Pertanika J. Sci. & Technol. 23 (1): 37 - 50 (2015)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Analysing Elephant Habitat Parameters using GIS, Remote Sensing and Analytic Hierarchy Process in Peninsular Malaysia

Suhaida Aini[1, 2*], Alias Mohd Sood[2] and Salman Saaban[3]

[1]*Malaysian Remote Sensing Agency, No. 13 Jalan Tun Ismail, 50480 Kuala Lumpur, Malaysia*

[2]*Department of Forest Production, Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*

[3]*Division of Biodiversity Conservation, Department of Wildlife and National Parks, KM10 Jalan Cheras, 56100 Kuala Lumpur, Malaysia*

ABSTRACT

Geographic Information System (GIS) and remote sensing are geospatial technologies that have been used for many years in environmental studies, including gathering and analysing of information on the physical parameters of wildlife habitats and modelling of habitat assessments. The home range estimation provided in a GIS environment offers a viable method of quantifying habitat use and facilitating a better understanding of species and habitat relationships. This study used remote sensing, GIS and Analytic Hierarchy Process (AHP) application tools as methods to assess the habitat parameters preference of Asian elephant. Satellite images and topographical maps were used for the environmental and topographical habitat parameter generation encompassing land use-land cover (LULC), Normalized Digital Vegetation Index (NDVI), water sources, Digital Elevation Model (DEM), slope and aspect. The kernel home range was determined using elephant distribution data from satellite tracking, which were then analysed using habitat parameters to investigate any possible relationship. Subsequently, the frequency of the utilization distribution of elephants was further analysed using spatial and geostatistical analyses. This was followed by the use of AHP for identifying habitat preference, selection of significant habitat parameters and classification of criterion. The habitats occupied by the elephants showed that the conservation of these animals would require good management practices within and outside of protected areas so as to ensure the level of suitability of the habitat, particularly in translocation areas.

Keywords: Asian elephant, AHP, habitat preference, home range, GIS, and remote sensing

Article history:
Received: 7 Mar 2013
Accepted: 11 July 2013

E-mail addresses:
suhaidaaini@gmail.com (Suhaida Aini),
ms_alias@upm.edu.my (Alias Mohd Sood),
salman@wildlife.gov.my (Salman Saaban)
*Corresponding Author

ISSN: 0128-7680

INTRODUCTION

As a spatial utilization measurement, home range estimation is an important tool in wildlife management. Today, the home range and habitat use of the Asian elephants are often determined from satellite telemetry relocation points, which are the primary sources of data. Home range can be defined as an area where an individual elephant traverses in its normal activities (Burt, 1943), in relation to various uses such as feeding, drinking, resting, pathway network, defecation and marking points (Salman & Nasharuddin, 2000). There are many methods to delineate the home range pattern including minimum convex polygon (MCP), harmonic mean, kernel and Jennrich-Turner home ranges. Most studies on Asian elephants have used MCP which shows the area of animal uses and movements (e.g., Linde *et al.*, 1999; Salman & Nasharuddin, 2000; Prithiviraj *et al*., 2008; Alfred *et al*., 2011). However, the disadvantage of MCP is that it is very sensitive to sample size. The kernel method is a more realistic interpretation of what an animal is likely to use (Martin *et al*., 2007) and it gives the most accurate representation of the structure of an animal's range and core area size (Ferrel, 2004).

There are many factors that influence an elephant's movement and distribution as well as its home range utilization. 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).

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. Due to a large decrease in the number and status of elephants in Peninsular Malaysia, their status was elevated from protected species in 1972 to totally protected species in 2010. Based on the IUCN data, there are only around 40,000 Asian elephants left in the wild (Asian countries), out of which only 1,223 – 1,677 were left in Peninsular Malaysia (Salman *et al*., 2011). 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 due to the conversion of forests to other forms of land use such as plantations, housing estates, highways and other development schemes (DWNP, 2006). Thus, this paper presents a study of the Asian elephant's habitat preference at two different study sites using remote sensing, GIS, and AHP approach. The home range estimated in the GIS environment through the analysis of habitat utilization based on environmental and topographical parameters would provide a better understanding of species and habitat relationships. Meanwhile, utilization distribution enables identification of significant elephant habitat parameters and prioritization of its criterion. The study is able to evaluate the parameters criteria uses and to add or modify them in order to suit the preferences of stakeholders and Department of Wildlife and Natural Parks (DWNP) base on a multi-criteria decision making approach.

