UNIVERSITI PUTRA MALAYSIA

GIS-BASED MULTI-CRITERIA EVALUATION TO DEVELOP ELEPHANT SUITABILITY HABITAT MODEL IN PENINSULAR MALAYSIA

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By

SUHAIDA BINTI AINI

Thesis Submitted to the School of Graduate Studies,
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Chair : Alias Mohs Sood, PhD
Faculty : Forestry

The greatest threats to biodiversity are the loss of habitat and forest fragmentation. Both of these factors are also the major threats to the survival of Asian elephants throughout Asia including within the Peninsular Malaysia. In addition, forest fragmentation creates a situation where the protected areas (PAs) are isolated from one another. As a result, the biodiversity resources may be reduced, resulting in the difficulty for some of the species such as the Asian elephant to breed and to look for sources of food and ultimately to move out of the areas. Hence, this study aims to develop an Asian elephant habitat suitability model using geoinformation tools with multi criteria evaluation (MCE) techniques. The satellite imageries and topographical maps were used to generate the environmental and topographical habitat parameters encompassing land cover, forest type, water resources, Digital Elevation Model (DEM), slope and salt-lick respectively. The elephants' home range was determined using satellite transmitter data in order to obtain the habitat preference parameters and their location distribution pattern. Result shows that the highly suitable areas for elephant habitat are mainly concentrated within the Ulu Jelai Forest Reserve, which is a secondary forest, and outside the protected areas. The developed model suggests that long-term conservation of this species requires more effective management of the large continuous areas (both within and outside PAs) consistent with the implementation of National Elephant Conservation Action Plan (NECAP) through the Managed Elephant Range (MERs) program and the construction of eco-viaduct in Peninsular Malaysia. The general Asian elephant suitability habitat map was classified into four levels of suitability with the total percentage of "highly suitable" consists of 43%, followed by "moderately suitable" at 41%, "lowly suitable" at 10% and 6% is "not suitable". Moreover, this study is capable of evaluating the parameter habitat criteria applied with the ability to modify or to add in order to provide habitats with good quality within their existing natural habitat. Tolerance to elephants presence outside PAs is a key recommendation that food resources are often abundant for Asian elephant. Therefore as an umbrella species, the in situ management of Asian elephants outside the protected areas is critical for their conservation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENILAIAN PELBAGAI KRITERIA BERDASARKAN SISTEM MAKLUMAT GEOGRAFI UNTUK MEMBANGUNKAN MODEL KESESUAIAN HABITAT GAJAH DI SEMENANJUNG MALAYSIA

Oleh

SUHAIDA BINTI AINI

February 2017

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Fakulti: Perhutanan

Ancaman terbesar terhadap biodiversiti adalah kehilangan habitat dan fragmentasi hutan. Kedua-dua faktor ini juga menjadi ancaman utama kepada kelangsungan hidup gajah Asia di seluruh Asia termasuk di Semenanjung Malaysia. Di samping itu, fragmentasi hutan mewujudkan keadaan di mana kawasan perlindungan (PAs) terasing daripada satu sama lain. Hasilnya, sumber biodiversiti akan berkurangan, menyebabkan kesukaran gajah untuk membiak dan mendapatkan sumber makanan dan akhirnya bergerak keluar dari kawasan tersebut. Oleh itu , kajian ini bertujuan untuk membangunkan model kesesuaian habitat gajah Asia menggunakan alat geoinformasi melalui pendekatan Penilaian Pelbagai Kriteria (MCE). Imej satelit dan peta topografi digunakan untuk menjana parameter habitat persekitaran dan topografi yang merangkumi masing-masing litupan tanah, jenis hutan, sumber air, Model Ketinggian Berdigit (DEM), cerun dan lokasi jenut. Kawasan keliaran gajah dikenalpasti dengan menggunakan data satelit transmiter untuk menilai keutamaan parameter habitat dan taburan lokasi. Hasil kajian menunjukkan bahawa kawasan yang sangat sesuai untuk habitat gajah tertumpu di Hutan Simpan Ulu Jelai iaitu hutan sekunder dan di luar kawasan perlindungan. Model kesesuaian habitat gajah Asia yang dibangunkan mencadangkan supaya pemuliharaan jangka panjang spesies ini memerlukan pengurusan yang lebih efektif di kawasan landskap (di dalam dan di luar kawasan perlindungan) selaras dengan Pelan Tindakan Konservasi Gajah (NECAP) melalui pelaksanaan program *Managed Elephant Range* (MERS) dan pembinaan *eco-viaduct* di Semenanjung Malaysia. Peta kesesuaian habitat gajah Asia telah dikelaskan kepada empat tahap kesesuaian dengan jumlah peratusan yang sangat sesuai adalah 43%, diikuti oleh kelas sederhana sesuai iaitu 41%, kelas kurang sesuai adalah 10% dan 6% bukan kelas sesuai.Selain itu, kajian ini dapat menilai kriteria parameter habitat yang digunakan dengan keupayaan untuk mengubah suai atau menambah bagi menyediakan habitat gajah yang berkualiti di dalam habitat semula jadi sedia ada.Toleransi terhadap kehadiran gajah di luar kawasan perlindungan merupakan cadangan penting yang perlu diberi perhatian di mana sumber makanan mudah dan banyak didapati. Oleh itu, sebagai spesies *umbrella*, pengurusan in-situ gajah Asia di luar kawasan perlindungan adalah kritikal untuk pemuliharaan mereka.

