Modeling the Potential Distribution of Wildlife Species in the Tropics

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Abstract: The process of ecosystem destruction during the last century not only caused habitat fragmentation, but also loss of many species. Unfortunately, the traditional strategies for protecting these natural treasures were not successful enough to secure the survival of remaining biodiversity. In this scenario, a rapid assessment for predicting the distribution of the remaining species and habitats is essential. While tropical rain forests are known as biological hotspots, only few studies have been done to determine the potential distribution of species. Distribution species modeling in tropical areas with high rate of deforestation and loosing connectivity is critically important for endangered wildlife species management program. Habitat modeling using remote sensing plays an important role in measuring and monitoring habitat characteristics in a large scale. This paper highlights and reviews the need of using geospatial modeling techniques to determine endangered species distribution in the tropics.

Key words: Species distribution model · Habitat models · Conservation · Remote sensing and GIS

INTRODUCTION

The Earth is now facing the crisis of global extinction of biodiversity. Undoubtedly, this extinction is due to human activities in recent centuries. With increasing of human population and demand on food supply, natural habitats are converting to rural and agricultural areas and many species are going to extinct [1]. If deforestation continues at current rate of 7.3 million ha/year most of the habitats including protected areas may also affected by process of fragmentation and loosing connectivity [2]. Many studies [3-5] have reported the relationship between patch size and species diversity (e.g. smaller areas can support less species [6]). All this problems are heading us to face the mass extinction. Data on threatened species are very limited. Only about 2.5% of the world estimated 1.8mil. described species have been assessed for IUCN Red list and within this assessment 38% of the species have been classified as threatened and 1.9% as extinct [7].

In this scenario, a rapid assessment for remaining species and habitats is essential. As human destructive activities are occurring at the global level, the use of remote sensing technologies to study ecosystems and species is apparent. Ecological studies need to determine the complex relationships of species and habitat. Remote sensing data can reveal some of the important factors limiting species distribution. Moreover, data can be applied in GIS based models to define the species habitat relationships. Distribution modeling of species can help us to define the core habitats which are mostly suitable to fulfill species requirements for survival. While tropical rain forests are known as biological hotspot, less study have been done for determining the potential distribution of species. Distribution modeling in tropical areas with high rate of deforestation and loosing connectivity is critically important for species management programs. This technique can be divided in two stages, namely gathering of field data through the species occurrence map and environmental data that can be derived from remote sensing images and GIS layers.

This paper therefore highlights the significant need of using geospatial modeling techniques to determine species distribution in the tropics and provides an overview on some of these techniques.

Deforestation and Wildlife Extinction: Tropical rain forest ecosystem has a globally significant value due to species richness and their complexity [8]. Deforestation, fragmentation unsustainable hunting of tropical forests
is the greatest threats to biodiversity and nature conservation in the ongoing sixth extinction [9-11]. Tropical forests represent less than 7% of land surface, but contain more than half the species of plants and animals [12-13]. Land use and forest cover are changing in the tropical rain forest. Approximately half of the potential dense tropical forest canopy have been removed and converted to other land use [10] even though moist tropics store most of the world’s records for local biodiversity [11]. Tropical deforestation is responsible for the mass extinction of species and it has effect on biodiversity in different ways such as habitat degradation and also isolation of formerly continuous forests in forest fragments [1, 13]. These invaluable ecosystems are important habitat for threatened mammals such as Rhino, Tiger, Leopard, Clouded Leopard, Sun Bear, Tapir and Sambar Deer.

It is increasingly recognized that the disappearance of the tropical rainforests will create a number of serious environmental problems that have negative impact on biodiversity [13]. Analysis of wildlife habitat is considered more important for management and planning of protected areas. The effects of fragmentation and habitat loss are modified by landscape configuration, specifically the size, shape and layout of habitat fragments [14]. With decreasing size and increasing fragmentation of habitats, it has become imperative to develop geospatial maps of habitat quality for habitat conservation intact.

