# 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).

Many factors affect the movement and distribution of elephants. These include biotic and abi otic, physical and anthropogenic factors associated with spatial or geographic information. Thus, geographic information systems (GIS) and remote sensing are spatial technologies that can be used for environmental research. These concepts provide a way to access and explain t he relationships between variables that are essential for integrating the concepts of scale and hierarchy into ecosystembased systems, evaluating (O'Neill, 1996) and monitoring research a nd management efforts (O'Neil et al., 2005).According to Kushwaha et al. (2002) used remot e sensing and GIS techniques to gather information about the physical vulnerability of wildlif e. The Research Hierarchy (AHP) method proposed by Saaty (1980) allows both objectives a

nd context to be considered in the selection of the best solution. In fact, AHP is widely used in many decision-making and human decision-making processes (Lee et al., 2001).
This approach is useful in identifying patterns and other methods that will be effective (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 GIS spatial and literature analysis, five factors were proposed as probabilities for significant environmental and physical landscape layers for elephant preferences, namely LULC, NDVI, proximity to water sources, DEM, and slope. LULC, NDVI and distance to water sources were suggested as the main significant habitat parameters, while topography was identified as a moderate predictor of elephant presence. However, this study shows that the aspect parameter has no effect on the distribution of elephants. It is also not recommended as a preferred elephant habitat parameter for the purpose of creating appropriate habitat mapping or modelling. This disagrees with the results published by Zhixi et al. (2005) who showed a good relationship between elephant movement and aspect, especially east-north aspect.

Another habitat characteristic that can be taken into account in the analysis is forest density (quality), which has a greater impact on elephant mobility than NDVI (greenness). A comprehensive knowledge of the interaction between Asian elephants and their habitat factors should also take into account the examination of human activity parameters, such as highways, towns, etc.

### Creation of Habitat Parameter Database

Using 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 image were obtained using information from Landsat 8 and 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 major application used in this study is QGIS. The NDVI map layers were created using QGIS's Raster Calculator Tool in the interim. For many years (Jackson et al., 1983; Eitel et al., 2010), 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.,1974) It is produced utilizing the near-infrared (NIR) and red wavelengths reflected by vegetation's band ratio approaches. 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)**

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 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.

Due to supervised classification's limitations in mapping certain forest status classes and cloud cover issues, the digitizing procedure was employed. During the digitizing procedure, unsupervised and supervised picture classifications made in the QGIS were used as references. Additionally, references and data validation for the LULC and forest status maps were made using the land use map (from the NBSSLUP).

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 1996, 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.

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.

