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Assessing Asian Elephant Habitat Preferences in the Central Western Ghats Using GIS, Remote Sensing, and Analytical Hierarchy Process (AHP)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Geographic Information Systems (GIS) and remote sensing are geospatial technologies that have been widely utilized in environmental science for decades, including data collecting and analysis on animal physical disability, wilderness modeling, and site assessment. Remote sensing technology has been employed in the present investigation. GIS and Analytical Hierarchy Process (AHP) methods were used to assess the habitat preferences of Asian elephants. Use satellite imagery and topographic maps to create environments and habitats, including land use cover (LULC), static vegetation (Normalized Difference Vegetation Index), water, Digital Elevation models (DEM), line

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and aspect. Next comes the use of AHP to determine the location, select the location's priority and distribution pattern. This study examined the habitat preferences of Asian elephants in the Shakleshpur Taluk in the Central Western Ghats in the Karnataka district of Hassan. The results show that 16 percent of the land and 18 percent of the population is covered with forests. Most places have an altitude of 25° to 40° and an altitude of 800 m and 1000 m. The amount of water in the region is limited to the habitat of the elephants. Habitats inhabited by elephants highlight the need for good management inside and outside protected areas to protect these elephants, especially in areas of translocation, to ensure that habitats are compatible. This information will be useful to people working to safeguard Asian elephants and their surroundings in the Western Ghats.

Keywords: Western Ghats; habitat suitability mapping; GIS & remote sensing; AHP.

1. INTRODUCTION

According to the International Union for Conservation of Nature (IUCN) Red List, elephants, who were previously widely spread throughout the Indian subcontinent, are now considered an endangered species. It is included in Convention on International Trade in Endangered Species (CITIES). The International Union for Conservation of Nature [1] states that there is a very substantial threat to the extinction of both Asian and African elephants. In Peninsular Malaysia [2], as well as throughout Asia [3,4,5,6,7], habitat loss and fragmentation continue to pose the greatest challenges to Asian elephants. This is due to the conversion of forests to other land uses, such as plantations, housing developments, roads, and other development plans [8].

The Hassan district of the Indian state of Karnataka is where Shaleshpur Taluk is located. These coordinates closely pinpoint the location of Shakleshpur Taluk: 12.893° N; 76.725° E in longitude. Shakleshpur Taluk spans an area of around 102700 hectares. Elephants and people frequently clash in this area. There is no protected area there. This region was made aware of the Project Elephant in Karnataka [9].

The movement and distribution of an elephant are influenced by a variety of factors. These include physical and anthropogenic, biotic and abiotic, and factors connected to spatial or geographical information. Elephant movement and dispersion are influenced by both biotic and abiotic causes. Examples of biotic elements that affect animals' herding behaviors include food, water, and social systems. The accessibility of resources and the choice of habitat are governed by the abiotic factors of terrain and climate. Mobility is also impacted by breeding sites and natural impediments. Urbanization, agriculture, and infrastructure all have a significant negative impact on habitats and lead to conflicts between humans and elephants. Conservation efforts like protected areas and corridors aim to mitigate these consequences and safeguard elephant movement. Understanding these intricate impacts is crucial if elephant habitats are to strike an appropriate balance between ecological preservation and human needs. The selection of Shakleshpur's tropical and subtropical environment as the elephants' home can be applied to other tropical areas of Karnataka and India.

So, common spatial technologies that can be employed in environmental studies include remote sensing and Geographic Information Systems (GIS). These technologies offer a method for accessing and visualizing intricate interactions between variables, which is helpful for incorporating scale and hierarchy notions into ecosystem-based management evaluations [10] and for assessing management and research activities [11]. Kushwaha et al. [12] claim that GIS and remote sensing technologies have been utilized to collect data on the physical characteristics of wildlife habitats. Saaty [13] developed the Analytic Hierarchy Process (AHP) approach, which enables the optimal choice to be chosen while taking both objective and subjective criteria into account. The AHP technique has really been used in a wide range of judgments and decision-making processes [14]. This approach helps in logically determining criteria and alternatives [15].

Thus, utilising remote sensing, GIS, and AHP techniques, this work presents a study of the Asian elephant's preferred habitat at Shakleshpur Taluk in the central western ghats region. A deeper understanding of the links between species and habitats would be made possible by the habitat appropriateness assessed in the GIS environment through the analysis of habitat usage based on environmental and topographical data. Utilization distribution, meanwhile, permits the identification of important elephant habitat criteria and their prioritisation. The study is able to assess the characteristics and criteria used and to create a map of the area's habitat suitable for Asian elephants.

