POTENTIAL DISTRIBUTION OF WHITE HANDED GIBBON (*Hylobates lar*) USING ECOLOGICAL NICHE MODELLING

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Natural Resources Science) with Honours

FACULTY OF EARTH SCIENCE
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2017

DECLARATION

I declare that this thesis entitled potential distribution of *Hylobates lar* using ecological niche modelling is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : MOHD FAKKERUL IMAN BIN RAZALI

Date : ______________________________

ACKNOWLEDGEMENT

First and above all, I praise to Allah S.W.T, the almighty for providing me this opportunity, bless and assistance to me in effort to finish the final year project thesis successfully.

I would like to thanks and give heartfelt gratitude to my Supervisor, Mr. Kamarul Ariffin bin Hambali @ Kambali and my Co-Supervisor as well, Dr. Nazahatul Anis binti Amaludin for their guidance and professional advice during carried out this research.

Special thanks to my family, relatives and fellow friends for their continuous support, attention and encouragement. Last but not least, I would like to thank all who in one way or another contributed in the completion of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AOO	Area of Occupancy
EN	Endangered
ENM	Ecological Niche Modelling
EOO	Extent of Occurrence
IUCN	International Union for Conservation of Nature
LC	Least concerned
MAXENT	Maximum Entropy Model
GIS	Geographical Information System

LIST OF SYMBOLS

%	Percentage
Km sq².	Kilometer square feet

Pemetaan Potensi Ungka Tangan Putih (*Hylobates lar)* Menggunakan Permodelan Ekologi (ENM)

ABSTRAK

Pemodelan taburan spesies yang berpotensi iaitu melalui pemetaan adalah salah satu kaedah penting bagi ramalan kewujudan spesies di seluruh kawasan kajian. Terdapat kira-kira 20 spesies primat dijumpai di dalam Malaysia menurut kajian. Dalam kajian ini, pemodelan lokasi data kejadian spesies dan pembolehubah alam sekitar telah diperolehi daripada Sistem Maklumat Geografi (GIS). Kajian ini juga menggunakan perisian Modelling Niche Ecological yang menggunakan MAXENT untuk menganggarkan taburan potensi spesies *Hylobates lar* di Malaysia. Melalui kajian ini, taburan spesies ini kebanyakkannya terdapat di selatan semenanjung Malaysia.

Potential Distribution of White Handed Gibbon (*Hylobates lar)* Using Ecological Niche Model (ENM)

ABSTRACT

Modelling the potential species distribution through mapping is one of the importance methods for prediction of species existence across the study area. There are approximately 20 species of primates found in Malaysia according to research. In this research, the modelling of the localities of species occurrence data and environmental variable were obtained from Geographical Information System (GIS). This study also used the software of Ecological Niche Modelling using MAXENT to estimate the potential distribution of *Hylobates lar* species in Malaysia. From the result, this predicted species distribution was found mainly at the southern peninsular Malaysia.

CHAPTER 1

INTRODUCTION

1.1 Background of study

Tropical rainforests have long been recognized as one of the most productive type of forests in the world. There are only three areas in the world where tropical rainforests are found – tropical South America, Central Africa and Southeast Asia. The rainforests of Southeast Asia are believed to be the oldest and among the most biologically diverse in the world. Malaysia is known as one of the world's mega diversity countries which rich of flora and fauna. The Titiwangsa Banjaran alone harness a significant amount of habitat that gives a varieties of forest includes montane and lowland rainforest. In fact, the tropical forest is the oldest forest and most abundant ecosystem on earth and many groups of animals and plants contribute to the complexity of the forest.

Among it multi diversity species is the primates. Primates in Malaysia are believed to vary among primatologists which about more than 20 species. The numbers of primates in Malaysia vary upon primatologists (Brandon-Jones *et al.,* 2004). Tropical rain forests in Malaysia consist of many different genus of primates that is *Nycticebus*, *Tarsius, Hylobates*, *Macaca*, *Pongo*, *Symphalangus* and subfamily of *Colobinae* which consist of genus *Trachypithecus, Nasali*, and *Presbytis*. *Nycticebus* and *Tarsius* fall into the prosimians category whereas *Macaca, Trachypithecus, Nasali*, *Presbytis* are considered as monkeys. The rest which are *Hylobates, Pongo,* and *Symphalangus* fall into apes category.