MATERIALS AND METHODS

The study area covers two different sites of satellite transmitted data from the elephant distributions known as Mek Boh and Mek Lukut, which are located in Terengganu National Park (TNP) and Northern Johor, respectively. Mek Boh was collared with a NOAA satellite transmitter between 1999 and 2000, and Mek Lukut with a GPS Satellite Collar in 2010 by the DWNP. TNP is located in the state of Terengganu, which has been one of the major places for translocated elephants since 1992. The second study site is located in the state of Johor in Peninsular Malaysia. With an average elevation of below 50 m, this area is mostly flat as compared to TNP. The land cover of this area comprises of inland forest, peat swamp forest and agricultural land (oil palm). However, both locations are covered with primary and mixed secondary forests. They consist of four natural forest types; lowland dipterocarp forest, hill dipterocarp forest, upper hill dipterocarp forest and montane forest. Detailed information of each captured elephant is summarized in Table 1 below.

TABLE 1: Summary of individual female elephant's distribution data

Location	Existing Forest Type	Elephant Name	Estimated Age (yr)	Weight (ton)	Type of Satellite	Tracking Record Date
TNP	Natural (Inland)	Mek Boh	25	2.5	NOAA (ARGOS instruments)	22 Aug 1999 – 9 Jan 2000
Northern Johor	Natural (Inland & Peat swamp)	Mek Lukut	25	1.5	GPS Satellite Collar (Africa Wildlife Tracking)	21 Jul 2010 – 31 Dec 2011

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 Elevation Model (DEM), slope and aspect. Satellite imageries were used to generate the NDVI, LULC and forest status map.

The acquisition of these images was based on the satellite transmitted data of both elephant distributions. In this case, data from Landsat TM (1999) and SPOT 5 (2010-2011) were used to generate relevant habitat parameters for Mek Boh and Mek Lukut, respectively. These images were analysed using two major processes, namely, image pre-processing and detailed image processing, as shown in Fig.1. 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

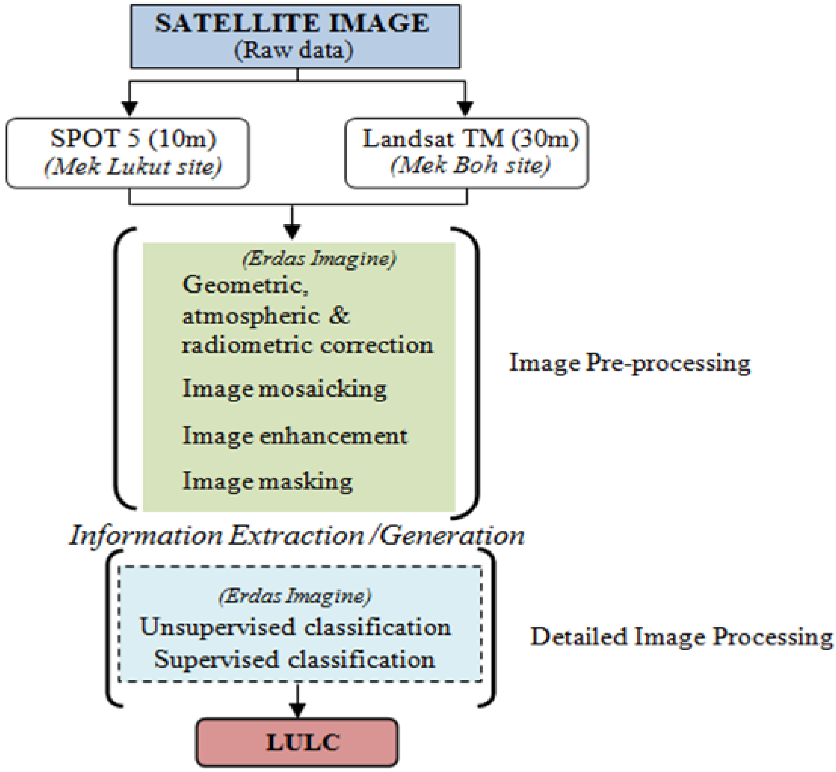

Fig.1: The main procedure of remote sensing data processing

interpretability of the image. This is an important procedure to increase the quality of the images for interpretation purposes, particularly through digitization process. Finally, image masking was applied to extract the images corresponding to the study area. Both unsupervised and supervised classifications were applied during the detailed images processing to generate an LULC map.