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May Almighty Allah bless you all.

Thank you.

I certify that a Thesis Examination Committee has met on 7 February 2017 to conduct the final examination of Suhaida binti Aini on her thesis entitled "GIS-Based Multi-Criteria Evaluation to Develop Elephant Suitability Habitat Model in Peninsular Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.
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AE	-	Asian elephant
AHP	-	Analytic Hierarchy Process
ASA	-	Analytical Study Site
AsESG	-	Asian Elephant Specialist Group
ASIAN WEN	-	Association of Southeast Asian Nations Wildlife
CBD	-	Convention on Biological Diversity
CFS	-	Central Forest Spine
CITES	-	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DEM	-	Digital Elevation Model
DOA	-	Department of Agriculture
DTCP	-	Department of Town and Country Planning
DWNP	-	Department of Wildlife and Natural Parks
ED	-	Euclidean Distance
EMU	-	Elephant Management Unit
ESA	-	Environmentally Sensitive Area
ERDAS	-	Earth Resources Data Analysis System
ESRI	-	Environmental Systems Research Institute
FDTCP	-	Federal Department of Town and Country
FELCRA	-	Federal Land Consolidation and Rehabilitation Authority
FELDA	-	Federal Land Development Authority
FLM	-	Fuzzy Large Membership
FR	-	Forest Reserve
FSM	-	Fuzzy Small Membership
GBO	-	Global Biodiversity Outlook
GIS	-	Geographic Information System

GPS	-	Global Positioning System
HEC	-	Human-elephant conflicts
IUCN	-	International Union for Conservation of Nature
JUPEM	-	Department of Survey and Mapping Malaysia
LULC	-	Land Use-Land Cover
MCE	-	Multi-Criteria Evaluation
MCP	-	Minimum Convex Polygon
MEA	-	Millennium Ecosystem Assessment
MEME	-	Management and Ecology research of Malaysian Elephants
MERs	-	Managed Elephant Range
MIKE	-	Monitoring the Illegal Killing of Elephants
MRSA	-	Malaysian Remote Sensing Agency
NDVI	-	Normalized Difference Vegetation Indices
NECAP	-	National Elephant Conservation Action Plan
NECC	-	National Elephant Conservation Centre
NFI4	-	4th National Forest Inventory
NIR	-	Near Infra-Red
NPBD	-	National Policy on Biodiversity
NRE	-	Ministry Natural Resources and Environment
PAs	-	Protected Areas
RISDA	-	Rubber Industry Smallholders Development Authority
RS	-	Remote Sensing
RSO	-	Rectified Skew Orthomorphic
SFM	-	Sustainable Forest Management
TNP	-	Terengganu National Park
WCS	-	Wildlife Conservation Society

WLC	-	Weighted Linear Combination
WWF	-	World Wide Fund for Nature

CHAPTER 1

INTRODUCTION

1.1 Research Background

According to the World Conservation Monitoring Centre, Malaysia is one of the world's 12 megadiverse countries, which collectively harbour the majority of the Earth's species (NRE, 2014). Biodiversity can be divided into three categories, and they are ecosystem diversity, species diversity and genetic diversity. It has important economic, social, technological, security, environmental, educational and recreational values for the country. Today, the biodiversity component is one of major intention in sustainable development process. A key challenge for sustainable development is to ensure that the requirements for conservation and wise use of biodiversity components are incorporated into all development aspects.

