Original Research Article

Mapping Asian Elephant Habitat Suitability Index in Alur Taluk, Central Western Ghats: A GIS, Remote Sensing, and Analytical Hierarchy Process (AHP) Approach for Conservation Assessment

ABSTRACT

Geographic Information Systems (GIS) and remote sensing are geospatial technologies that have been used for decades in environmental science, including the collection and analysis of data on the physical disabilities of animals, and modelling of wilderness and site assessment. In this study, remote sensing technology was used. GIS and Analytical Hierarchy Process (AHP) methods were used to assess the habitat index of Asian elephants. Use of satellite imagery and topographic maps to create environments and habitats, including land use cover (LULC), vegetation (NDVI), water, and elevation models (DEM). Next comes the use of AHP to determine the location, select the location's priority and distribution pattern. 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 assist those involved in protecting Asian elephants and their environment in the central Western Ghats region.

Keywords :Central Western Ghats, Habitat Suitability Index, GIS & Remote Sensing, AHP

INTRODUCTION

Elephants once widely distributed throughout Indian sub-continent have now categorized as endangered species as per red list of IUCN. It comes under Appendix – 1 of CITIES. According to the International Union for Conservation of Nature (IUCN, 2008), both the Asian and African elephants are facing a very real threat of extinction. Habitat loss and fragmentation remain the greatest threats to Asian elephants throughout their range in Asian countries (Santiapillai& Jackson 1990; Sukumar, 1992; Leimgruber et al., 2003; Hedges et al., 2005; IUCN, 2012), as well as in Peninsular Malaysia (Salman et al., 2011). This is a result of forests being converted to various types of land use, like plantations, housing developments, roadways, and other development plans (DWNP, 2006).

There are many factors that influence an elephant's movement and distribution. These include biotic and abiotic, physical and anthropogenic factors that are associated with spatial or geographical information. Hence, Geographic Information System (GIS) and remote sensing are common spatial technologies that can be used in environmental studies. These technologies provide a way to access and depict complex relationships among variables which are useful for incorporating scale and hierarchy concepts into ecosystem-based management assessments (O'Neill, 1996) and to evaluate research and management efforts (O'Neil et al., 2005). According to Kushwaha et al. (2002), remote sensing and GIS technologies have been used for gathering information on the physical parameters of wildlife habitats. The Analytic Hierarchy Process (AHP) method, which was introduced by Saaty (1980), allows the consideration of both objective and subjective factors in selecting the best alternative. In fact, the AHP method has been applied in a wide variety of decisions and human judgment process (Lee et al., 2001). This method is useful in identifying criteria and alternative in logical manner (Qureshi &Harisson, 2003).

Thus, utilising remote sensing, GIS, and AHP techniques, this work presents a study of the Asian elephant's preferred habitat at Alur 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.

MATERIALS AND METHODS

The study area is Alur 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 land cover of this area comprises of evergreen forest and agricultural land. The climate of Alur taluk is tropical, 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.

Selection of Significant Habitat Layers and Suggested Rules or Criteria

Based on the GIS spatial and literature analysis, five factors were suggested as the probabilities for significant environmental and physical landscape layers for elephant habitat preferences, namely, LULC, NDVI, Proximity to water sources, DEM, and slope. The LULC, NDVI and distance from water sources were suggested as main significant habitat parameters, while topography was identified as a moderate predictor of the presence of elephants. However, it is the finding of this study that the aspect parameter has no influence on the elephant distribution. It is also not suggested as an elephant habitat preference parameter in order to develop a suitability habitat mapping or modelling. This does not agree with the results published by Zhixi et al. (2005) who showed a good relationship between elephant movement and aspect factor, particularly the east-north aspect.

Forest density (quality) is another habitat parameter that can be considered in the analysis as it influences elephant movement and it is the most significant parameter compared to NDVI (greenness). In addition, an analysis of the human activity parameters such as road, settlements, etc. need to be taken into account for a holistic understanding of the relationship between Asian elephants and their habitat parameters.

Creation of Habitat Parameter Database

Habitat parameters were obtained from digitization of features, digital processing of remote sensing data and conversion of data from other sources. These include land use- land cover (LULC) such as forest status. Normalized Digital Vegetation Index (NDVI), water sources, Digital Eelevation Model (DEM), and Slope. Satellite imageries were used to generate the NDVI, LULC and DEM map.