The habitat suitability of each primates vary from different species which makes each species unique and distinct from each other. The vegetation and altitude are among the variables that play important role in separating each species niches in the wild. Human intervention also claims to be the factor that affect population placement of a primates species. Logging and urbanization in extremes can lead to habitat of a closed proximity to that area to be disrupted and no longer suitable for primates.

In this study the primates selected are the *Hylobates lar.* This species have been listed as Endangered (EN) on the IUCN Red List. Apart from that fact, gibbons also found out to be the main disperser of seeds for oversized fruit. Their role was vital. Primates are common consumers and dispersers of some megafaunal fruits. Megafauna are often considered to be the main dispersers of these fruits, because their large seeds and/or thick husks make them inaccessible to all but the largest fruit-eating animals (Guimar˜aes *et al*., 2008, Sekar & Sukumar, 2013). Also the dexterity of primates ensures efficient fruit handling and seed extraction and many large primate species consistently swallow and defecate intact seeds (McConkey, 2000, Giraldo *et al.,* 2007, Beaune *et al*., 2013).

Recently, numerous mathematical techniques have been developed to estimate the geographical distribution of a species based on the concept of a species' ecological niche (Sobero´n & Peterson, 2005). The specific requirement of a species niches were identified and a statistical model of occurrence were predicted using an ecological niche modelling tool. Due to its well-known capability in predicting species distribution the maximum entropy distribution (MaxEnt) will be used in this research. Through MaxEnt the variables and data of this *Hylobates lar* species were inserted and a map is generated to show the potential distribution of this species throughout peninsular Malaysia as this species know to exist only in the peninsular rather than in Sabah and Sarawak. Basically this study will only cover the species potential distribution in peninsular Malaysia. It is well proven that MaxEnt has been shown to perform well in comparison with alternative methods (Elith *et al*., 2006; Pearson *et al*., 2007; Phillips *et al*., 2006).

1.2 Problem statement

The justification of this research is to contribute additional data regarding the potential distribution and to determine the conservation status of Malaysian primates that is the *Hylobates lar* species. Lack of data may result in potential danger of the species as current population trends show that lots of primates species suffer a decline in numbers except for the crab eating macaques (*Macaca fascicularis*) which still can be found regularly and listed as least concerned (LC) under IUCN Redlist of Threatened Species. When the species distribution is known, only then will the conservation process can take place. The effectiveness of a conservation program also depends on the distribution of a species. If a species is well distributed throughout the area and not only restricted to a certain place only then a conservation program can be acclaimed to be effective. Potential distribution also helps in keeping track of a species population which is useful in deciding whether the species is in danger of extinction or not.

1.3 Objectives

The overall objectives of the study are to identify the potential distribution of primates which is *Hylobates lar* species generating the maps. It is hoped that output from this research can be considered for future research. The objectives of the study are as below :

1. To identify the potential distribution of *Hylobates lar* species in Malaysia by generating maps.

1.4 Expected outcome

What is expected by this research is to improve and gain awareness of the conservation status of primates as a wildlife species in Malaysia. Hence, through this study, the population numbers of primates can be maintained. This research is expected to be a guide for other researcher in primatology to conduct their studies. Result of population distribution can help researchers to target and focus at a certain location in order to search for a certain species instead of laboring work searching a wide range of area. It is a more efficient way to conduct research because of already predicted potential existence of a population (Phillips *et al.,* 2004; Dudı´k *et al.,* 2006).

