UNIVERSITI PUTRA MALAYSIA

ASSESSING RELATIONSHIP BETWEEN MAMMAL OCCURRENCE AND FOREST VEGETATION STRUCTURE BY USING GWR

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By

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ACCESSING RELATIONSHIP BETWEEN MAMMAL OCCURRENCE AND FOREST VEGETATION STRUCTURE BY USING GWR

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August 2017

Chairman : Norizah Kamarudin, PhD
Faculty : Forestry

Forests play the most important role in the ecosystem, providing shelter, food sources and territories to floras and faunas. Forests are degraded from time to time, and forest conversion to agricultural plantations, especially for oil palm cultivation, has led to the problem of deforestation. Large-scale removal of trees changes species composition and wildlife occupancy as wild animals are sensitive to changes of landscapes. Preserving the primary forest is an excellent way to sustain the species richness. This study was conducted to gain in-depth insights into the existence of wildlife by assessing the numbers of species in two forests with different vegetation structure conditions: i) disturbed forest, and ii) undisturbed forest. A total of 120 camera traps were used to capture the images of the numbers of wildlife in both forest areas, from May 2015 to March 2016. To understand the driving factors that bring about wildlife existence within these two forest conditions, habitat quality attributes were measured: i) trees with diameter of above 45 cm at breast height (DBH) (DM45); ii) trees with DBH below 45 cm (DL45); iii) number of bamboo clumps (BMBO); iv) number of liana species (LANA); v) number of palm trees (PLMT); vi) number of fallen trees (FLTR); vii) number of saplings (SPLG); and viii) number of seedlings (SDLG). Two types of analyses have been conducted: i) general linear modelling; and ii) spatial analysis by using Geographical Information System (GIS). The aims of analysis with general linear modelling are to compare mammal species occurrence with the number of images captured; and establish the relationships between mammal species occurrence and the local factors in both the undisturbed and disturbed forests. On the other hand, the purpose of GIS analysis is to determine the explanatory variables that have non-stationarity effects on the mammal species occurrence. From the images captured, 3,730 small to large-size mammal species are identified. Of that, 15 of mammal species with small to large size were taken for analyses. From the general linear model, the undisturbed forest (n=2.683) has the highest mammal species occurrences compared with that of the disturbed forest (n=1.383). The images captured in the undisturbed forest are also high (n=50.87) compared with that of the disturbed forest

(n=6.43). These comparative figures can be explained by the richness of biodiversity in the native forest. The mammal species occurrences are influenced by several factors; mammal species occurrence = f(number of lianas, trees with DBH >45 cm, number of palm trees, number of bamboo clumps, number of saplings). For GIS analysis, OLS Model 2 was examined and found to be the best model to determine the mammal species occurrences, based on the lowest AICc value of 210.81. The GWR Model 2 has been identified as the best method to determine the influence on mammal species occurrence (R^2=41.56%), compared with GWR Model 1 (R^2=32.87%), GWR Model 3 (R^2=36.09%), OLS Model 1 (R^2=25.86%), OLS Model 2 (R^2=24.90%) and OLS Model 3 (R^2=14.96%). The findings of this study about wildlife species richness and occupancy under different forest vegetation structures are indeed very valuable; the wildlife department can utilise this information as guidance for the purpose of conservation management and taking proactive measures.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

MENGENALPASTI HUBUNGAN ANTARA KEHADIRAN MAMALIA DAN STRUKTUR VEGETASI HUTAN DENGAN MENGGUNAKAN GWR

Oleh

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Hutan memainkan peranan yang paling penting dalam ekosistem, menyediakan tempat tinggal, sumber makanan dan wilayah untuk flora dan fauna. Hutan berkurangan dari semasa ke semasa, dan penukaran hutan kepada ladang pertanian, terutamanya bagi penanaman kelapa sawit, telah membawa kepada masalah penebangan hutan. Penebangan hutan secara meluas telah merubahan komposisi spesies dan kehadiran hidupan liar sebagaimana haiwan liar adalah sensitif kepada perubahan landskap. Memelihara hutan asli adalah cara terbaik untuk mengekalkan kekayaan spesies. Kajian ini dijalankan untuk mendapatkan pandangan yang mendalam ke dalam kewujudan hidupan liar dengan menilai bilangan spesies dalam dua jenis hutan yang berbeza: i) hutan tidak terganggu, dan ii) hutan terganggu. Sebanyak 120 perangkap kamera telah digunakan untuk menangkap imej bilangan hidupan liar di kedua-dua kawasan hutan, dari Mei 2015 hingga Mac 2016. Untuk memahami faktor-faktor penyebab kepada kewujudan hidupan liar di dalam kedua-dua jenis hutan, sifat-sifat kualiti habitat diukur : i) pokok yang bersaiz melebihi 45 cm pada paras Ketinggian dada (DBH) (DM45); ii) pokok dengan DBH bawah 45 cm (DL45); iii) bilangan rumpun buluh (BMBO); iv) bilangan spesies liana (LANA); v) bilangan pokok palma (PLMT); vi) bilangan pokok tumbang (FLTR); vii) bilangan anak pokok (SPLG); dan viii) bilangan anak benih (SDLG). Dua jenis analisis telah dijalankan: i) *Generalized Linear Model*; dan ii) analisis spatial dengan menggunakan GIS. Tujuan analisis dengan *Generalized Linear Model* adalah untuk membandingkan kehadiran spesies mamalia dengan bilangan imej yang ditangkap; dan mewujudkan hubungan antara kehadiran mamalia spesies dan faktor-faktor tempatan dalam kedua-dua hutan tidak terganggu dan terganggu. Sebaliknya, tujuan analisis GIS adalah untuk menentukan penerangan pembolehubah yang mempunyai kesan terhadap berlakunya spesies mamalia. Dari imej yang ditangkap, 3730 spesies mamalia bersaiz dari kecil hingga ke besar dikenal pasti. Dengan itu, 15 spesis mamalia bersaiz dari kecil hingga ke besar telah dikenalpasti untuk analisis. Dari *model Generalized Linear Model*, hutan tidak terganggu (n = 2,683) mempunyai spesies mamalia tertinggi