The acquisition of these images was based on the data from Landsat 8 and SRTM. These images were analysed using two major processes, namely image pre-processing and detailed image processing. Pre processing involved the procedure that was carried out before the image was processed by correcting the image of various errors such as geometric, atmospheric and radiometric corrections. This process was followed by image mosaicking and enhancement. Image enhancement was performed in order to improve the interpretability of the image. Finally, Image masking was applied to extract the images corresponding to the study area. Bothe unsupervised and supervised classifications were applied during the detailed image processing to generate an LULC map.

QGIS is the main software used in this study. Meanwhile the Raster Calculator Tool in QGIS was used to generate the NDVI map layers. NDVI was proposed by Rouse *et al* (1974), and it has been used to measure and monitor plant growth, vegetation cover, and biomass production from multispectral satellite data for many years (Jackson *et al.*, 1983; Eitel *et al.*, 2010). It is generated using the band ratio techniques of the the near-infrared (NIR) and red wavelength reflected by vegetation. The NDVI map is calculated from the following Map Algebra expression using the Raster Calculator Tool in QGIS:

NDVI = Float (R1 – R2) / Float (R2 + R1)

where R1 and R2 represent NIR and Red reflectance's, and where Float function was used in order to return a float data set with value between minus one (-1.0) and plus one (+1.0) for NDVI output. Healthy vegetation reflects much more in NIR wavelength than in visible wavelength, whilst unhealthy vegetation reflects more in visible wavelength and less in NIR wavelength. Generally, negative values for NDVI output represent water, snow and cloud, with 0.1 to 0.2 representing soil and 0.3 to 1 representing vegetation.

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 NBSSLUP) was also used as references and data validation for LULC and forest status maps.

For calculating proximity to the water, we have to first identify the water pixels, for this we need NDWI (Normalized difference water index).

Normalized Difference Water Index (NDWI), introduced for the first time in 1996 in Gao, reflects moisture content in plants and soil and is determined by analogy with NDVI as:

NIR- SWIR / NIR + SWIR

The NDWI product is dimensionless and varies from -1 to +1. Positive NDWI value indicate pixel having water and negative value indicates pixel does not have water content. NDWI value > 0.3 indicates presence of water bodies. After obtaining water pixel map of corresponding study area, using buffer ring catalogue option in QGIS buffer map of water pixels was created.

Meanwhile, DEM and slope were generated from topographic maps using analysis tools and also simplified using spatial modeller in QGIS. A DEM map was generated from contour lines, where spatial resolution was based on the satellite resolution image used. DEM data were further processed to generate slope maps.