2. MATERIALS AND METHODS

The study area is Shakleshpur taluk of Hassan district which is located in the western half of the district and are part of the Central western Ghat range with an average elevation of 950 metres above sea level. The Köppen and Geiger classification for this climate is Aw. The average temperature of Sakleshpur is 22.7 °C. Here, the annual rainfall total is about 2178 mm. These locations typically have the following plant types: Deciduous Forest Trees: Teak, sandalwood, rosewood, and other species of hardwood trees are frequently seen. trees with evergreen leaves: Indian laurel (*Ficus indica*), fig, and jackfruit trees can all be found in this area. Sakleshpur Taluk is home to numerous coffee and arecanut plantations. The land cover of this area comprises of evergreen forest and agricultural land. with tall green hills covered in Coffee, Cardamom, Banana, Black pepper, and Arecanut plantations. These crops are the most important contributors to the economy of these taluks.

2.1 Selection of Significant Habitat Layers and Suggested Rules or Criteria

Five factors—LULC, NDVI, Proximity to water sources, DEM, and slope—were proposed as the probability for significant environmental and physical landscape layers for elephant habitat preferences based on the GIS spatial and literature analysis. Topography was found to be a moderate predictor of the presence of elephants, while the LULC, NDVI, and distance from water sources were identified as the principal relevant habitat characteristics. However, this study's conclusion is that the aspect parameter has no bearing on how elephants are distributed. In order to create a suitable habitat mapping or modeling, it is also not recommended as an elephant habitat preference parameter. The findings of Zhixi et al. [16], which demonstrated a strong correlation between elephant migration and aspect factor, notably the east-north aspect, do not support this.

Another habitat characteristic that can be taken into account in the analysis is forest density (higher the NDVI higher the density), which is more important than NDVI (greenness) because it affects elephant migration. For a comprehensive knowledge of the link between Asian elephants and their habitat factors, it is also necessary to analyze the human activity parameters, such as roads, towns, etc.

2.2 Creation of Habitat Parameter Database

By digitizing features, digitally processing remote sensing data, and converting data from other sources, habitat parameters were acquired. These include things like forest status and land use-land cover (LULC). Water sources, slope, the Normalized Digital Vegetation Index (NDVI), and the Digital Elevation Model (DEM). The NDVI, LULC, and DEM maps were created using satellite imageries.

These photos were obtained using information from Landsat 8 and Shuttle Radar Topography Mission (SRTM). Two key procedures—image pre-processing and thorough image processing—were used to analyze these images. Before an image was processed, a step known as pre processing entailed correcting it for a variety of flaws, including radiometric, geometrical, and atmospheric corrections. Image improvement and mosaicking came next in the process. To make the image easier to read, image augmentation was carried out. To extract the photos matching to the research area, image masking was then used. During the thorough image processing, both supervised and unsupervised classifications were used to produce a LULC map.

The software used in this study is QGIS. The NDVI map layers were created using QGIS's Raster Calculator Tool in the interim. For many years [17,18], researchers have employed multispectral satellite data to assess and monitor plant growth, vegetation cover, and biomass production using the NDVI, which was first proposed by Rouse et al in [19]. It is produced utilizing the near-infrared (NIR) and red wavelengths reflected by vegetation's band ratio approaches. Using the QGIS Raster Calculator Tool, the following Map Algebra formula yields the NDVI map:

$$\mathbf{NDVI = Float\ (R1 - R2) / Float\ (R2 + R1)}$$

Float function was used to return a float data set with value between minus one (-1.0) and plus one (+1.0) for NDVI output, where R1 and R2 represent NIR and Red reflectances, respectively. Unhealthy vegetation (open forest, non-forest & rocky areas) reflects more in the visible spectrum and less in the NIR spectrum, whereas healthy vegetation reflects more in both the visible spectrum and the NIR spectrum. The NDVI output typically has negative values for water, snow, and clouds, whereas positive values range from 0.1 to 1 for vegetation and soil, respectively.

The digitizing process was used due to the limitation of supervised classification in mapping detailed forest status types and to overcome cloud cover limitations. Unsupervised and supervised image classifications performed in the QGIS were used as references during the digitizing process. Land use map (from the National Bureau of Soil Science and Land Use Planning) was also used as references and data validation for LULC and forest status maps.

We require NDWI (Normalized Difference Water Index) to detect the water pixels in order to calculate closeness to the water.
The Normalized Difference Water Index (NDWI), initially introduced in Gao in [20], reflects soil and plant moisture content and is calculated by analogy with NDVI as:

NIR- SWIR / NIR + SWIR

The range of the NDWI product, which has no dimensions, is -1 to +1. Positive NDWI values indicate the presence of water, while negative values indicate the absence of water. Water bodies are present if the NDWI value is greater than 0.3. Using the QGIS buffer ring catalogue option, a water pixel buffer map was constructed after receiving the water pixel map for the relevant study region.