CHAPTER 2

LITERATURE REVIEW

2.1 Primates in general

Primates can be classified into two sub order that is the prosimians and the anthropoids. The prosimians is made up of smaller creatures such as slow loris. Generally considered as lower primates, the prosimians usually are native to Madagascar, but are also found throughout Africa and in Asia. As the more primitive group they exhibit lower intelligence and more likely resemble other mammal groups. Anthropoids on the other hand, consist of monkey, ape and human. Apes are commonly larger than monkeys, have no tails and, as they are close relative to humans, are claimed to be more highly evolved. In this study the species focused is *Hylobates* genus that is *Hylobates lar*. This species are classified under threatened species IUCN Redlist of Threatened Species. Among the reasons why this species is selected because of the need to conserve it before it totally becomes extinct in the wild. Each species carries a unique role in ecosystem which cannot be taken lightly. Respectively each species of *Hylobates* had their own preferences of vegetative, altitude and other variables which suits their physiological need. Loridae family with two other family *Lemuridae* and *Tarsiidae* are known as premonkey that is included under higher classification of prosimians. Their unique characteristic made them the primary suspect for hunters in search for valuable and highly artistic value trophy. Lorises bites are venomous and dangerous which can be harmful to humans (Nekaris *et al*., 2013), therefore many have their teeth inhumanely rip off by animal traders in order to domesticate them to live as pets or to be used for tourist photography (Gray *et al*., 2015)

2.2 *Hylobates agilis* in Malaysia

Agilis is commonly known as agile gibbon with a scientific name of *Hylobates agilis*. Listed as Endangered (EN) due to its declining population because of illegal trading and habitat loss (Geissmann & Nijman, 2008) *agilis* is a species of gibbon that can be found in peninsular Malaysia. Its favorable type of forest is dipterocarp dominated forest with known existence in other type of forest such as swamp and lowland forests to hill, submontane, and montane forests (O'Brien *et al.,* 2004). Forest edges near human habitations does not affect the populations in Bukit Barisan Selatan National Park in Sumatra (O'Brien *et al.,* 2004). Immature leaves and insect are among its diet but only less significant amount of it because the more preferred meals consist of sugary fruits. Frugivorous is what we called this gibbon as it preferred food is fruit. Primates spend half their lives at sleeping sites (Sugardjito, 1983; Anderson, 1998, 2000; Ancrenaz *et al.*, 2004; Russon *et al.*, 2007; Mathewson *et al.,* 2008; Lutermann *et al.*, 2010). The selection of secure and stable sleeping places and the abundance of such sites in the forest can impact each individual's chances of survival and reproductive success (Lutermann *et al.*, 2010; Phoonjampa *et al.*, 2010). Gibbons' choice of sleeping site and tree is driven primarily by predator avoidance and secondarily by site stability (Cheyne *et al.,* 2012). The evidence show that gibbon has a preferable tree as a habitat and they do not live on all trees. Thus deforestation affect greatly on this species as without a suitable habitat there will be a decline in population of that species. Therefore the need to conserve the forests is vital to ensure this gibbon has place to live and reproduce. Classified as Endangered (EN) on the IUCN Red List (1) and listed on Appendix I of CITES (2) this species are currently threatened.

2.3 *Hylobates lar* in Malaysia

The white-handed gibbon (*Hylobates lar*) possesses the long arms and hands typical of gibbon species but with a distinct characteristic which is white hand as if the gibbon is wearing a white glove. They wear either a dark coat, which may range from gray to black to brown, or a light coat of light cream color to light brown (Brockelman, 2004). The long hand are perfectly suited to its locomotion in the wild as this species is known for it pendulous swinging from branch to branch. Their elongated forelimbs, hands, and feet are adaptations for branchiation, which is their primary mode of travel through forest canopies (Vereecke *et al.,* 2006). Despite lacking a tail, the gibbon's sense of balance is nevertheless acute, and it can even be found walking on its hind legs along branches high above the ground, characteristically raising its arms above its head for balance. This is predominantly a lowland species where it can be found at below 1,000-1,500 m in forest (Brockelman & Geissmann, 2008). White-handed gibbons are a high canopy species and are rarely found in the understory (Gron, 2010; Savini *et al*., 2009). Males usually weigh 5.0 to 7.6 kilogram and females weigh 4.4 to 6.8 kilogram (Brockelman, 2004; Gron, 2010; Vereecke *et al*., 2006). The white-handed gibbon is protected from international trade by its listing on Appendix I of the Convention on International Trade in Endangered Species (CITES) (4). The white-handed gibbon is classified as Endangered (EN) on the IUCN Red List (1).