berbanding dengan hutan terganggu (n = 1,383). Imej yang ditangkap di hutan tidak terganggu juga tinggi (n = 50.87) berbanding dengan hutan terganggu (n = 6.43). Angka-angka perbandingan dapat dijelaskan oleh kekayaan biodiversiti di hutan asli. Spesies mamalia kejadian dipengaruhi oleh beberapa faktor; mamalia spesies kejadian = f (bilangan pokok liana, pokok-pokok dengan DBH >45 cm, bilangan pokok palma, bilangan rumpun buluh, bilangan anak pokok). Untuk analisis GIS, OLS Model 2 telah diperiksa dan didapati model yang terbaik untuk menentukan kehadiran spesies mamalia, berdasarkan nilai AICC terendah dalam 210.81. GWR Model 2 telah dikenal pasti sebagai kaedah terbaik untuk menentukan pengaruh ke atas kehadiran mamalia spesies (R^2 = 41.56%), berbanding dengan GWR Model 1 (R^2 = 32.87%), GWR Model 3 (R^2 = 36.09%), OLS Model 1 (R^2 = 25.86%), OLS Model 2 (R^2 = 24.90%) dan OLS Model 3 (R^2 = 14.96%). Hasil kajian ini dapat mengenal pasti spesies hidupan liar adalah kaya di hutan asli berbanding hutan sekunder; jabatan hidupan liar boleh menggunakan maklumat ini sebagai panduan bagi tujuan pengurusan pemuliharaan dan mengambil langkah-langkah proaktif.

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I certify that a Thesis Examination Committee has met on 25 August 2017 to conduct the final examination of Jamhuri bin Jamaluddin on his thesis entitled "Assessing Relationship Between Mammal Occurance and Forest Vegetation Structure by Using GWR" 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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LIST OF ABBREVIATIONS

GWR	Geographically Weighted Regression
GIS	Geographical Information System
GWGLM	Geographically Weighted Generalised Linear Models
GAMs	Generalised Additive Models
TINDVI	Time-Integrated Normalised DifferenceVegetation Index
NDVI	Normalised Difference Vegetation Index
GR	Global Regression models
R^2	R-squared
SAF	Spatial Adaptive Filtering
OLS	Ordinary Least Square
SA	Spatial Auto-correlation
NCGN	National Center for Geographic Information and Analysis
AICc	Akaike Information Criterion Correction
UEQ	Urban Environmental Quality
VJR	Virgin Jungle Reserves
MUS	Malayan Uniform System

CHAPTER 1

INTRODUCTION

1.1 Background

Forest is an important resource in the world, and its diversity is a key to new discoveries. The forest provides an ecosystem as well as supports a variety of critical ecosystem processes such as wildlife habitat, biodiversity, the global climate system, and services to the communities living in or around the forest (Zakaria et al, 2005; Nagarajan et al, 2013). Nowadays, the forest is confronted with problems-- deforestation and degradation. Deforestation occurs all around the world and is the worst critical issue today. An estimated area of 7.3 million hectares (ha) of forest had been deforested worldwide for purposes of agriculture, urban development, and housing, as reported by FAO in 2010. In the early 2015, forests covered about 30 percent of the world's land mass (National Geographic, 2015). According to Federici et al., (2015), deforestation occurred affecting about 25% of the forest between the years 2001-2010, and increased to 33% in the following five years in 2011-2015. In addition, Keenan et al., (2015) reported that forest loss in all over the world was recorded to be about 12.8 thousand hectares (ha) annually in the years 2011-2015.