In Malaysia, biodiversity is contained within a variety of ecosystems, which can generally be classified as terrestrial, freshwater and marine (NRE, 2009). One of the most important terrestrial components of biodiversity is forest resource. Statistics from 2012 show that approximately 63 percent of land in Malaysia is made up of forests (NRE, 2014). It is the most important ecosystem for sustaining life, as well as the major repository for biodiversity resources. In Malaysia, over 90 percent of the terrestrial biological species occur within natural forests (NRE, 2009). Also, according to the Department for Wildlife and National Parks (DWNP), an estimated 80 percent of wildlife animal species are found in forest areas, and mostly are protected and endangered species. Malaysia is home to 434 species of mammals, 1,239 species of birds, 165 species of amphibians, 356 species of reptiles, 300 species of fresh water fish, 1,200 species of butterflies and 12,000 species of moths (NRE, 2014). However, according to International Union for Conservation of Nature (IUCN) Red List 2013, Malaysia is also home to 1,126 animals and plants facing the threat of extinction. Seventy (70) threatened species are from mammals, including Asian elephants, tigers, orang utan and gibbons. Until 2009, there were 753 protected and totally protected species under the Wildlife Conservation Act, 2010 in Malaysia. This list includes the Asian elephant.

According to the Ministry of Natural Resources and Environment (NRE, 2014), the greatest threat to biodiversity including Asian elephant is the loss of habitat and forest fragmentation. Both of these factors are a major threat to the survival of Asian elephants throughout Asia including in Peninsular Malaysia (Santiapillai and Jackson, 1990; Sukumar, 1990; Leimgruber *et al.,* 2003; Hedges *et al.,* 2005; Salman *et al.*, 2011; IUCN, 2015;). A lot of their habitat were converted

into plantations, dam, housing, highways and other development schemes (DWNP, 2013). In addition, the isolated clearing of forests in small areas can cause fragmentation which reduces the forest in term of size (NRE, 2014). As a result, the biodiversity resources may be reduced, resulting in the difficulty for some species such as elephant to breed and to look for sources of food. The global scenario also indicates that the main reason for biodiversity loss in tropical forests over the past fifty to hundred years was due to drastic changes affecting animal habitats (MEA, 2005). With food from natural sources steadily decreasing, Asian elephants are often forced to raid crops in agricultural areas, and this can lead to human-elephant conflicts (HEC).

In Malaysia, the threats to wildlife conservation were addressed with the implementation of policies and guidelines, the enforcement of laws, and other strategies, with the co-operation of the federal and state governments, as well as non-governmental organisations (NRE, 2014). The Malaysian government also contributes by co-operating with organisations such as the Convention of Biodiversity (CBD) and other international parties to enhance the conservation and management of biodiversity resources. This involves decision-making across multiple geographic scales and multiple ecological dimensions. Similarly, any decisions on conservation issues, always take geographical parameters such as location, distance, direction, proximity, topography, etc. into consideration. Furthermore, the National Elephant Conservation Action Plan (NECAP) was developed and launched in 2013 in order to conserve elephant populations in Peninsular Malaysia. The purpose of the NECAP is to provide a focused conservation strategy that lays out specific actions for the next 10 years (2013 - 2022) with the overall goal of securing viable and ecologically functional elephant populations in Peninsular Malaysia (NRE, 2014).

Application of remote sensing and Geographic Information System (GIS) tools has assumed an increasingly important role in conservation biology and wildlife management by providing means for modelling potential distributions of species and their habitats (Ekwal Imam, *et al.*, (2009); Aditya Singh *et al.,* 2011; Mariela Palacios González *et al.*, 2015; Ashfaq A. Zarri *et al.*, 2017). Smart satellite remote sensing technologies can be very useful in retrieving relevant information about biodiversity present on earth surface (Khare S. *et al.*, 2016). Many studies in various fields have applied the fusion of remote sensing and GIS-based MCE in decision making, particularly for site selection and habitat suitability, by using either the boolean or fuzzy overlay and other approach (e.g. Jiang *et al*. 2000, Ron Store *et al*., 2003, Randal Greenea *et al*., 2010; Maryam, 2010; G. Areendran *et al*., 2011; Devcharan Jathanna *et al*, 2015).