2.4 Ecological niche modelling

A niche is an ecological construct refers to the optimum environment for growth, reproduction and survival of species. Niches consist of three main factors such as substrate, microclimates and competition. Species distribution modelling is well known for accuracy in predicting distribution and it is widely used by ecologist to predict species distributions. A niche-based model represents an approximation of a species' ecological niche in the examined environmental dimensions (Philips *et al.,* 2006). These techniques are very helpful for finding poorly known distributions of species in poorly sampled areas, such as the tropics (Nazeri *et al.*, 2012). Fundamentally, this ecological niche model (ENM) predicts areas that are suitable to be inhabited by a species according to the species specific need for them to occupy a habitat. The very distinctive characteristic of a species in determining their habitat will be the main foundation for this ENM to predict their existence in rather unknown territories. Factors such as altitude, favorable foods and type of trees are among variables that are taken into measure. A species' fundamental niche consists of the set of all conditions that allow for its long-term survival, whereas its realized niche is that subset of the fundamental niche that it actually occupies (Hutchinson, 1957). This statement made it clear that a niche are divided into two which is the fundamental niche and realized niche. The ENM prediction are based on the fundamental niche of a species. Where all the need for a species to survive in the long term are entered into the program and the areas that satisfy the requirement will be claimed to be the potential realized niche. A niche based model thus represents an approximation of the species' realized niche, in the study area and environmental dimensions being considered (Philips *et al*., 2006). Typically the fundamental niche will be smaller than realized niche. This is due to the fact that human factors and environmental barriers play a part in preventing species colonization in the area that is predicted to be potential habitats. Another argument about this fundamental niche and realized niche is that if these two does not fully overlap then any modeling algorithm cannot characterize the species' full fundamental niche (Philips *et al.,* 2006). This happens due to absence of data on necessary information at occurrence localities. Subject to that matter, this problem rise from the fact that occurrence records are drawn from too small of a geographic area. In a larger study region, however, spatial variation exists in community composition as well as in the environmental conditions available to the species. Therefore, given sufficient sampling effort, modeling in a study region with a larger geographic extent is likely to increase the fraction of the fundamental niche represented by the sample of occurrence localities (Peterson & Holt, 2003). By definition, then, environmental conditions at the occurrence localities constitute samples from the realized niche (Philips *et al*., 2006).

In this study, based on the *Hylobates lar* ecological niche requirements a statistical model of occurrence were predicted using MaxEnt software. MaxEnt was known by its capabilities to incorporating complex dependencies among the predictor factors, leading to better prediction of species distribution (Ray *et al.,* 2016). Locality data and environmental variables are entered into the software and the results are processed in a form of maps showing the predicted distribution of this species. Binary maps of presence or absence are created based on threshold value. The climate variables typically used in model construction are, in most cases, not thought to be directly limiting the distribution of the species, in which case the models they produce are at best indirect estimates of the niche.

2.5 Maximum Entropy Modelling (MaxEnt)

In general, there are two categories of ENM available that require either: (1) presence-absence data for the target species, or (2) presence-only data for prediction (Tsoar *et al*., 2007). Among many different modeling methods under ecological niche modelling maximum entropy distribution also known as MaxEnt has been found to perform best (Elith *et al*., 2006), and may remain effective despite small sample sizes (Hernandez *et al*., 2006; Pearson *et al*., 2007). MaxEnt is tools that widely use to predict species distribution. Its debut in the field of ecology was at the year 2004 where it become available to use and at that point on this software has been frequently use to model species distribution (Elith *et al.,* 2011).