Such drastic changes of forest coverage could have impacts on all ecosystems that rely on the forest, especially wildlife. Forest conversion to oil palm plantations, for example, has significantly caused changes in species composition and wildlife occupancy, and this is due to the sensitivity of wildlife to landscape changes (Bernard, 2014; Fitzherbert et al., 2008). Landscape changes can be defined as changes between unlogged forests to logged forests. An unlogged forest is known as pristine forest while a logged forest is deforested forest. Forest degradation is a major threat to the wildlife. Several researches had been conducted in wildlife study such as that by Olsoy et al., (2016); they quantified the effects of deforestation and fragmentation on a wide range of conservation plans for jaguar species covering the areas from Mexico to Argentina. They found out that deforestation is a major threat to jaguar populations. They noted that deforestation has caused the jaguar network to decrease and forest fragmentation to increase in the corridors. Forest loss of the protected area is less compared with that of the unprotected area in the jaguar corridors. Rapid deforestation in the corridors indicates difficulties in maintaining the connectivity of jaguar species.

Besides that, Azhar et al., (2015) studied the effects of in-situ habitat quality and landscape characteristics, in the oil palm agricultural matrix, on tropical understorey birds, fruit bats and butterflies. In this study, they found that the local and landscape variables have positive relationships with the richness of the bird, fruit bat, and butterfly species. They found that the oil palm small-holdings

located near the rice fields have fewer bird species. In contrast, roads can support increases in bird and fruit bat richness, but it declines at sites that have a high crop density. They also found that the height of oil palm stands decreases the number of species of the fruit bat richness but increases the number of species of the butterfly richness.

On the other hand, a study by Bernard et al., (2014) on terrestrial mammal species richness and composition in three small forest patches within an oil palm landscape in Sabah, Malaysia found that such habitats are not suitable for mammal species in the long term; meanwhile, there are some mammal species present in the forest patches only for the purpose of finding food sources and resting places. Large-bodied mammal species including the low density species were not found in this study area; mammals detected in the forest patches were mainly those species that are well-adapted to living in highly modified habitats, and are generally of low conservation concern. All these studies were carried out with the aim of overcoming wildlife-human conflicts resulting from deforestation. The analysis method used in their studies are based on the traditional regression, the results of which point straight towards illusionary data, with no consideration for spatial location and attribute data; besides the weightage values for variables studied have not been taken into account. However, a new regression technique called geographically weighted regression (GWR) analysis explicitly incorporates the issue of spatial location; it is capable of considering the spatial characteristics and non-stationarity of variables to be studied (Brunsdon et al., 1996; Fotheringham et al., 1998).

Spatial analysis of GWR can determine the diversity of wildlife at local and landscape levels spatially (González-Maya et al., 2016; Mcnew et al., 2013; Mellin et al., 2014; Shi et al., 2006). The GWR is a regression method which enables modelling of various local and landscape spatial relationships, which can then be examined and explored so that the researcher can understand better the factors influencing spatial patterns. Furthermore, GWR can also be used to predict spatial patterns based on observation and understanding (Brunsdon et al., 1996). Fundamentally, GWR is a spatial analybruntical tool used by some researchers in case studies to make decisions. The final outputs of decision making are presented spatially with informative tabular data. Such information can help solve problems especially in forest areas, and it improves the understanding of analyses related to non-stationarity data such as habitat quality measurement, abiotic and biotic measurement. GWR is a suitable tool that can be used in the study of forests; it can determine the wildlife problems, as shown in the studies by González-Maya et al. (2016), Mcnew et al. (2013) Shrestha (2006) and Windle et al. (2009).

But, conservation plans for wildlife can be a difficult task, if there is no information available about the wildlife presence within a huge forest area. As such, it is absolutely essential to understand the habitat suitability and species diversity in logged-over forests. Tobler et al., (2008) in his work pointed out that to determine the range and conservation status of native mammals in forested areas, particularly species which are elusive and sensitive to human presence, camera

trap is an ideal method in such research. The use of camera-trapping method is to monitor recurring presence and potential absence of wildlife; the recorded images help estimate the population size and density of wildlife in a forest area. Additionally, camera-traps are ideally suited to sample medium to large sized terrestrial mammals (Adila et al., 2017; Bernard et al., 2014; Azlan & Sharma, 2006; Sasidhran et al., 2016), and some under-canopy avian species (Ancrenaz, et. al., 2012). Ideally, camera-trapping methods are used to study abundances and species richness. Therefore, this study intends to apply the integration of geospatial analysis of GWR and the traditional regression method to estimate the distribution of wildlife in the tropical forest, with camera trapping used to gather location data.

1.2 Problem Statement

Understanding why the different numbers of some species at different locations is useful for conservation measures and actions. Hence, the statistical analysis needs to be conducted in greater detail regarding location information. Common statistical techniques and modelling approaches are based on non-spatial factors. This analysis limits our understanding of the spatial variation in the presence of species that are absent in the reports presented. Therefore, this study intends to further analyse the spatial variations of wildlife species under different forest vegetation structures by using both the conventional regression method which excludes locational information, and spatial statistical methods of Geographically Weighted Regression (GWR).

1.3 Objectives

This study aims to determine the occurrence of small to large size mammalian biodiversity under different forest vegetation structures; undisturbed and disturbed forests. The specific objectives are as below:

1. To examine the relationships between mammal species occurrence and local vegetation structures in undisturbed and disturbed forests.

2. To determine the local and landscape factors that influence species distribution by using GWR analysis under different forest vegetation structures; undisturbed and disturbed forests.

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