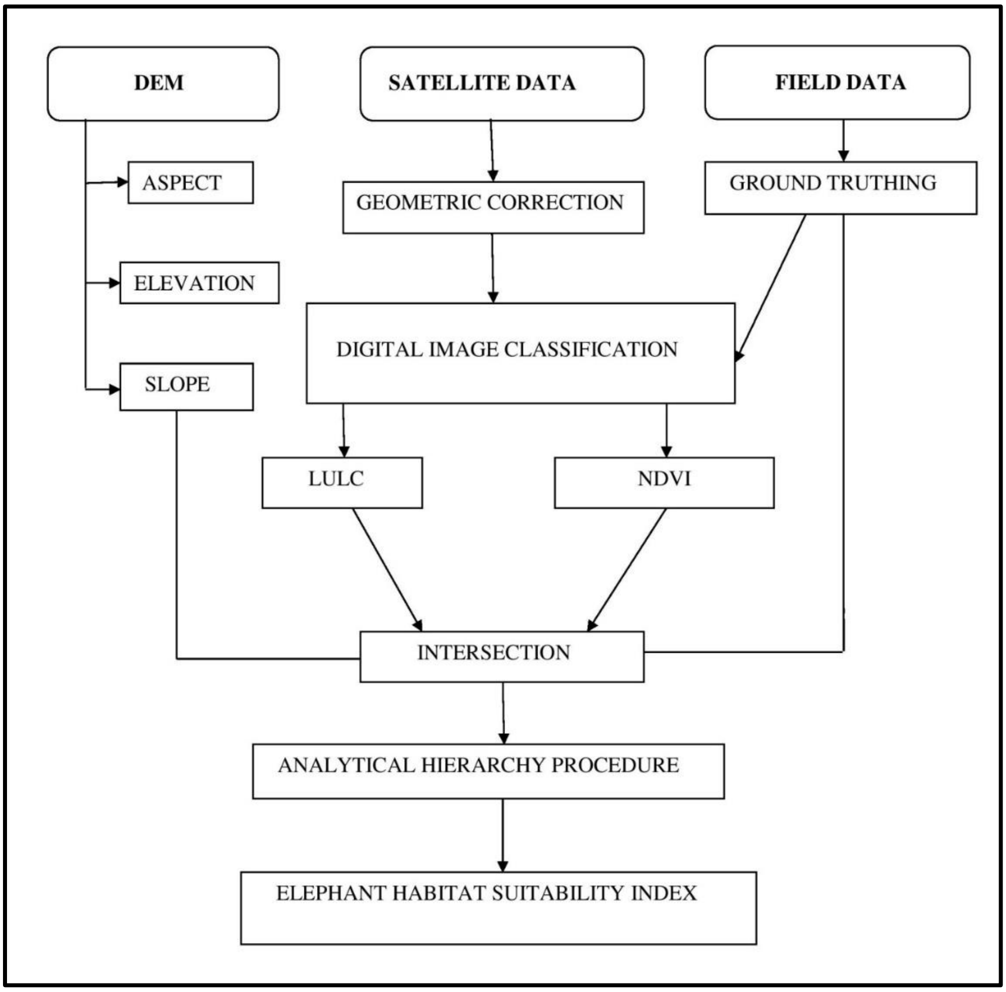

Fig. 1. The procedure of generating habitat suitability map

In the meantime, QGIS' spatial modeller was used to produce DEM and slope from topographic maps while also simplifying them. Contour lines were utilized to create a DEM map, with the spatial resolution determined by the satellite resolution image. Slope maps were created by further processing DEM data.

2.3 Allocation of AHP

To determine the priority score for each habitat parameter criterion, the current studies and literature were considered as references. Priority determination was done concurrently after conversation with a representative officer from the forest official. For this reason, weights based on the AHP technique were allocated to each habitat parameter and associated criterion (see Table 1). Accordingly, AHP is a suitable method for determining the weighting to be allocated to each habitat characteristic based on the nine intensities of relevance [21] shown in the Table.

In essence, the AHP technique is used to rate a group of alternatives or to choose the best among them. Three steps are involved in creating an overall priority rating: (i) creating the AHP hierarchy; (ii) comparing elements of the hierarchical structure pairwise; and (iii) The reciprocal matrix was computed in this investigation to produce a matrix comparison. Score assign was based on literature Boroushaki & Malczewski [22]. This matrix was subsequently utilized to generate a normalized matrix and create a priority ranking for each habitat characteristic. In order to gauge how consistent the AHP outcomes were, consistency index and consistency ratio calculations were made.