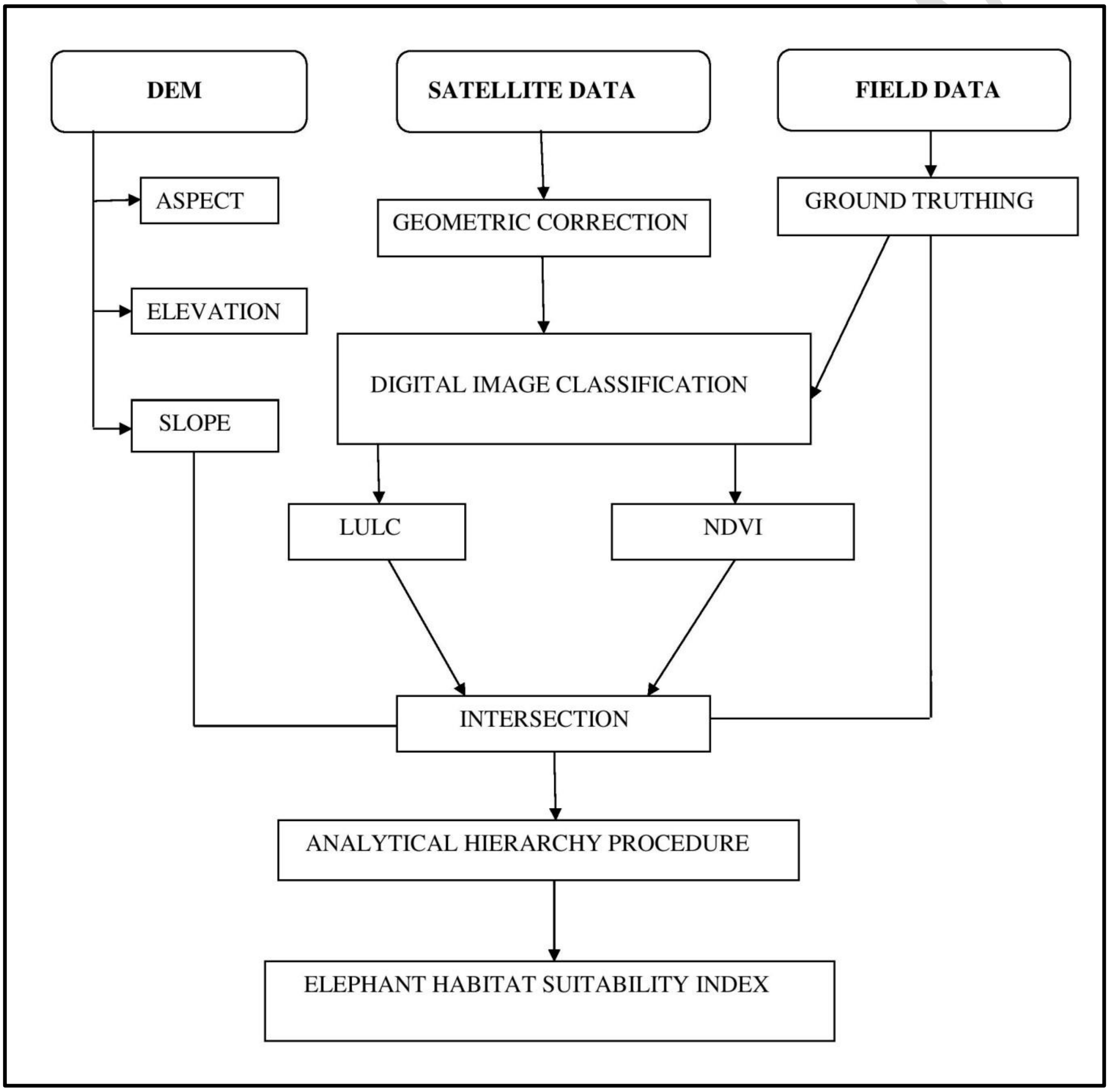


Fig. 1. The procedure of generating habitat suitability map

Allocation of AHP

The existing studies and literatures were used as references in identifying the priority score for each habitat parameter criterion. Simultaneously, priority identification was done through consultation with a representative officer from forest official. For this purpose, each habitat parameter and its criteria were assigned weight based on the AHP procedure (see Table 1). In this regard, AHP is an appropriate method to deriving weightage to be assigned to each habitat parameters based on nine intensity of importance (Kushwaha & Roy, 2002) shown in Table .

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

Basically, the AHP procedure is employed for rating a set of alternatives or for selecting the best in a set of alternatives. The AHP procedure involves three major steps: (i) developing the AHP hierarchy, (ii) pairwise comparison of elements of the hierarchical structure, and (iii) constructing an overall priority rating (Boroushaki& Malczewski, 2008). In this study, the reciprocal matrix was calculated to generate a matrix comparison. Subsequently, this matrix was used to compute a normalized matrix in order to construct a priority rating for each habitat parameter. Finally, consistency index and consistency ratio were calculated to measure the level of consistency of the AHP results.

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**.

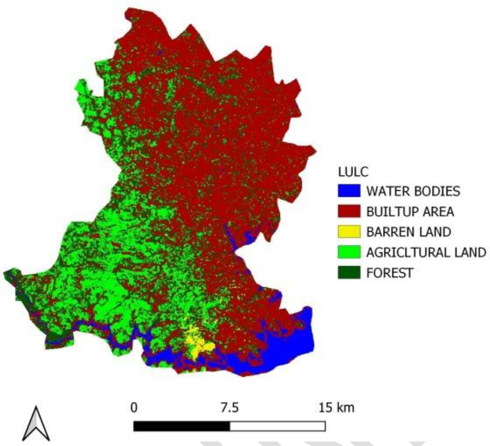
Subsequently, the suggested ranking of priority computed by AHP for the significant habitat parameters were LULC (24%), NDVI (18%), distance from permanent water sources (18%), slope (23%) and Elevation (17%), with a consistency ratio of 9%. Thus, it is an acceptable range for consistency. It is important to note that a consistency ratio of the order 10% or smaller is a reasonable level of consistency. The ranking of the habitat parameters computed by AHP can be used as a general guideline to identify habitat suitability mapping or modelling, particularly using weighted overlay in the GIS application. Finally, rules or criteria of significant habitat parameters computed by AHP and distribution analysis were classified into five levels of suitability, namely, highly suitable, moderately suitable, marginally suitable, marginally unsuitable, and highly unsuitable.