ArcGIS10 is the main software used in this study. Meanwhile, the Raster Calculator Tool in ArcGIS 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 technique of 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 ArcGIS:

$$NDVI = Float\ (R_1 - R_2) / Float\ (R_2 + R_1)$$

where R_1 and R_2 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.

LULC and forest status maps were produced by using screen digitizing of both satellite images in the GIS environment. 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 ERDAS Imagine were used as references during the digitizing process. Land use map (from the Department of Agriculture) and National Forest Inventory map (from the Department of Forestry) were also used as references and data validation for LULC and forest status maps, respectively. Meanwhile, DEM, slope, aspect and river buffer layers were generated from topographic maps using analysis tools and also simplified using spatial modeller in ArcGIS 10. 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 and aspect maps while river buffer was generated with certain distances.

Satellite Transmitter Data of Asian Elephant Distribution

The distribution data of Mek Boh and Mek Lukut were plotted on the map in Rectified Skew Orthomorphic (RSO) projection to facilitate home range and habitat preference analysis. According to DWNP, the accuracy of the transmitted location is governed by the frequency of the signals received. Based on the data, the percentage of the satellite tracking performance of Mek Boh and Mek Lukut was 24.0% and 66.7%, respectively. The poor accuracy of Mek Boh's tracking performance was possibly due to the high density of forest cover in TNP compared to Northern Johor.

Spatial utilization was analysed using Animal Movement Extension in ArcView 3.3 using kernel method and further analysed using ArcGIS 10. The home range patterns for Mek Boh and Mek Lukut were calculated using the kernel and MCP methods. However, the kernel method was used for further analysis so as to get more realistic interpretation of what an animal is likely to use (Martin *et al*., 2007), the most accurate representation of the structure of an animal's range and the size of core area (Ferrel, 2004). The kernel home range pattern overlaid with the satellite images is shown in Fig.2, while the home range obtained from both the methods is shown in Table 2. The small size of the home range for Mek Boh could possibly have been influenced by the forest status of the area, as TNP is one of the major protected areas in Peninsular Malaysia. In contrast, the land cover in Mek Lukut's distribution area comprises of plantations (oil palm) where the home range size is influenced by the degree of habitat fragmentation (Alfred *et al*., 2012).

Analysis of Elephants' Habitat Preferences

The home range area and the overall distribution data were analysed in ArcGIS 10 with six habitat parameters, namely, LULC, NDVI, DEM, slope, aspect, and river buffer, to study the habitat utilization by both elephants. Subsequently, the overall distribution data of the elephants were analysed to identify the significant habitat parameters and to prioritize their criterion. Using the Spatial Analyst tool, all values for each habitat parameter were extracted

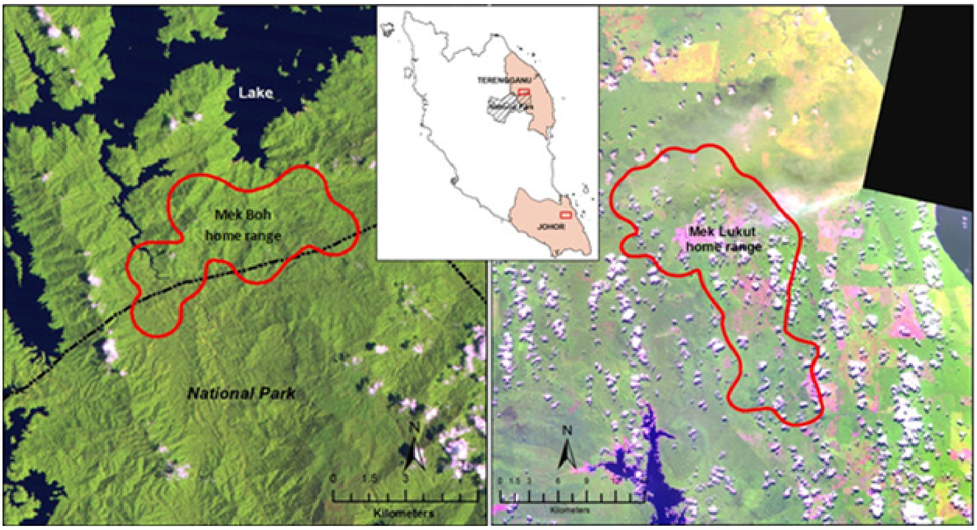

Fig.2. Mek Boh and Mek Lukut home range pattern (kernel) overlaid with Landsat TM and SPOT 5 satellite image, respectively. Inset: Map of Peninsular Malaysia showing the location of the study areas.