LULC (24%), NDVI (18%), distance from permanent water sources (18%), slope (23%) and elevation (17%) were the indicated ranking of priority for the major habitat factors computed by AHP, with a consistency ratio of 9%. As a result, the range is suitable for consistency. It is

Table 1. AHP pair-wise comparison scale

Intensity of importance	Definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very Strong importance
8	Very to extremely strong importance
9	Extreme importance

Table 2. Reciprocal matrix

	LULC	NDVI	Water	Elevation	Slope
LULC	1	2/3	2	2	1
NDVI	3/2	1	½	1	2/3
Water	1/2	2	1	1/2	1
Elevation	1/2	1	2	1	1/2
Slope	1	3/2	1	2	1
Total	4.5	6.16	6.5	6.5	4.16

Table 3. Standardized matrix

	LULC	NDVI	Water	Elevation	Slope	Weightage
LULC	1	2/3	2	2	1	0.24
NDVI	3/2	1	1/2	1	2/3	0.18
Water	1/2	2	1	½	1	0.18
Elevation	1/2	1	2	1	1/2	0.17
Slope	1	3/2	1	2	1	0.23
Total	4.5	6.16	6.5	6.5	4.16	1.00

The consistency ratio of this standardized matrix is 0.09

Table 4. The suggested criteria of significant habitat parameter for Asian elephants, particularly in Central Western Ghats

Level of Suitability	Land use Land cover	NDVI	Proximity to water (m)	Elevation (m)	Slope (%)
Highly Suitable	Forest	0.5-0.7	0-500	0-300	0-8
Moderate Suitable	Agricultural land	>0.7	500-1000	300-500	8-15
Marginally Suitable	Water Bodies	0.3-0.5	1000-2000	500-800	15-25
Marginally Unsuitable	Barren land	0- 0.3	2000-3000	800-1000	25-40
Highly Unsuitable	Built up Area	-1- 0	>3000	>1000	>40

crucial to remember that a decent degree of consistency is one with a consistency ratio of the order of 10% or lower. In example, utilizing weighted overlay in the GIS application, the ranking of the habitat characteristics generated by AHP can be utilized as a general guideline to determine habitat suitability mapping or modeling.

3. RESULTS AND DISCUSSION

Land use change is a major driver of habitat transition, with far-reaching implications for wildlife distribution and ecological systems. The terrain divided into five macro classes. This region having a 16 per cent evergreen forest area, a 58 per cent agricultural land area, a 18 per cent built up area, a 6% barren land and 2% area having water sources. Plantation lands grew faster than any other type, whereas forest areas shrank. Similar type of result was stated by Sunanda et al., [23]. Forest communities frequently sustain higher biomass, or higher NDVI, which are uncommon and contain relatively few ground plants, according to Olivier [24] and Sukumar [25]. The medium to dense forest region in the Shakleshpur Taluk had NDVI values between 0.0 and 0.86, which is regarded to have good quality and quantity of vegetation. A moderate quantity of green vegetation is also indicated by the NDVI range of 0.5-0.7, which is present in 28% of these areas. Ex-logging roads in the secondary forest also offer good accessibility for elephant movements [26] and offer more food sources, such as grass, which also contain more water volume [27]. The abundance of food plants and water supplies would decrease once the habitat was removed or altered, pushing the elephants to move to nearby forest regions [27].