MaxEnt is a maximum entropy based machine learning program that estimates the probability distribution for a species' occurrence based on environmental constraints (Phillips *et al*., 2006). It requires only species presence data and environmental variable layers for the study area. The Maxent model is most commonly used as a bio climatic model with inputs of biologically important climatic factors which are derived from temperature and precipitation measurements. The software takes species presence-only data and chooses the distribution of a species under study that is closest to a uniform distribution. Pearce and Ferrier (2000) found that prediction of species distribution based on presence-only data was reasonably accurate for species conservation and other uses. Furthermore, MaxEnt maximizes entropy within distributions that satisfies the constraints derived from species occurrence points. Presence only data raise many question on their efficiency of predicting species distribution. Widely use of presence-only data for modelling species distributions has fueled excessive discussion about the sorts of distributions (e.g., potential vs. realized) that can be modelled with presence-only data in comparison to presence absence data (Sobero´n & Peterson, 2005; Chefaoui & Lobo, 2007; Hirzel & Le Lay, 2008; Jime´nez-Valverde *et al*., 2008; Sobero´n & Nakamura, 2009; Lobo *et al.*, 2010). Here are some advantages and disadvantages in using MaxEnt. First the good effect of using MaxEnt, It need only presence data, together with environmental information for the whole study area which reduce time on collecting data. Also incorporate interactions between different variables and the abilities to utilize both continuous and categorical data that needed in running the research. Continuous variables take arbitrary real values which correspond to measured quantities such as altitude, annual precipitation, and maximum temperature whereas the categorical variables take only a limited number of discrete values such as soil type or vegetation type (Philips & Dudik, 2008). Apart from that, the efficient deterministic algorithms that have been developed within the programme are guaranteed to converge the optimal (maximum entropy) probability distribution. This increases the rate of accuracy and reduces the margin of errors. Furthermore, as this maximum entropy modeling is an active area of research in statistics and machine learning, the progress in the field as a whole can be readily applied. However there are some weakness in using MaxEnt for example it is an immature statistical method which means there are fewer guidelines for its use in general and making it becoming a bit hard to understand and use. Besides that the amount of regularization requires further study (Phillips *et al*., 2004), as does its effectiveness in avoiding over-fitting compared with other variable selection methods (Guisan *et al.*, 2002). This facts again stressing that this module need more studies and improvement needed to be done in order to make it become more highly efficient tool for species distribution model. Special-purpose software is required, as MaxEnt is not available in standard statistical packages which make accessibility an issue where only a certain criteria of people can use it.

The latest version of MaxEnt software, that is version: 3.3.3k can be downloaded at (http://www.cs.princeton.edu/~schapire/maxent/). This software is free to download for educational and research purposes. Outputs generated (which is in a form of map) from this software in this study will go through testing to ensure it validity of the results. The maps generated from MaxEnt that contains the predicted distribution of *Hylobates lar*.

