*, 2020). Bhaskar (2012) and Wagner *et al.* (2013) conducted studies on land use changes in Pune's urban area, attributing the observed trend to the expansion of built-up areas. Both studies highlighted the detrimental impact of urbanization on the region's natural landscape. While previous research has documented the decline of grasslands and semi-natural vegetation in Pune's urban areas, the specific impact on the hilly region remains less explored. This study emphasizes the shrinking savanna vegetation on the hills within the Pune metropolitan area, shedding light on the vulnerability of these often overlooked urban ecosystems. This knowledge can inform the development of sustainable urban planning and conservation strategies for these vital ecological resources.

MATERIALS AND METHODS

Study area

The Pune Metropolitan Region (PMR) is located in Maharashtra, western India, and includes the city of Pune, Pimpri-Chinchwad, and surrounding rural and semi-urban areas (Figure 1). The region is situated on the Deccan Plateau, with coordinates between 18.43^{0}N and 18.72^{0}N latitudes and 73.71^{0}E and 73.97^{0}E longitudes, covering an area of 518.1 km^2. Notable hills include Durga Tekadi, Vetal Hill, Pachgaon-Parvati Hill, Pashan-Baner Hill, Ramtekadi and the Sahyadri mountain range to the west, providing natural beauty and diverse ecosystems. Major rivers such as the Mula, Mutha, Pavana, and Indrayani are vital for the region's water supply and agriculture. The flatlands around the rivers are fertile and support agriculture and urban development. The region's elevation ranges from approximately 560 meters above sea level in the metropolitan areas to higher altitudes in the surrounding hills. The original vegetation of the PMR is savanna. Pune has a tropical wet and dry climate, with hot summers ranging from 25° C to 38°C and a monsoon season bringing significant rainfall, with an average annual precipitation of around 700 mm. Winters are mild and pleasant, with temperatures ranging from 8°C to 28°C.

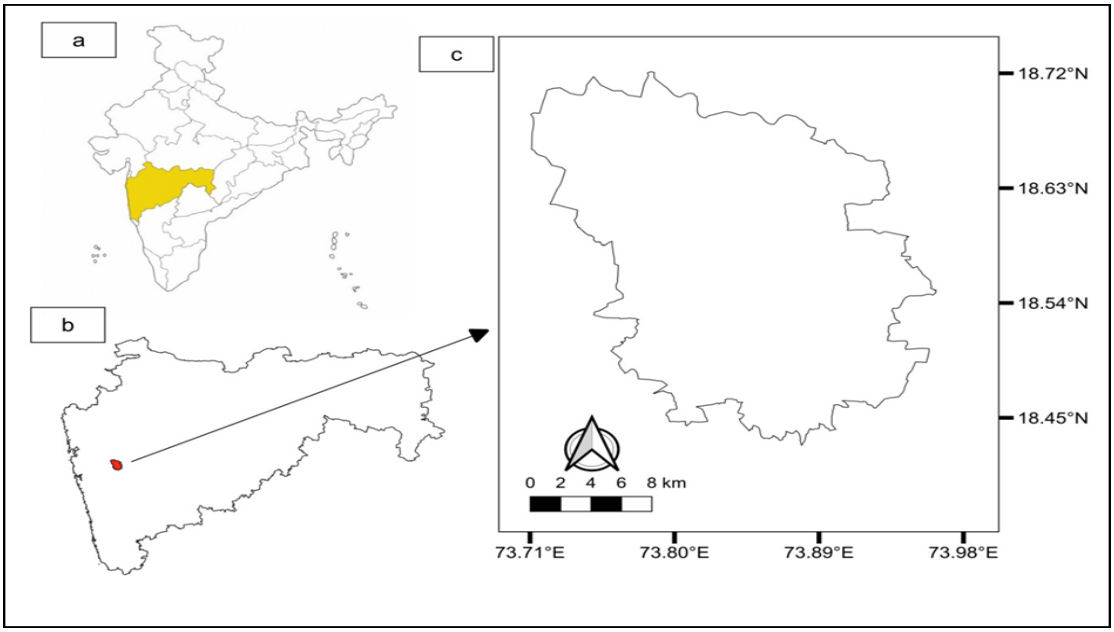

Figure 1. Location map of study area a) Location of Maharashtra state in India b) Location of Pune metropolitan region in Maharashtra c) Map of Pune metropolitan region.