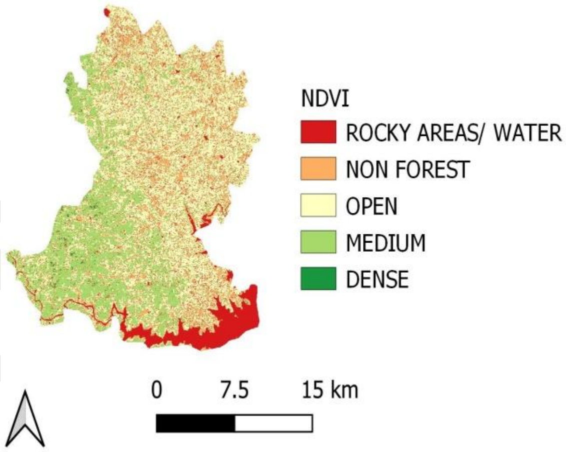
Table 4: The suggested criteria of significant habitat parameter for Asian elephants, particularly in Central Western Ghats.

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

RESULTS AND DISCUSSION

Land use change is a key driver of habitat transformation, with far-reaching ramifications for wildlife distribution and ecological systems.The terrain divided into five macro classes. This region having a 4 per cent evergreen forest area, a 27 per cent agricultural land area, a 59 per cent built up area, a 2% barren land and 8% 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.,* 2014. According to Olivier (1978) and Sukumar (1989), forest communities often support higher biomass (i.e. higher NDVI) which are rare and have relatively small numbers of ground plants. The NDVI values for the Alur taluk were between 0-0.81, and medium to dense forest area are considered as having good quality and quantity of vegetation. 38 percent of these area having NDVI range of 0.5-0.7 which also indicate a moderate density of green vegetation.In addition, ex-logging roads in the secondary forest offer good accessibility for elephant movements (Salman &Nasharuddin, 2000) and provide greater food sources (i.e. grass) which also contain higher water volume (Alfred et al., 2012). Once the habitat was cleared or converted, the availability of food plants and water sources would reduced, forcing the elephants to travel to adjacent forest areas (Alfred et al., 2012).





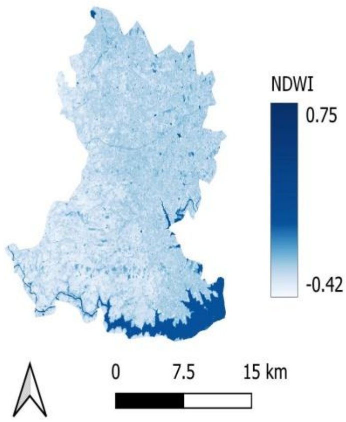
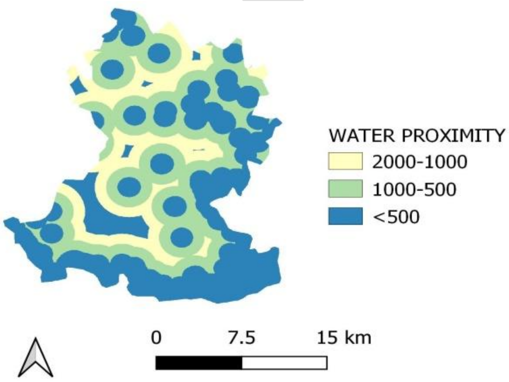
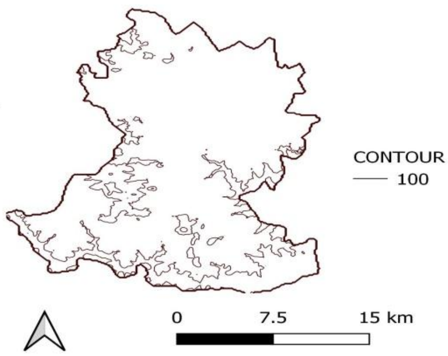