TABLE 2: Home range estimation using MCP and kernel

Elephant Name	Tracking Record Dates	Home range (km2)	
		≤95% MCP	Kernel
Mek Boh	22 Aug 1999 – 9 Jan 2000	21	34
Mek Lukut	21Jul 2010 – 31 Dec 2011	411	31

and included into the elephant distribution data layers. These data layers were further analysed using the Geostatistical Analyst Tool to examine the relationship between elephant distribution and habitat parameters. Subsequently, the Histogram Tool was applied to plot the frequency of the data and to compute the statistical information where the use of utilization distribution directly enhanced the studies of animal movement, species interactions and resource (Marzluff *et al.*, 2001). In addition, significant correlation between the overall elephant distribution data and the same habitat parameters was analysed using Microsoft Excel.

Allocation of AHP

The results of the distribution data analysis 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 DWNP. For this purpose, each habitat parameter and its criteria were assigned weight based on the AHP procedure (see Table 3). 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 3.

TABLE 3: 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

Adapted from Saaty (1980)

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.

RESULTS AND DISCUSSION

In general, both elephants utilized the secondary forest habitat, where ground plants were abundant, with various logging histories within their home ranges that were computed based on the kernel method. Fig.3 shows the percentage of forest habitat type utilized by Mek Boh and Mek Lukut within their home ranges. According to Olivier (1978) and Sukumar (1989), secondary forest communities often support higher biomass (i.e. higher NDVI) compared to primary forests, which are rare and have relatively small numbers of ground plants. The NDVI values for the home ranges of Mek Boh and Mek Lukut were between 0.4 to 0.5, and these are considered as having good quality and quantity of vegetation. These also indicate a moderate density of green vegetation. However, the cloud cover on the satellite image was identified as one of the constraints for NDVI data generation, particularly in Peninsular Malaysia.

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). In addition, Mek Lukut's home range was opened more for new selective logging and also intensively converted into other land uses, particularly for oil palm plantation as compared to Mek Boh's place (National Park) that was influenced by forest fragmentation and deforestation. 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).

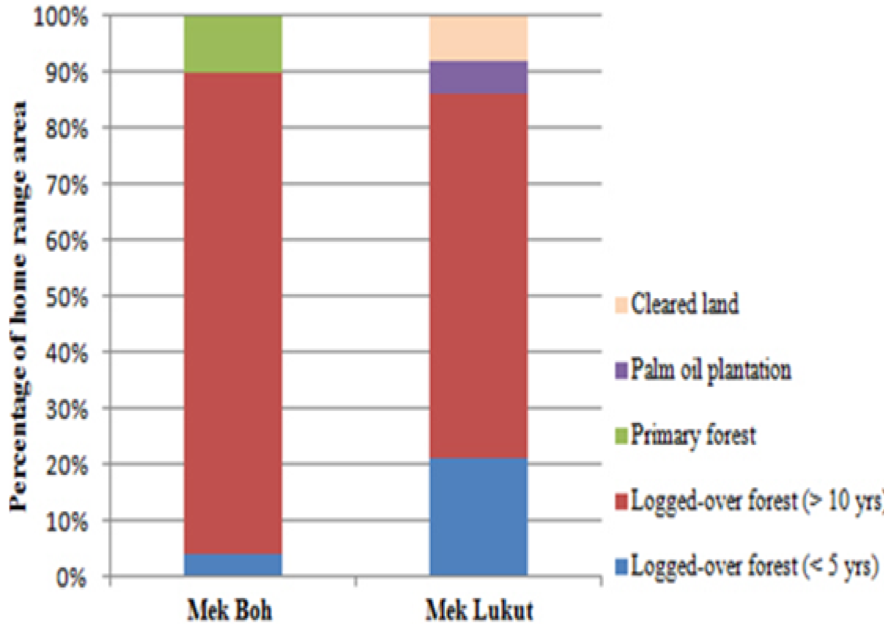

Fig.3. The percentage of the areas with different forest types utilized by tracked elephants. 90% of home range area utilized by Mek Boh is outside the protected areas (TNP) which are covered by secondary forest.

Besides, most of Mek Lukut and Mek Boh are located below 100 m and 750 m altitude with 18° and 25° slope, respectively. The results of the correlation analysis show insignificant relationships (Fig.4) between elevation, slope and elephant distribution, 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 1055 meters above the sea level (Mek Boh), which is within the montane forest type. 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 Southern region of Peninsular Malaysia is flatter as compared to the Northern 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). The results in Fig.5 show a significant correlation between the distances from water sources and elephant distributions. Furthermore in this study, Mek Lukut and Mek Boh utilized areas that are located less than 1.5 km from permanent water sources in the elephants' movement range areas, in which the percentages of the data gathered were 84% and 73%, respectively (Fig.6).