Data and methodology

For the land cover classification in this study, we downloaded Landsat 8 OLI & TIRS data with a spatial resolution of 30 m for the year 2020 from the United States Geological Survey database (https://earthexplorer.usgs.gov/). We selected Landsat data with less than 5% cloud cover. We chose satellite data from the dry season to avoid the effects of clouds and shadows, which could lead to overestimated vegetation cover. We extracted information about land cover types from the Landsat data using reflectance information (Avtar *et al.*, 2017). Additionally, we analysed the data quality and land cover types using visual image interpretation techniques. The land use classification was performed using QGIS software (Figure 2), and the data were projected to the Universal Transverse Mercator (UTM) projection system zone 43N and the World Geodetic System 84 (WGS 84). We used the minimum distance algorithm of the semi-automatic classification (SCP) plugin of QGIS software to classify land cover types. The land use map was divided into four classes: a) built-up areas (artificial features), b) tree cover (natural and planted tree cover), c) savanna (grassland-scrub vegetation), and d) water (ponds, lakes). Human activities that impact land use were also documented during the field surveys. For accuracy assessment, a stratified sample of pixels from the image for each class was generated using the SCP plugin, and these pixels were cross-validated for their location accuracy using Google Earth images and true colour composite (TCC) and false colour composite (FCC) of Landsat data. The percentage of pixels from each class labelled in the image classified correctly by the classifier was estimated, as well as the proportion of pixels from each class erroneously labelled into every other class; these estimations were used to calculate the error matrix (Lillesand *et al.*, 2008). From the error matrix, accuracy was calculated.

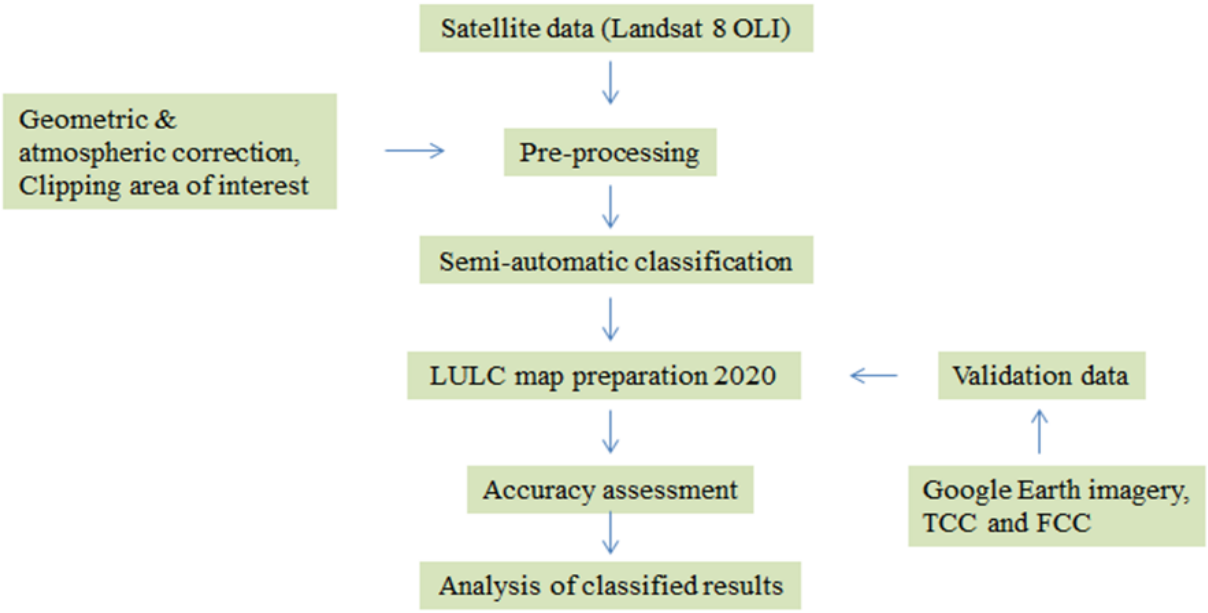

Figure 2. Flowchart of methodology.