GIS provides tools for the effective development of habitat suitability models with its capability for parameter integration (O'Neil *et al*., 2005) and have been frequently used to predict the impact on biodiversity in environmental assessments (Gontier *et al.,* 2006). In this regards, Maryam (2011) considered

habitat suitability as a fuzzy concept, which always involves uncertainty, and offers the opportunity to include expert knowledge as well. A study by Zuther *et al.* (2005) has concluded that fuzzy modelling is a useful tool for the habitat suitability index, which helps to plan and perform habitat restorations and restocking measures. Mesgari *et al*. (2008) also concluded that the co-existence of different classes in one location can be modelled properly (overlapping of factor classes) by using fuzzy membership functions in site selection model application.

Today, all GIS software provide a basic tool for using the MCE approach, such as Boolean overlay, union, intersect, weighted and fuzzy overlay tool. In addition, the output models should have as much information as possible in order to help users to assess the confidence of the output. It is important that a GIS model is built based on the purpose of the study, understanding the method of processing, and the availability of GIS components such as software, as well as the quality of the data. As such, this study has been using fuzzy logic approach to develop an elephant habitat suitability model in order to deal with uncertain geographic information on habitat parameters such as imprecise animal behaviour and the absence of fixed boundaries. This study is capable of offering another feasible analysis with a reasonably high level of reliability to stakeholders in order to identify highly suitability habitat for Asian elephant conservation particularly in translocation areas and to maintain the sustainability of the forests including PAs. Perhaps the applied approach of habitat suitability model using geoinformation tools (RS, GIS: MCE through fuzzy logic approach) will be able to support the administrative actions for effective management and conservation of biodiversity resources in the country. Thus, for the continued survival of Asian elephants, the establishment of suitable habitats both within and outside of the PA is most important in order to support a new population of Asian elephants in the relocation site. Conversely, the study approach will be able to provide the GIS community with the flexibility needed and required by their field and effectively represent and handle uncertain data.

Subsequently, the management of PA is the key to wildlife conservation including Asian elephant where National Park is the major protected area (4,343 km^2) in Peninsular Malaysia. This park consists of lowland primary forest, and has been the main release area for translocated elephants since 1983. However, the secondary forest often support higher biomass such as NDVI (Sukumar (1989) and Olivier (1978), rather than primary forests. Secondary forest also provides regrowth of high quality plants for food source of elephant.

Presently, Geographic Information System (GIS) is used as an aid in spatial decision making, incorperating Multi-Criteria Evaluation (MCE), which is recognised as one of the most important procedures of decision support operations. GIS deals with information data that has both spatial and non-spatial characteristics. It provides tools for the effective development of models such

as the suitability habitat, with its capability for parameter integration (O'Neil *et al.*, 2005). The GIS model can help to better understand a phenomenon by retaining significant features or relationships. Furthermore, GIS-based habitat suitability models have been frequently used to predict the impact on biodiversity in environmental assessments (Gontier *et al.,* 2006).

There are many factors influence the movements, distributions and elephant home range which are significantly associated with geospatial information. These include a basic requirement of ecological components such as food, protective cover and living space. Geographical and human activity factors also play an important role in elephant distribution. However, according to Wheelock (1980), elephants, when given the chance, move naturally in response to availability of water, food and shade. In terms of size, the home range of Asian elephant was influenced by several factors encompasses of forest type, forest quality (e.g. fragmented forest rate), forest density and also topographical areas such as elevation and slope.

Hence remote sensing is a well-known means of providing data for ecological dam environmental studies. It is also a major spatial data provider in real or near-real time occurrence. The remote sensing data can be interpreted in many ways, and provides a significant amount of information for wildlife management and conservation. This information can be directly interpreted from images or through digital processing. This includes information on forest type, crown density, the ecosystem, the type of vegetation and environmental parameters. Information regarding changes in human activities can also be obtained through this process. The relationship between remote sensing and the GIS is based on the fact that remote sensing (RS) provides an important source of digital data input for the GIS database. This database then constantly needs for timely and accurate updates of its spatial entities.