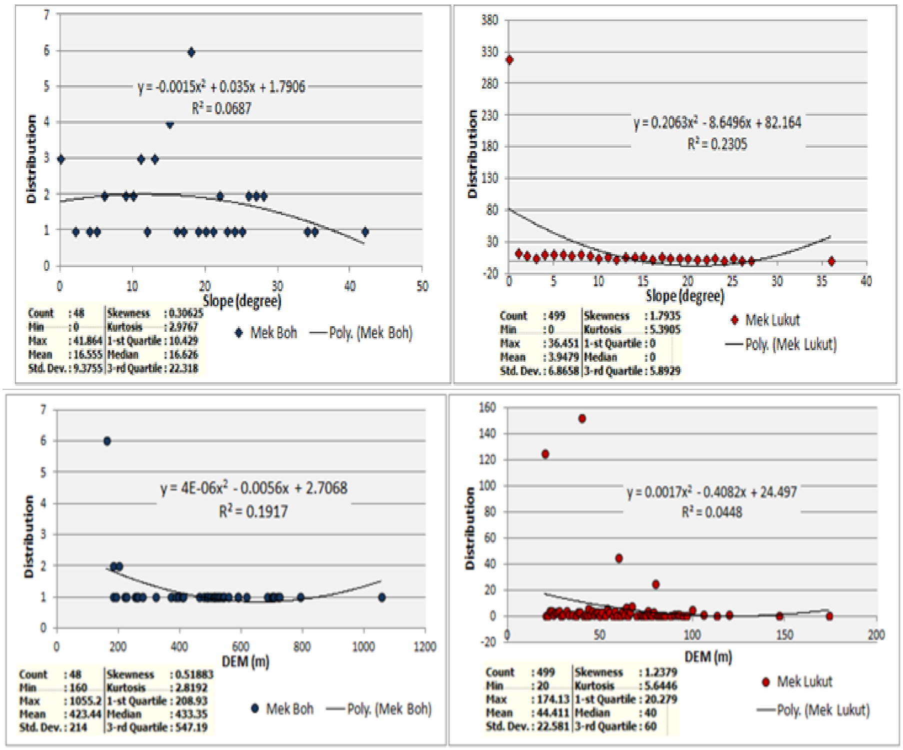

Fig.4. Polynomial regression, elephant distributions proved to be weakly constrained by slope (upper) and altitude (lower)

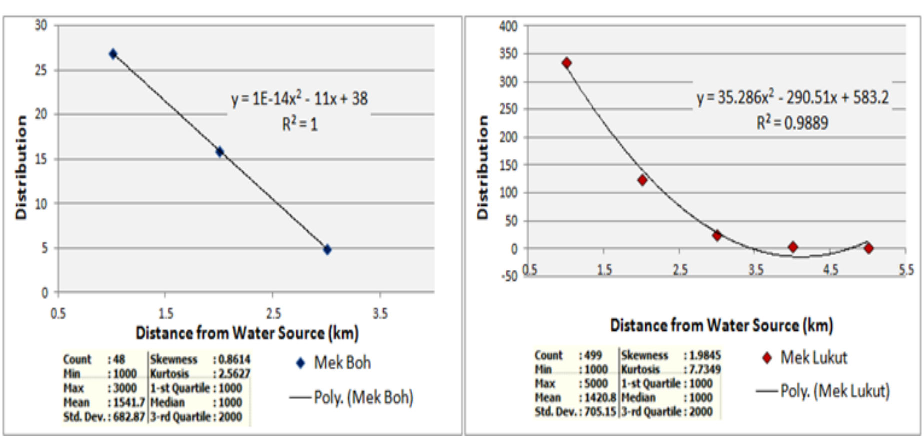

Fig.5. Negative correlation; as the distance from water source (km) increases, the number of elephant distribution decreases