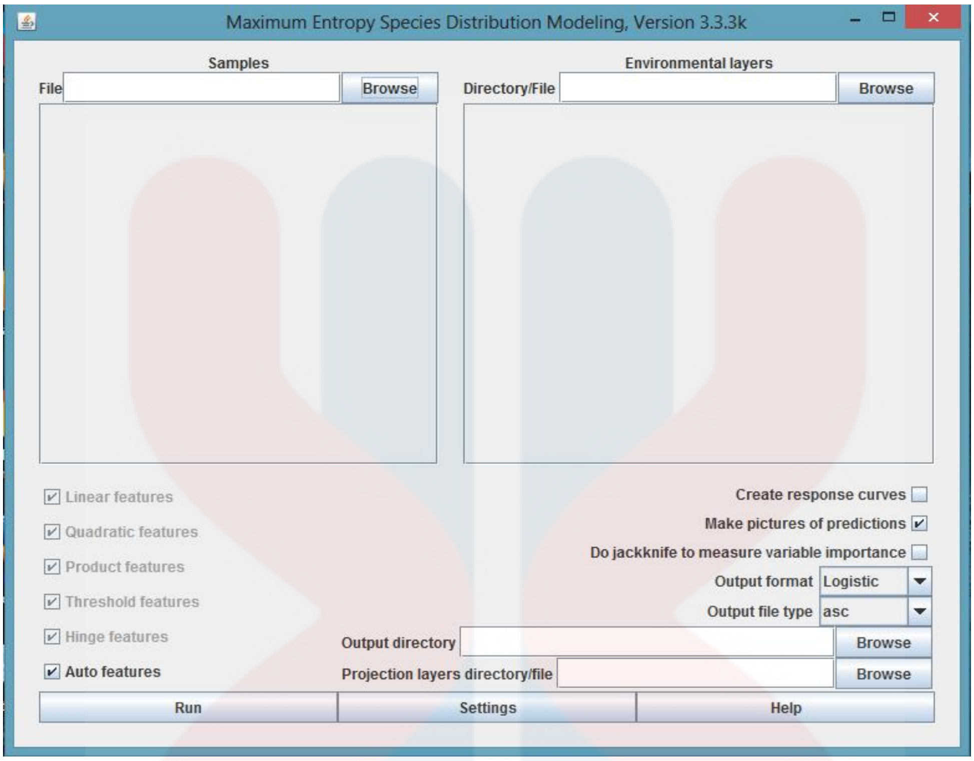


Figure 2.1 Maximum Entropy user interface

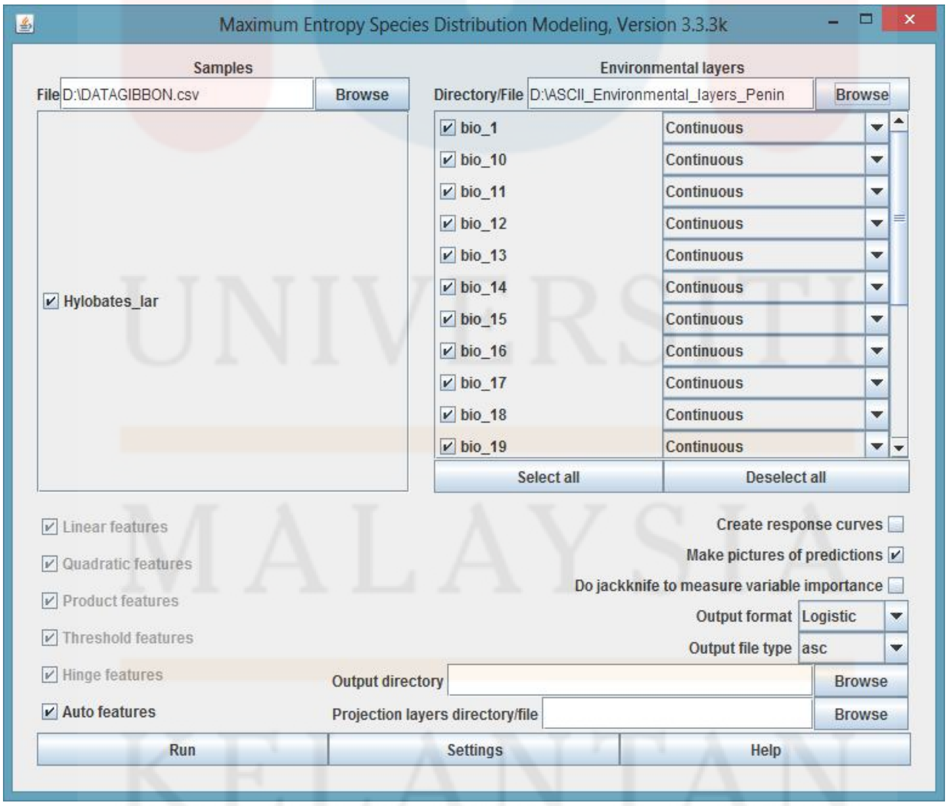


Figure 2.2 Maximum Entropy