RESULTS

The analysis of satellite imagery revealed a decrease in the original savanna vegetation across all the hills in the study area (refer to Figure 3). The reduction in savanna vegetation is attributed to built-up areas, tree cover, and other human activities. A major part of the hills are now covered by plantations, with a significant portion occupied by exotic plants (refer to Figure 4). Urban development has encroached upon the hill regions, particularly with the establishment of slums on the slopes. The classified LULC map's overall accuracy is 94.32%, with a kappa coefficient of 0.88 (Table 1).

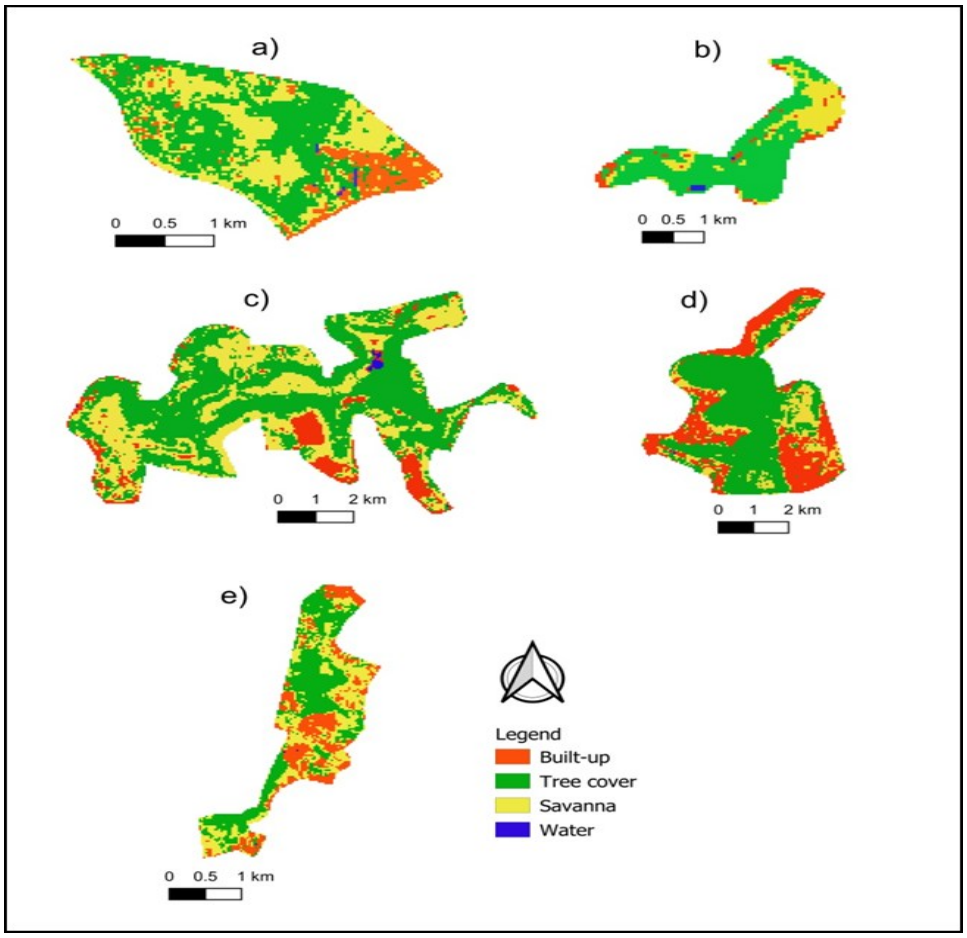

Figure 3. LULC classification map of hills present in the PMR in 2020 - a) Durga Tekadi, b) Pashan-Baner Hill, c) Vetal Hill complex, d) Pachgaon-Parvati Hill, e) Ramtekadi.