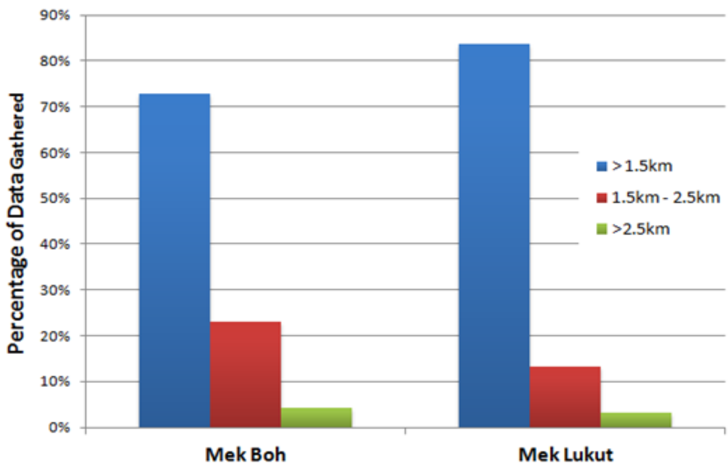

Fig.6: The percentage of different classes of distance from water sources utilized by both the elephants

Selection of Significant Habitat Layers and Suggested Rules or Criteria

Based on the GIS spatial and frequency distribution analysis, five factors were suggested as the probabilities for significant environmental and physical landscape layers for elephant habitat preferences, namely, LULC, NDVI, distance from 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.

Subsequently, the suggested ranking of priority computed by AHP for the significant habitat parameters were LULC (38%), NDVI (32%), distance from permanent water sources (20%), slope (6%) and DEM (4%), with a consistency ratio of 2.5% (Fig.7). 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. However, a consistency ratio greater than 10% requires a revision of the judgment in the matrix (weights) used in the APH analysis. 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 three levels of suitability, namely, highly suitable, moderately suitable, and marginally suitable (see Table 4).

Forest density (quality) is another habit at 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 distance from road, agricultural buffer zone, settlements, etc. need to be taken into account for a holistic understanding of the relationship between Asian elephants and their habitat parameters.

Estimating Weights for Elephant Habitat Parameters using AHP

Reciprocal matrix

Habitat Parameters:	LULC	NDVI	Water Source	Slope	DEM
LULC	1.000	1.500	2.000	6.000	8.000
NDVI	0.667	1.000	2.000	7.000	7.000
Water Source	0.500	0.500	1.000	4.000	6.000
Slope	0.167	0.143	0.250	1.000	2.000
DEM	0.125	0.143	0.167	0.500	1.000
SUM	**2.458**	**3.286**	**5.417**	**18.500**	**24.000**

Normalized matrix

Habitat Parameters:	LULC	NDVI	Water Source	Slope	DEM	Sum	% Priority
LULC	0.407	0.457	0.369	0.324	0.333	1.890	**37.80%**
NDVI	0.271	0.304	0.369	0.378	0.292	1.615	**32.30%**
Water Source	0.203	0.152	0.185	0.216	0.250	1.006	**20.13%**
Slope	0.068	0.043	0.046	0.054	0.083	0.295	**5.90%**
DEM	0.051	0.043	0.031	0.027	0.042	0.194	**3.88%**
SUM	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**5.000**	**100.00%**

lambda max: 5.10
consistency index (CI): 2.54%
consistency ratio (CR): 2.27%

Fig.7: The suggested level of priority for elephant habitat parameters using AHP

TABLE 4: The suggested rules or criteria of significant habitat parameters for Asian elephants, particularly in Peninsular Malaysia

Level of Suitability	Elevation (m)	Slope (degree)	Distance from water sources (km)	NDVI	Forest status
Highly suitable	<750	0 –20	<1.5	0.4 - 0.5	Mixed secondary forest
Moderate	750 -1000	20 – 40	1.5 - 2.5	0.5 - 0.6	Mixed secondary forest; Primary forest; Protected areas;
Marginally	>1000	>40	> 2.5	<0.4 & >0.6	Primary forest; Protected areas

CONCLUSION

The availability of spatial data from remote sensing and advances in GIS can assist in effective assessment of Asian elephants' habitat preferences. This is because remote sensing data provide accurate and timely information on essential habitat parameters, while GIS offers an advanced tool for data analysis and modelling. In particular, the method of home range estimation provided in a GIS environment offers a viable method for quantifying habitat use and assists with a better understanding of species and habitat relationships. In addition, the use of spatial and geostatistical analyses, as well as AHP approach to select the significant habitat parameters and classification of its criteria, provides a more reliable identification of suitable elephant habitat for preservation or translocation purpose. In addition, AHP is flexible enough to allow a revision and change expert judgment or decision marker from time to time in order to fulfil the requirement of wildlife conservation and physical development. The results also show that there is a strong relationship between distribution of elephant and forest cover, particularly the secondary forest and availability of permanent water sources. Physical landscape criteria, such as the elevation and slope, were identified as moderate habitat parameters in elephant distributions, while aspect parameter did not show any influence. The habitat utilized by elephants suggests that conservation of the species requires good management practices within and outside the protected areas to ensure that Asian elephants will still remain in tropical forests as a good umbrella species.