interface during data insertion

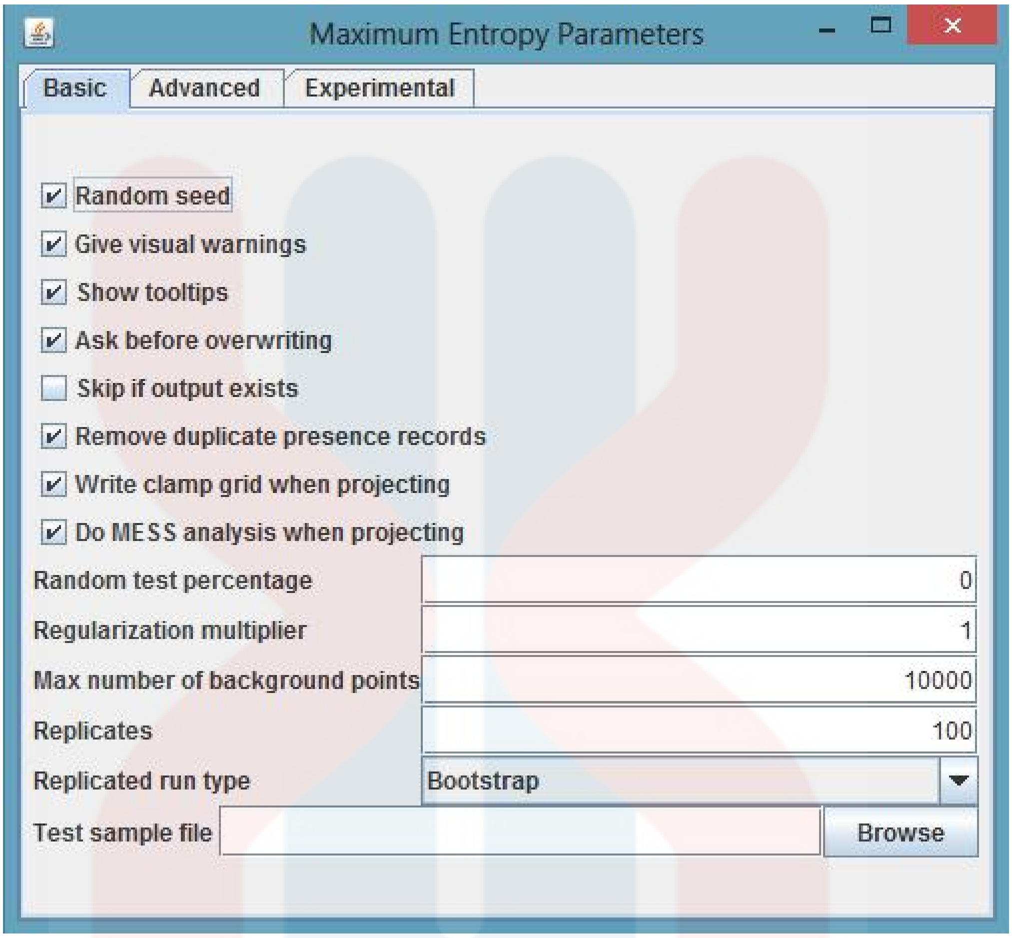


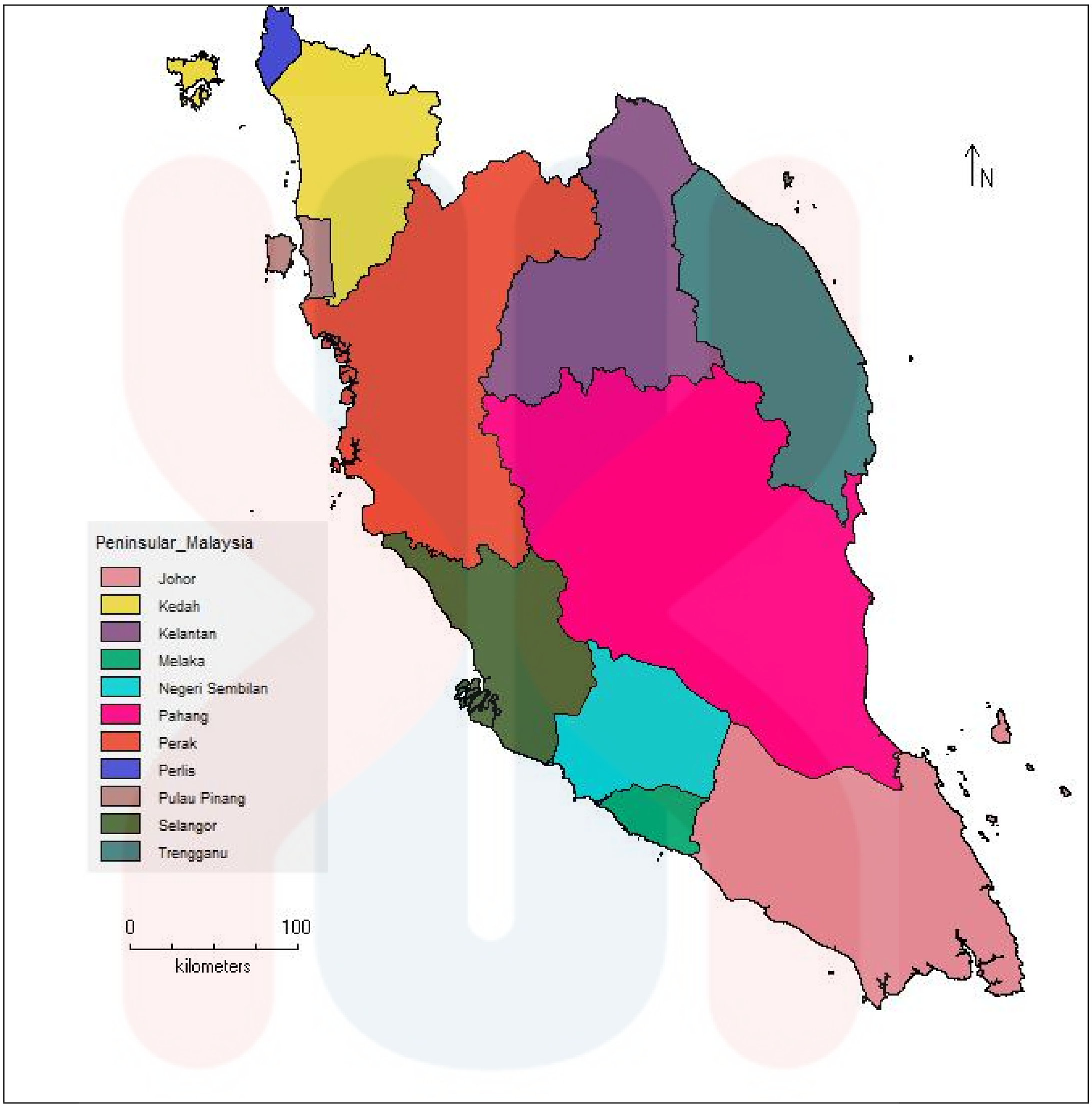
Figure 2.3 Maximum Entropy setting interface