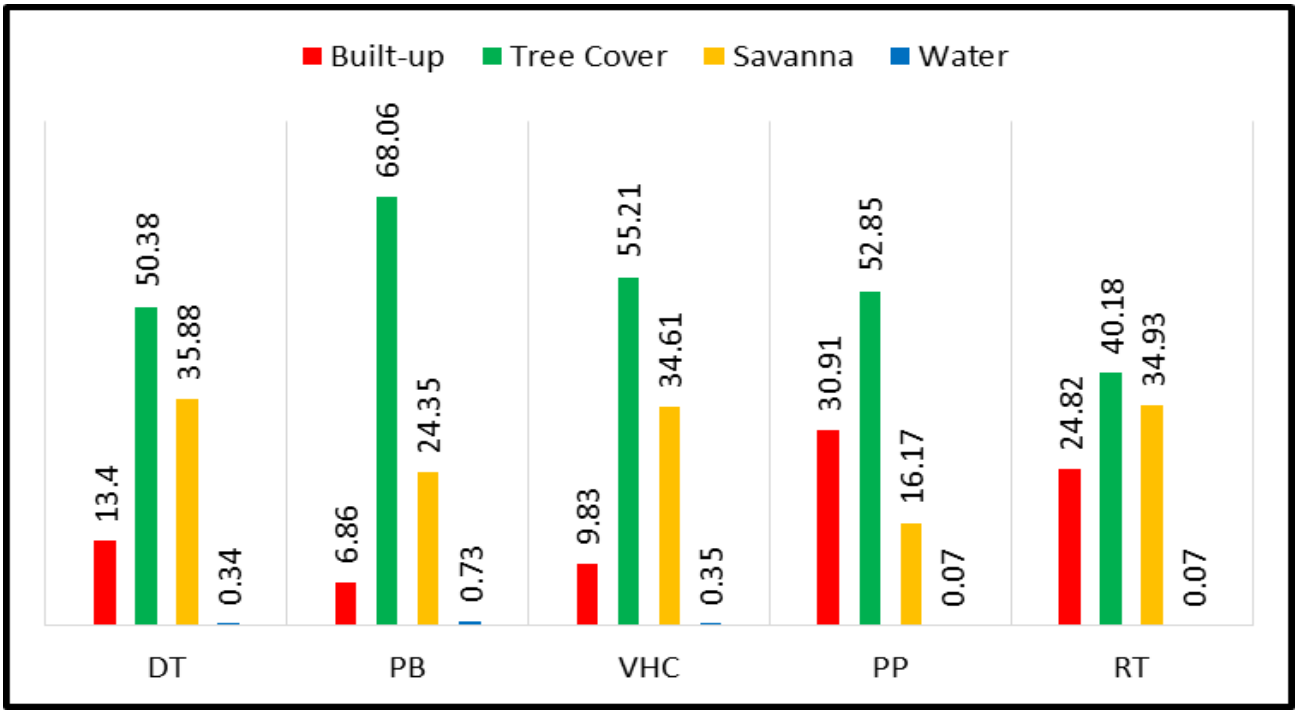

Figure 4. Percentage of LULC classes over the major hills present in the PMR for the year 2020. *DT* Durga Tekadi, *PB* Pashan-Baner Hill, *VHC* Vetal Hill complex, *PP* Pachgaon-Parvati Hill, *RT* Ramtekadi.

Table 1. Information of accuracy assessment of LULC map for the year 2020.

LULC types	PA (%)	UA (%)
Build-up	99.28	96.40
Tree cover	94.87	86
Savanna	84.18	93.84
Water	100	100
Overall accuracy	94.32	
κ coefficient	0.88	

DISCUSSION

Anthropogenic activities, deforestation, population growth, and urbanisation are the primary drivers of change in LULC (Liu *et al.*, 2014; Wang *et al.*, 2018). Economic reforms in India since 1991 spurred significant changes, attracting foreign investment particularly to the information and communication sector. This led to the establishment of IT parks in Pune, a strategically positioned city on the Deccan plateau with a strong foundation of basalt rock ideal for industrial development. Pune's transformation into India's second-largest IT hub, coupled with its existing strengths in automobiles and manufacturing, fuelled urban expansion. This growth, driven by expanding industrial areas, IT parks, transportation networks, and markets, has come at a cost - a sharp decline in agricultural land and, importantly, natural grassland areas (Dixit *et al.*, 2001; Gohain *et al.*, 2020; Joshi *et al.*, 1992; Joshi & Kumbhojkar, 1997; Nalavade, 2001, Nerlekar & Kulkarni, 2015; Sakthivel *et al.*, 2018). Pune's growth isn't solely driven by economic factors. As Farrell & Nijkamp (2019) point out, demographics and other soft factors like history, culture, and politics also play a significant role. Pune thrives on its reputation as a centre for education, research, and job opportunities, all contributing to a high quality of life. The city's vibrant cultural scene, ongoing infrastructure development, and strong healthcare system further solidify its attractiveness for residents and businesses alike.