Therefore, the management and conservation of biodiversity components is important in ensuring that resources are utilized in a sustainable manner for the socio-economic development of the nation that was highlighted by the National Policy on Biodiversity (NPBD). In this case, the management and conservation of wildlife should be given the same attention as flora diversity. Thus, geospatial technology can provide spatial information and analysis capabilities, which are needed to support the management and conservation of wildlife. The wildlife conservation and management can be successful in ensuring the survival of endangered and protected animals with the availability of spatial data from remote sensing (real time) and advances in GIS technology.

1.2 Problems Statements

The greatest threats to biodiversity are the loss of habitat and forest fragmentation. Both of these factors are also the major threats to the survival of Asian elephants throughout Asia including within the Peninsular Malaysia (Hedges *et al.,* 2005; IUCN, 2015; Salman *et al.*, 2011, NRE, 2014). A lot of their habitat was converted into plantations, dam, housing, highways and other development schemes (DWNP, 2012). Based on the records of the Federal Department of Town and Country Planning (FDTCP, 2007), in the early 1950's, 90 percent of the total land area in Peninsular Malaysia, was covered by forest

and it is has been decreased to 37.7 percent in 2010 (Miettinen *et al.*, 2011). Subsequently, the management of protected areas (PAs) is the key to wildlife conservation including Asian elephant where National Park is the major protected area (4343 km^2) in Peninsular Malaysia. However, several design criteria of protected areas cannot yet be put in place encompasses requirement for connectivity between habitat fragments and redundancy in site selection (NRE, 2008) of biodiversity conservation and wildlife protection. In addition, forest fragmentation creates a situation where the protected areas (PAs) are isolated from one another. As a result, the biodiversity resources may be reduced, resulting in the difficulty for some of the species such as the Asian elephant to breed and to look for sources of food and ultimately to move out of the areas. To some extent, the possibility of translocated elephants left the parks (released site) in attempts to returns to their original habitat (captured site).

This study focuses on research in approaches for incorporating explicit handling of uncertainty, especially by fuzzy sets in order to develop suitability habitat of Asian elephant in GIS environment. It provides tools for the effective development of suitability habitat model, with its capability for parameter integration (O'Neil *et al.,* 2005). The GIS model can help to better understand a phenomenon by retaining significant features or relationships where as the membership function in fuzzy model was used to define the level of confidence of data. The utilization distribution enables identification of significant elephant habitat parameters and prioritization of its criterion. The fusion of fuzzy logic within the GIS environment provides comprehensive facilities in Weighted Linear Combination procedure and improves the reliability of Multi-Criteria Evaluation (MCE) output particularly on suitability evaluation.

In this study, the MCE method through the fuzzy logic model in GIS environment was used to analyze suitable elephant habitat area feasibly because it is more preserve and easier to understand. It provides tools for the effective development of suitability habitat model, with its capability for parameter integration (O'Neil *et al.,* 2005). The GIS model can help to better understand a phenomenon by retaining significant features or relationships where as the

membership function in fuzzy model was used to define the level of confidence of data. Moreover, the use of real time satellite imagery incorporated with field surveys data is more accurate and cost efficient to produce a habitat parameters particularly for preparation of forest type data that are very significant requirement for Asian elephant conservation areas. Consequently, the spatial information in macro level (landscape area using remote sensing data) for habitat suitability, is most significant, in order to assist the stakeholders (DWNP and NRE) in the conservation of Asian elephants, particularly in identifying the site for relocation and potential preservation areas where the conservation of this animal requires a complete knowledge of their habitat requirements.

1.3 Objectives of the Study

The general objective of this study is to develop an Asian elephant habitat suitability model using geoinformation tools in Northern Pahang.
The specific objectives of the study are:

i) To determine the home range and habitat utilization using elephant distribution data (satellite transmitter data);
ii) To identify the significant habitat parameters and significant habitat characteristics of the Asian elephant; and
iii) To develop a GIS database and Asian elephant suitability habitat model using remote sensing data and GIS along with MCE through fuzzy logic approach.