Role of Geospatial Technologies in Wildlife Conservation: Working on wildlife conservation and management always being disturbed due to unavailability of good quality data on species and habitat suitability of different species [15]. Traditional methods of wildlife habitat evaluation that have been used long years ago have obvious limitation due to inaccessibility to the whole study area, especially in dense tropical area whereas there are often lack of field data. Predictive habitat modeling which is part of habitat suitability modeling can be used to fulfill this need. Geospatial technology including Remote Sensing, Geographic Information System (GIS) and Global Positioning System (GPS) along with a Distribution Species Models (DSM), provide an efficient methods for determining habitat suitability and quality which has great implication in biodiversity conservation. Remote sensing can provide accurate inputs data for species distribution models and can be use for Developing conservation strategies [16].

Effective wildlife management depends upon obtaining reliable information about a species as well as incorporating that information into sound and testable management plans. Satellite remote sensing provide most valuable spatial database in the time domain [13] and Geospatial Multi-criteria analysis provides an effective tool for habitat assessment. Despite efforts by scientists and policy makers about the rate of decline of species, there is still a gap in global patterns of species distribution [17,18]. Remote sensing data can be applied for monitoring the current system of our natural habitats and species assessment [16, 18]. In fact, from global to local scales, the only feasible way to monitor the Earth’s surface to prioritize and assess the success of conservation efforts is through remote sensing.

An initial step in conservation planning is to measure and map biodiversity by compiling the data that will form the picture of biodiversity across the planning region. Currently a suite of remote sensing satellites, having various resolutions, are available to generate spatial information on vegetation and land-cover. Remotely sensed data with spatially continuous coverage have been used for assessment and monitoring of biodiversity in different scale from regional to global [16, 18]. Since 1980s one of the important usage of satellite multispectral imagery have been exploring the composition of biodiversity [19]. The simplest approach to determine species richness or distribution of species from remotely sensed data is to discover habitat suitability of species [18]. It has become imperative for the survival of the tropical rain forest species to add more suitable habitat. Remote sensing data has been widely used for studying habitat suitability and distribution of wildlife species [20-25]. Specific information on habitat characterization is necessary to develop appropriate strategies for conservation [26]. Modern strategies for wildlife habitat mapping and modeling of animal movements require the use of environmental map layers which is derived from remote sensing data [27, 28]. These data are often processed for variety of environmental features including vegetation, land use, landscape structure and phonoology. Satellite telemetry is another usage of remote sensing that is widely used in wildlife management. Attaching ultra-high frequency (UHF) radio transmitters to wildlife that are tracked by satellites give us locations in latitude and longitude forms. These data then can be used to map a species present location which is one of the inputs for habitat suitability models. Satellite tracking is also a useful method for tracking species which are difficult to track and also extremely useful methods inaccessible habitats like tropical rain forests. Another application of remote sensing is mapping of the land cover [29] whereas it can
be applied for rapid assessment in the tropics [30]. With very high spatial and spectral resolutions of hyper and multispectral sensors, our ability to resolving objects in spatial scale can be further improved. The airborne hyperspectral imaging sensor from Faculty of Forestry, Universiti Putra Malaysia, IKONOS system from Space Imaging and the Quick Bird system from Digital Globe may offer hyper and multispectral imagery at resolutions of 0.5-1 m, 4 m and 2.4-2.8 m, respectively and panchromatic imagery at 1 m and 0.6-0.8 m, respectively.

**Species Distribution Models:** Each species has some requirements based on its behavioral, biological, genetics and evolutionary history to choose a habitat for survival and each habitat must provide these species requirements. By identifying species requirements within habitats we can define suitable areas for species survival. This issue is critical, especially in tropical areas with high species richness that the habitat is losing the suitability due to human pressure.

The history of the models is back to 1976 when Habitat Evaluation Procedure (HEP) was developed by U.S. Fish and Wildlife Service. Since then habitat suitability models have become a non-separable component of wildlife management ecosystem conservation. The main objectives of Habitat modeling are predicting distribution of wildlife species in geographical area with high species diversity [31], locating of species of concern [32], predicting area of suitable habitat that may not be currently used by species [33] and aid to species re-introduction or prediction of the spread of an introduced species (Table 1). They can also be used to predict species richness, presence or absence of a species[31], probability of a species occurrence [34], or an index of habitat suitability for a species [35].

In many cases, whereas conservation and management decisions must be made in a relatively short period of time with limited information [49] habitat modeling play significant role. These techniques can create large-scale predictions of habitat suitability for wildlife species, without detailed knowledge of their physiology and behavior. Furthermore, using habitat models can be a cost-effective and productive endeavor. Habitat models simplify the representation of Ecological processes which are very complex and too difficult to show every factor that influences species distribution or abundance [50]. They are working on the basis of the fact that the particular habitat variables can explain significant patterns in species distribution or abundance.