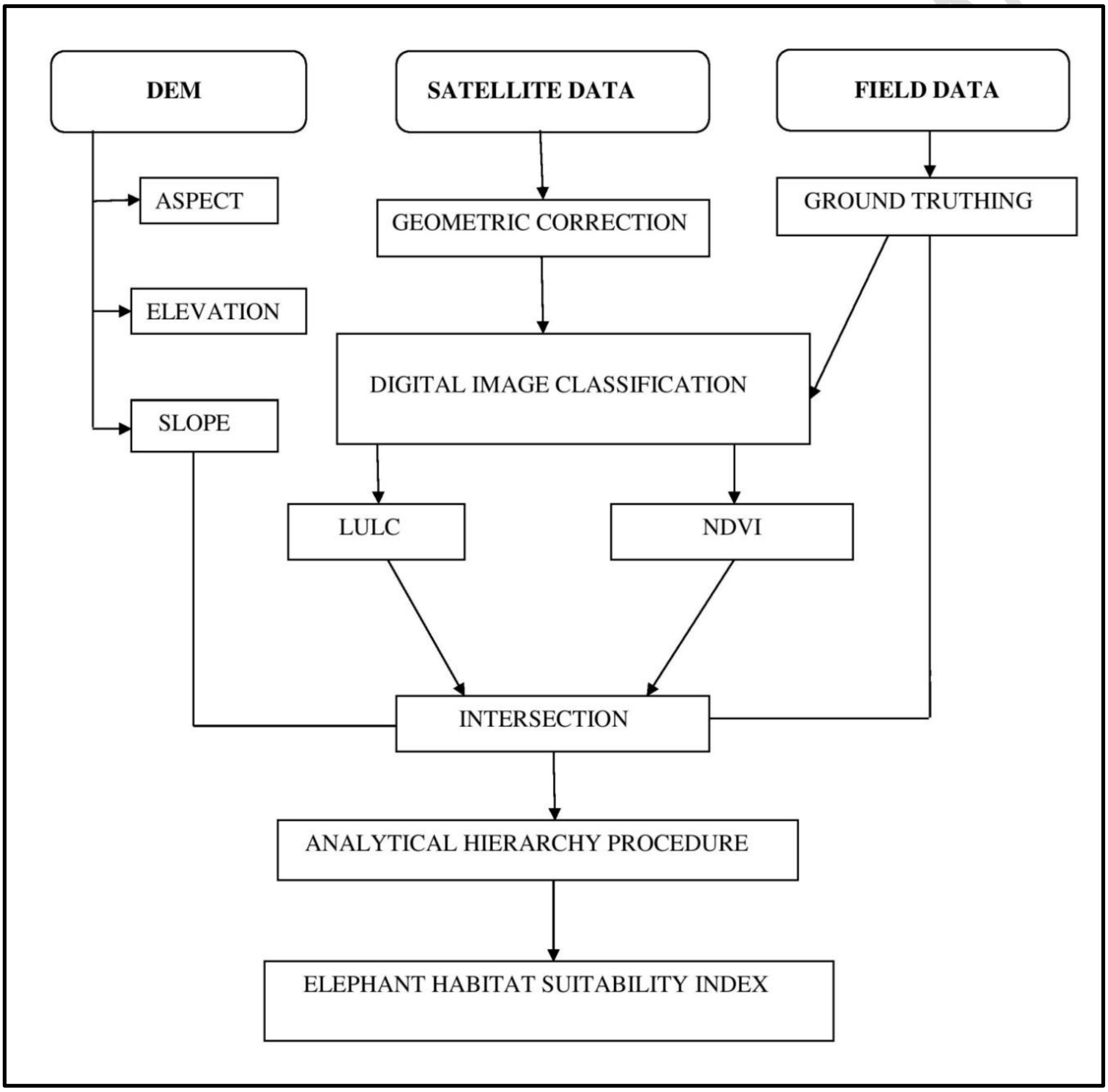


Fig. 1. The procedure of generating habitat suitability map

**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 (Kushwaha & Roy, 2002) shown in the 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 |

In essence, the AHP technique is used to rate a group of alternatives or to choose the best among them. There are three main steps in the AHP process: 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) Boroushaki & Malczewski (2008). The reciprocal matrix was computed in this investigation to produce a matrix comparison. 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.

**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**.

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 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. 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. Forest communities frequently sustain higher biomass, or higher NDVI, which are uncommon and contain relatively few ground plants, according to Olivier (1978) and Sukumar (1989). The Alur Taluk's NDVI readings ranged from 0 to 0.81, and medium-density forestland is regarded as having good quality and quantity of vegetation. A considerable amount of green vegetation is also indicated by the fact that 38% of these areas have NDVI values between 0.5 and 0.7. Ex-logging roads in the secondary forest also offer good accessibility for elephant movements (Salman & Nasharuddin, 2000) and offer more food sources, such as grass, which also contain more water volume (Alfred et al., 2012). The abundance of food plants and water supplies would decrease as the habitat was destroyed or altered, pushing elephants to travel to adjacent forest areas (Alfred et al., 2012).