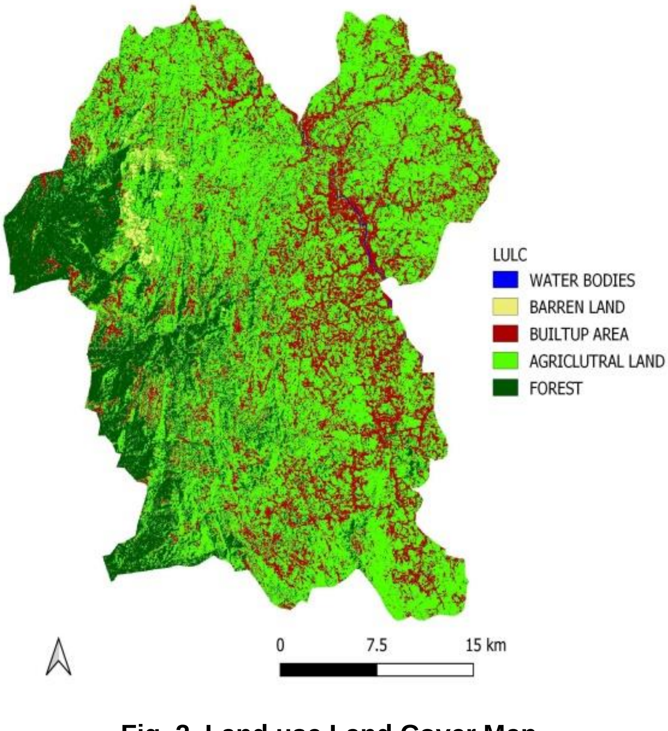

Fig. 2. Land use Land Cover Map

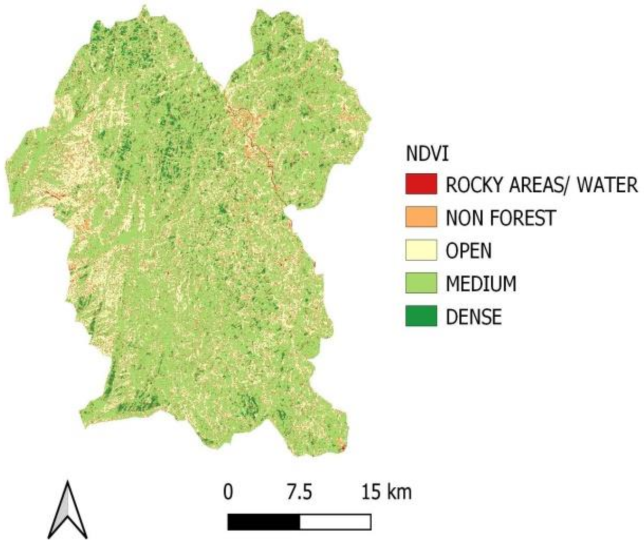

Fig. 3. NDVI Map

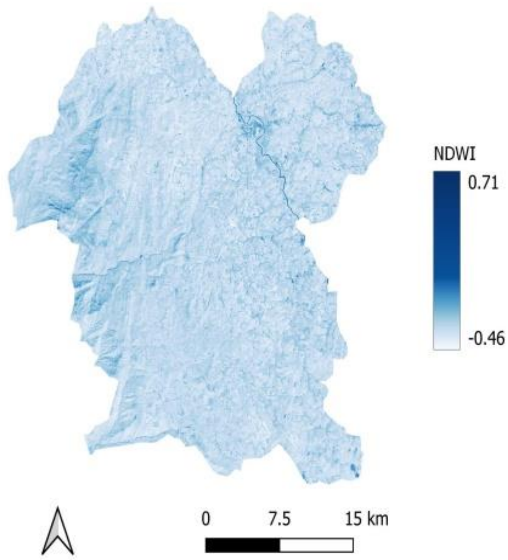

Fig. 4. NDWI Map

In addition, the majority of the region has a slope of 25° and 40° and is situated between 800 and 1000 meters above sea level. Elephants may go to a wide range of elevations in their habitat, from sea level to montane [28,25,29,30]. According to this study, elephants are accustomed to environments up to 1055 meters above sea level. However, elephants could favor lowland locations when food sources are also present. Due to the terrain of the locations, where the Eastern section of the taluk is flatter than the Western region, variations between the DEM and slope criteria used by both elephants were present.

The investigation of water sources revealed results that were in line with earlier studies that claimed the availability of water sources had an impact on elephants' range behavior [27]. As a result, throughout the year, the geographical and temporal distributions of elephants are significantly influenced by the availability of water sources [31-33]. This study indicates that 24 per cent of area was close to water source *i.e.*, up to 500m. In this study, the factual situation in the field is directly proportionate to the research findings and the views of Santiapillai, [34] and Krishnan, [35] in which it was indicated that this area is limited in terms of water for elephant habitat.