Fig. 2. Land use Land Cover Map Fig.3. NDVI Map Fig.4. NDWI Map





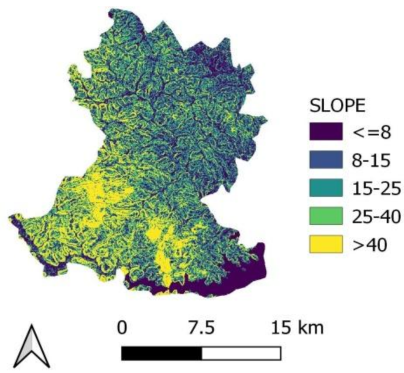


Fig. 5. Proximity to Water Fig. 6. Contour Map Fig. 7. Slope Map

Besides, most of area are located between 800 m and 900 m altitude with 8° and 25° slope, respectively. where elephants are capable of moving to a wide variety of range elevations, from sea level to montane (Wheelock, 1980; Sukumar, 1989; Mohd Momin Khan, 1992; Ente et al., 2010). This study found that the elephants are used to areas up to 975 meters above the sea level. However, elephants may prefer lowland areas where there is availability of food sources as well. The differences between the criteria of DEM and slope utilized by both elephants were due to the topography of the areas, where the Eastern region of taluk is flatter as compared to the Western region.

The result of the water sources analysis was also shown to be consistent with those of the previous studies which reported the ranging behaviour of elephants as being influenced by the availability of water sources (Alfred et al., 2012). Thus, the availability of water sources plays an important role in the spatial and temporal distributions of elephants throughout the year (de Beer & van Aarde, 2008; Ngene et al., 2009; Claudia et al., 2012). This study indicates that 54 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 Krishnan, (2019) in which it was indicated that this area is not limited in terms of water for elephant habitat.

Our study agrees with previous studies which described elephant presence is minimum in human activity area (Blake *et al.*, 2008; Neupane *et al.*, 2019) 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.

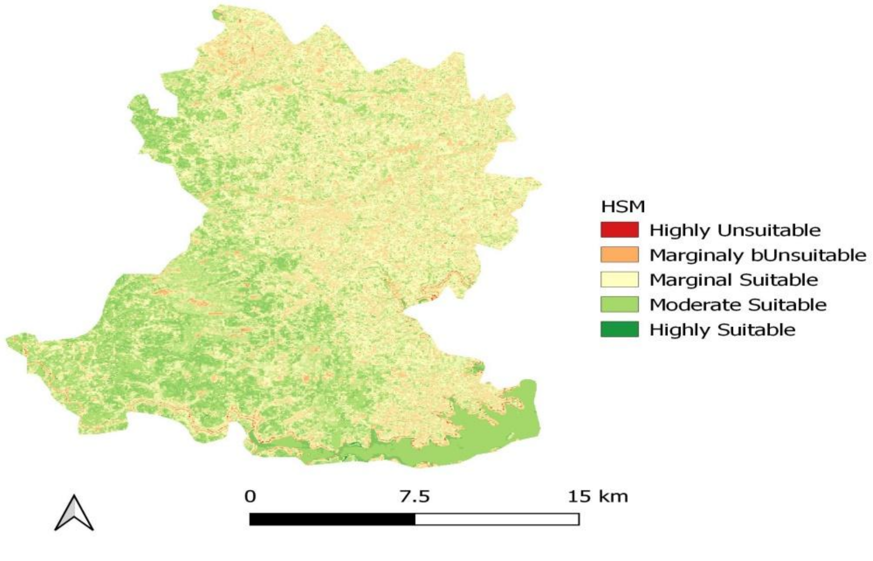


Fig. 8. Habitat Suitability map for Asian elephant in Alur taluk.

The result revealed that 16 per cent of the land is highly suitable, 24 per cent is moderately acceptable, 48 per cent is marginally suitable, 11 per cent is slightly unsuitable, and 1 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 (Douglas-Hamilton et al., 2014)..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 (Hoare & Du Toit, 1999).The Asian elephant's habitat is being fragmented in China (Zhang and Wang, 2003). Similarly, we observed fragmentation in our research field.

CONCLUSION

Availability of information in distant spatial areas and advances in geographic information systems help to better assess the interests of Asian elephants. This is because remote sensing data provides accurate and timely information on key parameters, while geographic information systems provide advanced tools for data analysis and modelling. In addition, the use of spatial and geostatistical analysis and AHP to select critical habitats and their distribution patterns allowed the identification of suitable elephant habitats for conservation or resettlement. In addition, AHP is flexible enough to update and change expert judgments or decision symbols from time to time to meet wildlife conservation and natural development needs. The results also showed a positive relationship between the distribution of elephants and forest cover, especially forests and slopes.Physical criteria such as height and proximity to water were identified as the negative side of the elephants being somewhere in the middle of their distribution and being useless. Habitats used by elephants indicate that protecting this species requires effective management inside and outside protected areas to ensure Asian elephants remain a good umbrella species in the jungle.

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