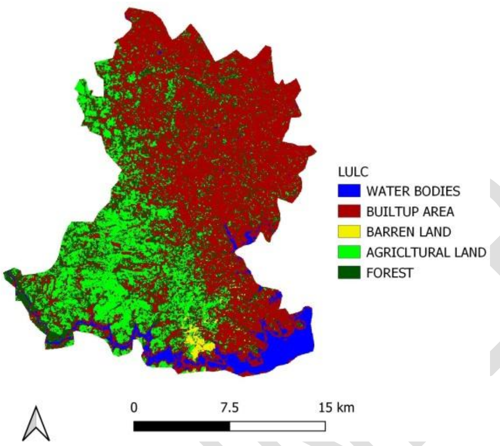


Fig. 2. Land use Land Cover Map

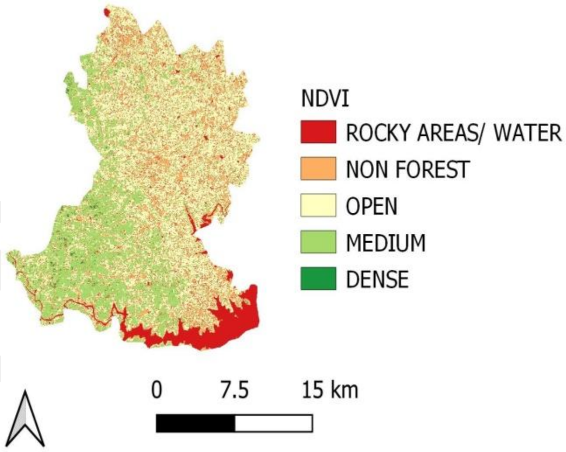


Fig.3. NDVI Map

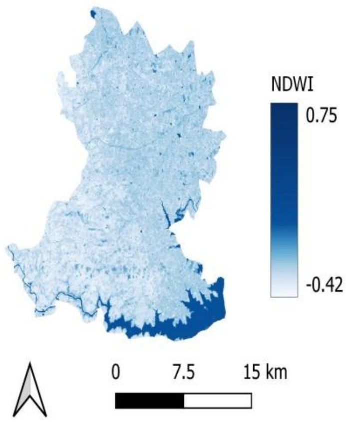


Fig.4. NDWI Map

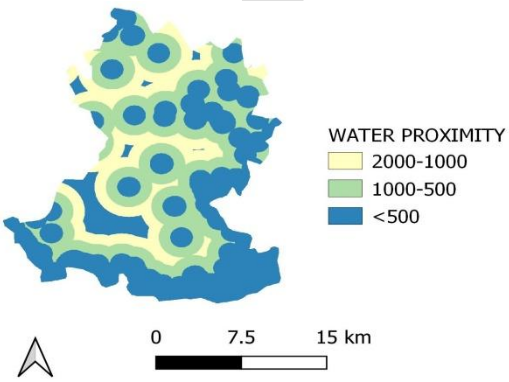


Fig. 5. Proximity to Water

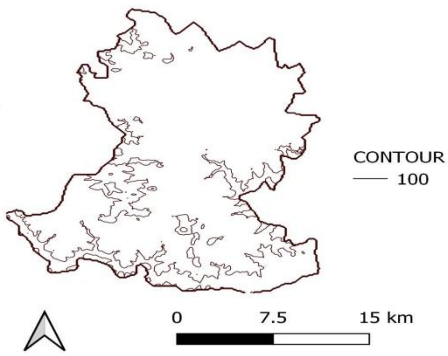


Fig. 6. Contour Map

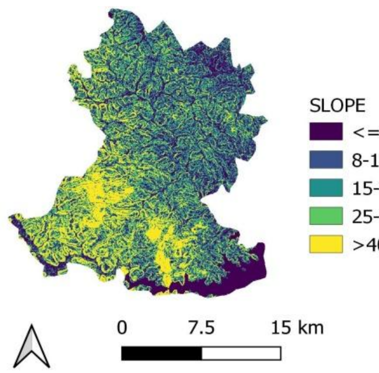


Fig. 7. Slope Map

The majority of the land is also between 800 and 900 meters above sea level, with slopes of 8 and 25 degrees, respectively. Elephants may go to a wide range of elevations in their habitat, from sea level to montane (Wheelock, 1980; Sukumar, 1989; Mohd Momin Khan, 1992; Ente et al., 2010). According to this study, elephants are accustomed to environments up to 975 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 (Alfred et al., 2012). Therefore, throughout the year, the availability of water sources has a significant impact on the spatial and temporal distributions of elephants (Claudia et al., 2012). According to this study, 54% of the land was within 500 meters of a water source. According to Krishnan (2019), who reported that there are no water shortages in this location for elephant habitat, the real field scenario in this study is directly related to the research findings.

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.

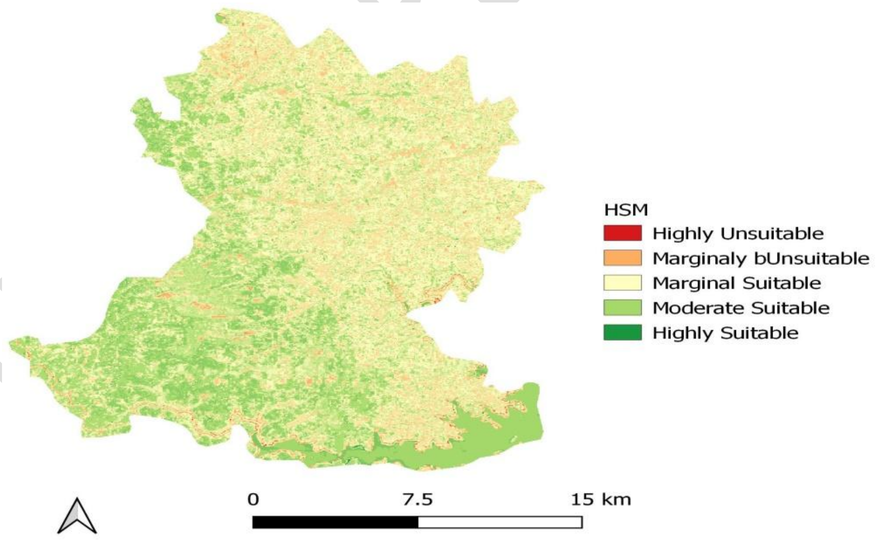


Fig. 8. Habitat Suitability map for Asian elephant in Alur taluk.

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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