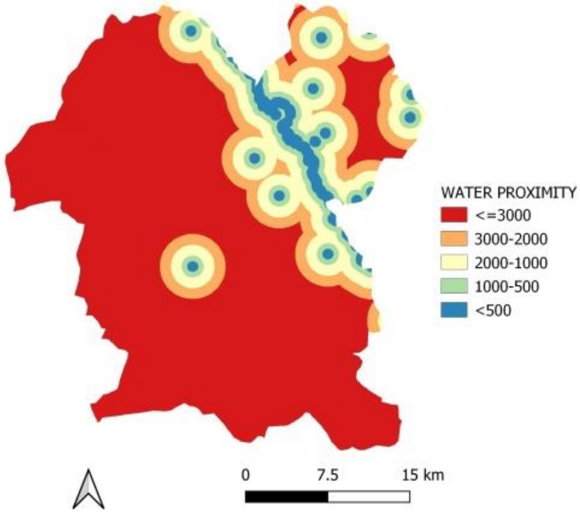

Fig. 5. Proximity to water

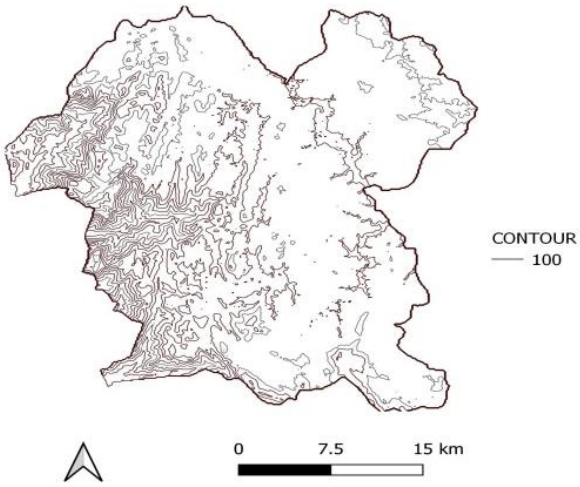

Fig. 6. Contour Map

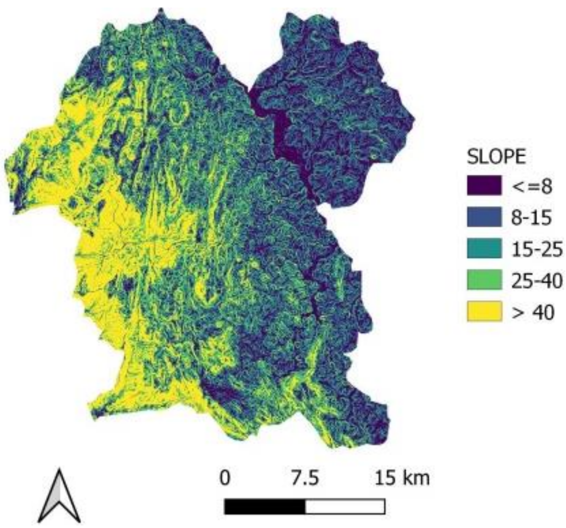

Fig. 7. Slope Map

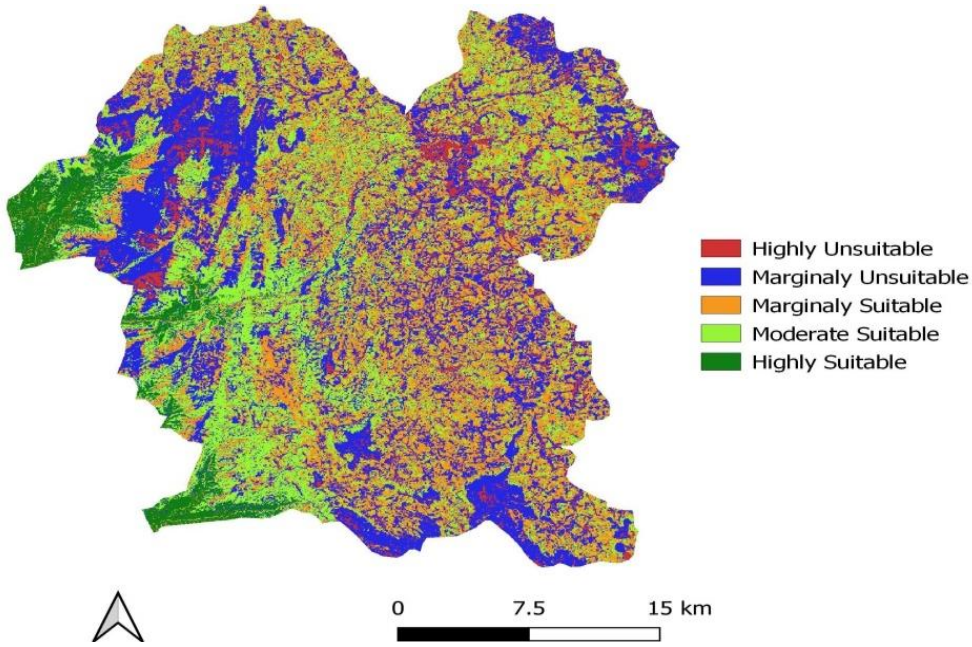

Fig. 8. Habitat Suitability map for Asian elephant in Shakleshpur taluk

Our study agrees with previous studies which described elephant presence is minimum in human activity area [36,37] such as paths and settlements. Analytical hierarchy procedure was used to create habitat suitability map by integrating all variables themed map according to provided weightage.