Species habitat modeling relies on number of implicit assumptions. The success of habitat models is ultimately related to the existence of strong and predictable associations between species and habitat variables [51]. Habitat models are based on key ecological concepts such as niche because of the inclusion of biotic interactions and competitive inclusion in the observed data and carrying capacity by assuming equilibrium between the species and their pattern of occurrence in the habitat.

Although many methods have been used to model habitat suitability [52], these methods could be classified into two groups, those that require presence - absence data and those required only presence data of species.

### Table 1: Some potential application of habitat suitability models [Modified from Manel (2001) & Guisan (2005)]

<table>
<thead>
<tr>
<th>Field of Application</th>
<th>Type of Usage</th>
<th>References</th>
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<tbody>
<tr>
<td>Conservation Biology</td>
<td>Identifying habitat for reintroducing species</td>
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<td></td>
<td>Identifying core habitats</td>
<td></td>
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<tr>
<td></td>
<td>Identifying the effective variables in influencing species distribution</td>
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<td></td>
<td>Providing spatially explicit assessment of habitat suitability</td>
<td></td>
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<td></td>
<td>Predicting habitat suitability for the area that no information about the occurrence of species</td>
<td>[36-40]</td>
</tr>
<tr>
<td>Landscape Ecology</td>
<td>Incorporate landscape structure and composition variables such as habitat patch size, edge effects and juxtaposition of habitat requisites</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incorporating habitat quality in to models of wildlife population viability</td>
<td>[41]</td>
</tr>
<tr>
<td>Applied Ecology</td>
<td>Predict distribution change in response to changing climate or land use</td>
<td>[42]</td>
</tr>
<tr>
<td>Marine Ecology</td>
<td>supporting the implementation of environmental legislation, integrated coastal zone management, ecosystem-based fisheries management, marine protected areas, habitat identification, mapping coral habitat and determining the effective factors in distribution</td>
<td>[43-47]</td>
</tr>
<tr>
<td>Invasive Ecology</td>
<td>Predict sensitive habitat to invasive species</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td>Model negative effect of non-indigenous species on native biota</td>
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Most of the commonly used modeling for model construction are based on multiple regression methods and require binary data [53]. Generalized Additive Modeling or GAM [54], discriminate function analysis [55], Generalized Linear Modeling or GLM [56] and Artificial Neural Networks or ANN [57], are some examples of modeling that uses presence - absence data. More recently, methods of habitat modeling that only use presence-only data have been developed (Table 2), namely Genetic Algorithm for Rule Set Prediction or GARP [58], Ecological Niche Factor Analysis - ENFA [59] and MaxEnt - Maximum Entropy [60]. BIOCLIM or Climatic Envelope [61] and the DOMAIN or Climatic Envelope [62]. These methods of using only the presence data allow us to use data where knowledge of absences is inadequate or not trustable [62-63].

All of these models are based on the concept of ecological niche [64]. They use some rules and mathematical algorithms to define the ecological niche of the species based on the distribution that build on multidimensional environmental space and after defining niche of species, it is projected in to the geographical space and then produces a predictive map. Even though habitat models have got some limitations which have been the subject of debate such the fact that in reality habitat is not the only factor that determines the distribution of species and inter specific interactions such as competition and prediction could have a significant effect on the distribution and abundance of certain species, they are still known as one of the most appropriate tools for evaluation of habitat suitability or quality.

In conclusion, tropical forests are the habitat of many species which are mostly unknown for scientists. By using habitat models can help us to better manage and conserve species in this sensitive and invaluable habitat. Despite the great implications of habitat models distribution in areas such as in the tropics, unfortunately few studies have been conducted using these techniques for conservation of species. Habitat modeling using remote sensing play an important role in measuring habitat characteristics in a large scale and monitoring the changes occurs to the habitat as a result of natural or human process during different temporal scales. Future efforts should focus more on development of methods that are capable of considering biological and behavioral factors affecting distribution of species. At the same time they should be able to consider environmental change scenarios in order to better understand and manage human interferes in distribution of species.

REFERENCES