ACKNOWLEDGEMENTS

We would like to take this opportunity to thank the Department of Wildlife and National Park, Malaysia, especially Biodiversity Conservation Division for providing the satellite transmitter data of elephant distributions. Special appreciation also goes to the Malaysian Remote Sensing Agency for providing the satellite imageries and related geospatial data.

REFERENCES

Alfred, R., Ahmad, A.H., Payne J., Williams, C., & Ambu, L.N. (2012). Home Range and Ranging Behaviour of Bornean Elephant (*Elephas maximus borneensis*) Females. *PLoS ONE 7*(2), e31400. doi:10.1371/journal.pone.0031400.

Antunes, P., Santos, R., & Luı´s Jorda˜O. (2011). The application of Geographical Information Systems to determine environmental impact significance. *Environmental Impact Assessment Review, 21*, 511-535.

Govil & Sen, P. K. (2011). Geospatial modeling to assess elephant habitat suitability and corridors in northern Chhattisgarh, India. *Tropical Ecolog, 52*(3), 275-283.

Boroushaki, S. & Malczewski, J. (2008). Implementing an extension of the analytical hierarchy process using ordered weighted averaging operators with fuzzy quantifiers in ArcGIS. *Computers & Geosciences, 34,* 399 – 410.

Burt, W. H. (1943). Territoriality and home range concepts as applied to mammals. *Journal of Mammalog, 24,* 346-352.

Claudia, P., Skidmorea, A.K., Hein A.M.J., van Gils, A., Herbert, H.T., & Prins (2012). Identifying transit corridors for elephant using a long time-series. *International Journal of Applied Earth Observation and Geoinformation, 14,* 61-72.

de Beer, Y., & van Aarde, R.J. (2008). Do landscape heterogeneity and water distribution explain aspects of elephant home range in southern Africa's arid savannas? *Journal of Arid Environments, 72,* 2017-2025.

Dixon, K.R. & Chapman, J. A. (1980). Harmonic mean measure of animal activity areas. *Ecology, 61,* 1040-1044.

DWNP (2006). *Elephant Capturing Manual in Peninsular Malaysia.* Department of Wildlife and National Parks.

Ewer, R. F. (1968). *Ethology of Mammals*, New York: Plenum Press, p. 418.

Ferrel, V. O. (2004). The concept of home range in relation to elephants in Africa (2004). *Journal of the African Elephant, African Rhino and Asian Rhino Specialist Groups, Pachyderm, 37*, July–December.

Hasmadi. M.I. (2009). Developing policy for suitable harverst zone using multi-criteria evaluation and GIS-based decision support system. *International Journal of Economics and Finance, 1*(2), 105-117.

Hedges, S., Tyson, M.J., Sitompul, A.F., Kinnaird, M.F., Gunaryadi, D., & Aslan (2005). Distribution, status, and conservation needs of Asian elephants (Elephas Maximus) In Lampung Province, Sumatra, Indonesia. *Biological Conservation, 12*4, 35-48.

IUCN SSC Asian Elephant Specialist Group, H., Rübel, A., & Wikramanayake, E. (2008). *Elephas maximus*. In IUCN 2012. *IUCN Red List of Threatened Species.* Version 2012.1.

Jackson, R.D., Slater, P.N., & Pinter Jr, P.J. (1983). Discrimination of growth and water stress in wheat by various vegetation indices through clear and turbid atmospheres. *Remote Sensing of Environment, 13*(3), 187-208.

Jan, U., Eitel, H., Keefe, R.F., Dan, S., Long, A., Davis, S. & Vierling, L.A. Active ground optical remote sensing for improved monitoring of seedling stress in nurseries. *Sensors, 10*, 2843-2850.

Katajisto, J. (2006). Kernel-based home range method for data with irregular sampling intervals. *Ecological Modelling, 194*, 405-413.

Kernohan, B. J., Millspaugh, J. J., Jenks, J.A., & Naugle, D. E. (1998). Use of an adaptive kernel home-range estimator in a GIS environment to calculate habitat use. *Journal of Environmental Management, 53*, 83-89.