Pune boasts a long tradition of nurturing its urban hills with trees. From Durga Tekdi to Pachgaon-Parvati Hill, these green spaces have been the focus of numerous tree plantation initiatives. Driven by a desire for increased green cover, biodiversity conservation, and environmental sustainability, both government bodies and local communities have played a vital role. The Municipal Corporations and Maharashtra Forest Department have spearheaded various schemes, including establishing urban forests, tree adoption programs, and promoting sustainable landscaping practices. Plantation programs on the hills favoured exotics, neglecting the valuable potential of local flora. Exotic plant species like *Gliricidia sepium* (planted for soil improvement) and *Leucaena leucocephala* a known invasive (Hiremath & Sundaram, 2013) have significantly altered the local ecosystem on the hills (Choudaj & Wankhade, 2021; Punalekar *et al.*, 2010). These plants, along with the widespread invasion of *Lantana camara*, displace native vegetation and disrupt habitats. Furthermore, urban development has compounded the issue. Approximately 35% of Pune's population resides in slums (Bapat,

2009), often on slopes, further reducing natural vegetation. Infrastructure projects like roads and housing have fragmented remaining grasslands, while activities like water tank construction, sports complexes, factories, stone quarrying, and garbage dumping have directly impacted the landscape. The cumulative effect of these factors has been a substantial decline in the original savanna environment.

Urban sprawl fragments and destroys crucial urban grasslands, jeopardizing biodiversity, particularly for specialist species that rely on these open habitats (Choudaj & Wankhade, 2021). While often perceived as degraded forests by citizens (Bond, 2016), savannas are in fact ancient ecosystems offering vital services beyond aesthetics (Ratnam *et al.*, 2016). Their loss disrupts carbon capture (Liu *et al.*, 2023), increases soil erosion, and alters water cycles. These green spaces not only benefit wildlife but also provide recreational and educational opportunities for urban residents. Furthermore, savannas support pollinators critical for agriculture (Kraus *et al.*, 2023). The slow recovery rate of destroyed savannas, coupled with potential species extinction (Nerlekar & Veldman, 2020), underscores the urgency of conserving these remnant patches. Preserving these grasslands is essential for maintaining biodiversity, regulating climate, and ensuring the continued provision of ecosystem services. To protect the remaining urban grasslands, we need a multifaceted approach. Public awareness campaigns can help dispel misconceptions about savannas, highlighting their ecological value. Collaborative efforts among citizens, local authorities, and environmental organizations can lead to effective conservation strategies. This might involve restoration projects that use native plant species and integrate these areas into sustainable urban planning initiatives. By acknowledging the importance of these green spaces and taking action, we can ensure that urban grasslands continue to thrive, benefiting both people and nature.

Figure 5. Causes for shrinking of Savanna vegetation over the hills, a) Exotic plantations, b) *Lantana camara* inva-

CONCLUSION

This study shows that urban development has encroached upon environmentally sensitive habitats. The expansion of urban areas has come at the expense of productive savanna vegetation, causing a decline in vegetation cover over the hills due to exotic plantations and human activities. It is essential to protect these habitats from ecosystem degradation factors such as afforestation of non-native species, dumping of waste, slums, roads and other anthropogenic activities. It is crucial to raise awareness and educate citizens and policymakers about conserving these unique habitats.

ACKNOWLEDGEMENTS

The research is part of first authors PhD work. We are grateful to the University Grants Commission of India for providing a research fellowship to the first author to complete his PhD. We also acknowledge the support from the Indian Space Research Organisation (ISRO), the Departmental Research Development Program – Savitribai Phule Pune University (DRDP-SPPU), and the University Grants Commission – Centre for Advanced Studies (UGC-CAS). Special thanks to Dr. Sameer Bajaru of the Bombay Natural History Society, India, for his guidance in GIS. We would also like to acknowledge the Department of Zoology, Savitribai Phule Pune University, for providing research facilities.

Conflicts of interest - The authors declare no conflict of interests.

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