1.4 Scope of the Study

In order to achieve the objective, the scope of this study was identified as follows:

i) The study area covers protected and non-protected areas in Lipis District, including the National Park in Pahang State (Northern Pahang);

ii) Remote sensing data will be used in order to identify thematic layers on habitat parameters such as land cover, forest types (primary & secondary), forest status and Normalized Difference Vegetation Indices (NDVI). Topographical, land use and 4th National Forest Inventory (NFI4) map data sources will also be used for the creation of other habitat parameter data layers; DEM, slope, aspect, distance from water source and salt-lick;

iii) Analysis of elephant distribution data (satellite transmitter), factors influencing elephant distribution and habitat utilization will be carried out using GIS (spatial analysis), Microsoft Excel (for significant correlation),

in two different sites provided by Department of Wildlife and national Parks (DWNP);

iv) Results from the above analysis (selection of the significant habitat layers and suggested rules/criteria for habitat parameters) will be utilized at the study area (Northern Pahang) in order to develop a habitat suitability model for Asian elephants;

v) The development of the suitability habitat model will employ a fuzzy logic overlay function in ArcGIS using identified habitat parameters and criteria; and

vi) The study will be structured into five phases, namely, i) Preliminary Research and Literature Review; ii) Data Preparation and Collection; iii) Database Design and Development; iv) Model Application Development/Validation and v) Output in order to achieve the objective of the study as illustrated in Figure 1.

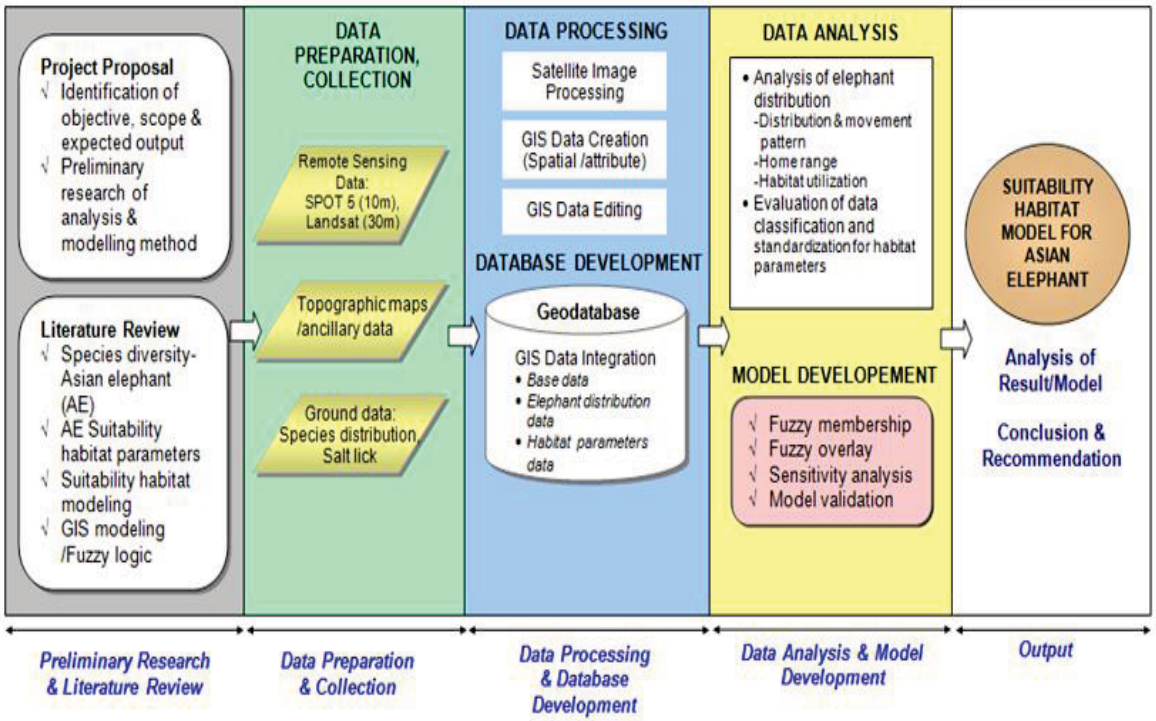

Figure 1: Research framework

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