Kushwaha, S.P.S. & Roy, P.S. (2002). Geospatial technology for wildlife habitat evaluation. *Tropical Ecology, 43*(1), 137-150.

Lee, W.B., Lau, H., Liu, Z., & Tam, S. (2001). A fuzzy analytical hierarchy process approach in modular product design. *Expert System, 18*, 32 – 42.

Leimgruber, P., Gagnon, J.B., Wemmer, C., Kelly, DS., Songer, M.A., & Selig, E.R. (2003). Fragmentation of Asia's remaining wild lands: implications for Asian elephant conservation. *Animal Conservation, 6*, 347-359.

Linde E. T. O., Young, T.P., Silver, S.C., & Koontz, F.W. (1999). A Geographic Information System Method for estimating home range size. *The Journal of Wildlife Management, 63*, 748-755.

Martin, N.T., Foguekem, D., Macallister, M., Ngassam, P., & Loomis, M. (2007). Application of ArcView Animal Movement Analysis Extension as a tool for monitoring elephant movement: preliminary results from northern Cameroon. *Pachyderm, 43*, July–December.

Marzluff, J.M., Knick, S.T., & Millspaugh, J.J. (2001). High-teck behavioral ecology: modelling the distribution of animal activities to better understand wildlife space use and resource selection. In J.M. Marzluff (Ed.), *Radio Tracking and Animal Populations.* San Diego, CA: Academic Press.

Ngene, S.M., Skidmore, A.K., van Gils, H., Douglas-Hamilton, I., & Omondi, P. (2009). Elephant distribution around a volcanic shield dominated by a mosaic of forest and savanna (Marsabit Kenya). *African Journal of Ecology, 47*, 234–245.

Olivier, R. (1978). Distribution and Status of the Asian Elephant. *Oryx, 14*, 379 -424.

O'Neill, R.V. (1996). Recent development in ecological theory: hierarchy and scale. Gap analysis – a landscape approach to biodiversity planning, *American Society for Photogrammetry and Remote Sensing*. Bethesda, Maryland, USA.

O'Neil, T.A., Bettinger, P., Marcot, B.G., Luscomb, B.W., Koeln, G.T., Bruner H.J., Barrett, C., Pollock, J.A., & Bernatas, S. (2005). Application of Spatial Technologies in Wildlife Biology. *The Wildlife Society*, 418 – 447.

Prithiviraj, F.., Eric, D., Wikramanayake, H.K., Janakaa, L.K.A., Jayasinghe, M. G., Sarath, W. K., Weerakoon, D., & Pastorini, J. (2008). Ranging behavior of the Asian elephant in Sri Lanka. *Mamalian Biology*, 73, 2-13.

Qureshi, M.E. & Harrison, S.R. (2003). Application of the analytical hierarchy process to riparian revegetation policy options. *Small-scale Forest Economics, Management and Policy, 2*(3), 441 – 458.

Rouse, J.W., Haas, R.H., Schelle, J.A., Deering, D.W., &. Harlan, J.C. (1974). Monitoring the vernal advancement or retrogradation of natural vegetation. *NASA/GSFC, Type III, Final Report, Greenbelt,* MD, 371.

Saaty, T. L. (1980). *The Analytic Hierarchy Process.* McGraw-Hill International Book Co. (New York and London). Book (ISBN 0070543712).

Salman, S. & Nasharuddin, O. (2000). A study on the home range and habitat utilization of a translocated elephant (*Elephas maximus*) using satellite transmitter in Terengganu National Park. *Journal of Wildlife and Park, 20*, 21-26.

Salman Saaban, Nasharuddin Bin Othman, Mohd Nawayai Bin Yasak, Burhanuddin Mohd Nor, Ahmad Zafir, & Ahimsa Campos-Arceiz, (2011). Current Status of Asian Elephants in Peninsular Malaysia. *Journal of the Asian Elephant Specialist Group Gajah, 35*, 67-75.

Santiapillai, C. & Jackson, P. (1990). The Asian elephant: an action plan for its conservation. *IUCN/SSC Asian Elephant Specialist Group, Gland.*

Sukumar, R. (1989). *The Asian elephant: ecology and management. Cambridge studies in applied ecology and resource management.* Cambridge: Cambridge University Press.

Sukumar, R. (1990). Conservation of Asian elephants: problems and prospects. *Species, 22*, 13-14.

Zhixi, L., Hongga, L., & Feng, L. (1995). Evaluation of Asian Elephant Habitat. *GIS Development ASPRS/ACSM*.