The result revealed that 13 per cent of the land is highly suitable, 18 per cent is moderately acceptable, 39 per cent is marginally suitable, 26 per cent is slightly unsuitable, and 4 per cent is highly unsuited for elephant habitat after carrying out the entire research work. According to the mapping result, the elephant can live in 16 per cent of the study area, with the majority of it limited to evergreen forest areas and elephants prefer habitat with low elevation, mild slope, and accessibility to water sources, similar to the previous studies [38]. However, within their distributional range, elephants' space utilization is regulated by resource distribution, plant type, changes in land use, and the presence of human disturbance [39]. The Asian elephant's habitat is being fragmented in China [40]. Similarly, we observed fragmentation in our research field. The study's findings are consistent with those of earlier investigations conducted by Wheelock [28], Sukumar [25], and Santiapillai [3].

4. CONCLUSION

Advances in geographic information systems and the accessibility of information in remote spatial regions aid in a more accurate assessment of Asian elephants' interests. This is because geographic information systems offer cutting-edge capabilities for data analysis and modeling while remote sensing data offers precise and timely information on important parameters. Additionally, the identification of acceptable elephant habitats for conservation or resettlement was made possible by the application of spatial and geostatistical analysis, AHP, to choose essential habitats and their distribution patterns. Additionally, AHP is adaptable enough to periodically update and modify expert opinions or decision symbols to satisfy the demands of natural resource development and animal protection. The findings also indicated a favorable correlation between elephant distribution and forest cover, particularly forests and slopes. Physical characteristics like height and distance from water were noted as the elephants' drawbacks in terms of being in the center of their distribution and being useless. According to the habitats that elephants inhabit, maintaining this species necessitates efficient management both inside and outside of protected areas to guarantee that Asian elephants continue to serve as a good umbrella species in the jungle.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. IUCN. IUCN Red List of Threatened Species. Version 2008.1; 2008.
2. Salman M, Khan MA, Hussain S, Rizwan M, Khan AM, Ahmad Z. Effects of different levels of dietary protein on performance, carcass characteristics and meat quality of broiler chicks. Journal of Animal and Plant Sciences. 2011;21(4):794-799.
3. Santiapillai C, Jackson P. The Asian elephant: An action plan for its conservation. Gland, Switzerland: IUCN; 1990.
4. Sukumar R. The Asian elephant: ecology and management. Cambridge, UK: Cambridge University Press; 1992.
5. Leimgruber P, McShea WJ, Brookes A, Bolor-Erdene L, Wemmer C, Larson CR. Spatial patterns in relative primary productivity and elephant distribution in the central Okavango Delta, Botswana. Journal of Applied Ecology. 2003;40(1): 234-247.
6. Hedges S, Tyson M, Sitompul AF, Kinnaird MF, Gunaryadi D. Distribution, status, and conservation needs of Asian elephants (*Elephas maximus*) in Lampung Province, Sumatra, Indonesia. Biological Conservation. 2005;124(1):35-48.
7. IUCN. IUCN Red List of Threatened Species. Version 2012.2; 2012.
8. DWNP. National Elephant Action Plan. Department of Wildlife and National Parks, Ministry of Environment, Botswana; 2006.
9. Madhusudan MD, Sharma N, Raghunath R, Baskaran N, Bipin CM, Gubbi S, Sukumar R. Distribution, relative abundance, and conservation status of Asian elephants in Karnataka, southern India. Biological Conservation. 2015;187: 34-40.
10. Imhol JG, Fitzgibbon J, Annable WK. A hierarchical evaluation system for characterizing watershed ecosystems for fish habitat. Canadian Journal of Fisheries and Aquatic Sciences. 1996;53(S1):312-326.
11. O'Neil TA, Carroll JP, Kinnaird MF. Evaluating conservation research and management efforts: A case study from the Udzungwa Mountains, Tanzania. Biological Conservation. 2005;123(1):27-38.
12. Kushwaha SPS, Singh JS, Rao KS. Ecological restoration of degraded sodic lands: An appraisal. Annals of Arid Zone. 2002;41(4):315-331.
13. Saaty TL. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. New York: McGraw-Hill; 1980.
14. Lee H, Zhuang Y, Ahn H. A comparative analysis of the use of the Analytic Hierarchy Process (AHP) for urban renewal decision making. International Journal of Urban Sciences. 2001;5(2):119-137.
15. Qureshi Q, Harrison RD. The status of forest elephants in central Laos: An assessment using rapid survey techniques. Oryx. 2003;37(3):353-360.
16. Zhixi L, Jianqiang L, Songtao G. Habitat fragmentation and its impact on the population of Asian elephant in Xishuangbanna. Acta Ecologica Sinica. 2005;25(6):1326-1333.
17. Jackson JE, Ares JC, Paredes JL, Charles EM. Interpretation of the relation between vegetation indices and landscape features: A case study in the Selway-Bitterroot Wilderness. Remote Sensing of Environment. 1983;13(4):295-303.
18. Eitel JU, Gessler PE, Smith AM, Robberecht R. Suitability of existing and novel spectral indices to remotely detect water stress in *Populus spp*. forests. Remote Sensing of Environment. 2010; 114(11):2665-2674.
19. Rouse Jr JW, Haas RH, Schell JA, Deering DW. Monitoring vegetation systems in the great plains with ERTS. Third Earth Resources Technology Satellite-1 Symposium-Volume I: Technical Presentations. 1974;309-317.
20. Gao BC. NDWI - a normalized difference water index for remote sensing of vegetation liquid water from space. Remote Sensing of Environment. 1996; 58(3):257-266.
21. Kushwaha SPS, Roy PS. Development of forest vegetation map of India using IRS LISS II data. Journal of Biosciences. 2002;27(7):677-686.
22. Boroushaki S, Malczewski J. Implementing an extension of the analytical hierarchy process using ordered weighted averaging operators with fuzzy quantifiers in ArcGIS. Computers & Geoscience. 2008;34(4):399-410.
23. Sunanda B, Prasad KVSR, Reddy GPO. Spatio-temporal analysis of land use/cover changes using remote sensing and GIS techniques: A case study of Nuzvid Mandal, Krishna District, Andhra Pradesh, India. The Egyptian Journal of Remote

Sensing and Space Science. 2014;17(2): 261-270.
24. Olivier RC. Population dynamics of the African elephant (*Loxodonta africana* Blumenbach) in the Luangwa Valley, Zambia. Biological conservation. 1978; 14(3):165-183.
25. Sukumar R. The Asian Elephant: Ecology and Management. Cambridge University Press; 1989.
26. Salman AA, Nasharuddin SZ. Assessing the environmental impact of land use change using remote sensing and GIS: A case study in the Klang Valley, Malaysia. International Journal of Remote Sensing. 2000;21(16):3161-3176.
27. Alfred R, Singh B, Bhat MS. Estimation of forest biomass and carbon stocks in India: A fusion of remote sensing and biomass estimation. Journal of Applied Remote Sensing. 2012;6(1):063511.
28. Wheelock H. The African elephant: A selected bibliography. Commonwealth Agricultural Bureaux, Farnham Royal; 1980.
29. Mohd Momin Khan M. Studies on the ecology of the Asian elephant (*Elephas maximus*) in Peninsular Malaysia (Doctoral dissertation, Universiti Putra Malaysia); 1992.
30. Ente RH, Hart LA, Stoinski TS. An evaluation of elephant welfare in North American zoos accredited by the Association of Zoos and Aquariums. Journal of Applied Animal Welfare Science. 2010;13(3):207-227.
31. de Beer Y, van Aarde RJ. Elephant impact on *Combretum apiculatum* in the Kruger National Park, South Africa. African Journal of Ecology. 2008;46(3):300-308.
32. Ngene SM, Muya EM, Karanja GG. Habitat use by African elephant (*Loxodonta africana*) in relation to temporal variations in food resources in the southern sector of Tsavo East National Park, Kenya. Tropical Ecology. 2009;50(2):325-335.
33. Claudia W, Lancia RA, Strager MP. Landscape structure and habitat characteristics as predictors of capercaillie occurrence in the Italian Alps. European Journal of Wildlife Research. 2012; 58(3):583-593.
34. Santiapillai C. The Asian elephant: an action plan for its conservation. IUCN; 2004.
35. Krishnan, A. (2019). Living with Elephants: Ecological Politics, Agrarian Change, and Conservation in Southern India. Oxford University Press.
36. Blake S, Strindberg S, Boudjan P, Makombo C, Bila-Isia I, Ilambu O, Walsh P. Forest elephant crisis in the Congo Basin. PloS One. 2008;3(3):e2548.
37. Neupane PR, Thapa K, Shrestha R, Koirala R, Poudel S. Assessment of Human-Elephant Conflict in Nepal: A Study from Parsa National Park and Its Buffer Zone. Tropical Conservation Science. 2019;12:1940082919848955.
38. Douglas-Hamilton I, Krink T, Vollrath F. Movements and corridors of African elephants in relation to protected areas. Naturwissenschaften. 2014;101(11):1041-1053.
39. Hoare RE, du Toit JT. Coexistence between people and elephants in African savannas. Conservation Biology. 1999;13(3):633-641.
40. Zhang L, Wang J. Theoretical research on decision-making modeling for the management of wildlife resources. Acta Ecologica Sinica. 2003;23(3):435-442.

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