CHAPTER 3

METHODOLOGY

3.1 Study sites

This study covered Peninsular Malaysia states of Perlis, Kedah, Penang, Perak, Kelantan, Terengganu, Pahang, Selangor, federal territories of Kuala Lumpur and Putrajaya, Negeri Sembilan, Malacca, and Johor. The Peninsular makes up an area of 13,100,000 ha which bounded by borders of Thailand on the north and Singapore on the south. The generated maps of potential distribution of selected species was manipulated using DIVA-GIS for a better result.



Figures 3.1 Map of study area generated using Arc GIS version 10.3

3.2 Locality data

Data used comprise of secondary data which obtained from published or unpublished records of studied species that is *Hylobates lar.* Data collection for this research derived from the report related from government and local authority's report, journals and also the usage of other books and publications will also be taken for consideration. Data also collected at the Global Biodiversity Information Facility (GBIF at http://www.gbif.org/).

3.3 WorldClim

Temperature and precepitation variables are extracted from the WorldClim database (Hijmans *et al*., 2005). This variables help to predict by creating more biologically meaningful variables that are derived from the monthly temperature and rainfall value. The 19 variables are stated in table 3.1 on the next page.

Table 3.1 Climate variables that can be downloaded from WORLDCLIM

Code	Variables
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3	Isothermality (BIO2/BIO7) (* 100)
BIO4	Temperature Seasonality (standard deviation *100)
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range (BIO5-BIO6)
BIO8	Mean Temperature of Wettest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO10	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO16	Precipitation of Wettest Quarter
BIO17	Precipitation of Driest Quarter
BIO18	Precipitation of Warmest Quarter
BIO19	Precipitation of Coldest Quarter

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Species distribution

The most vital part in running a Maxent software was locality data. In this study most of the locality data was obtained from The Global Biodiversity Information Facility (GBIF at http://www.gbif.org/) and some from journal that has been studied throughout this research.

Data that has been collected was analyzed and interpreted where the sources of that data was reviewed to avoid any false data. Furthermore, any redundant data that is locality that shares coordinates or situated near each other was deleted. Then each localities was put in a table using Microsoft Excel to create a datasets of localities for this species that is *Hylobates lar*.

Arc GIS version 10.3 was use to manipulate the localities and a basemap of peninsular Malaysia that is the study area was added and created a map that show us the localities whereabouts in the peninsular Malaysia map.

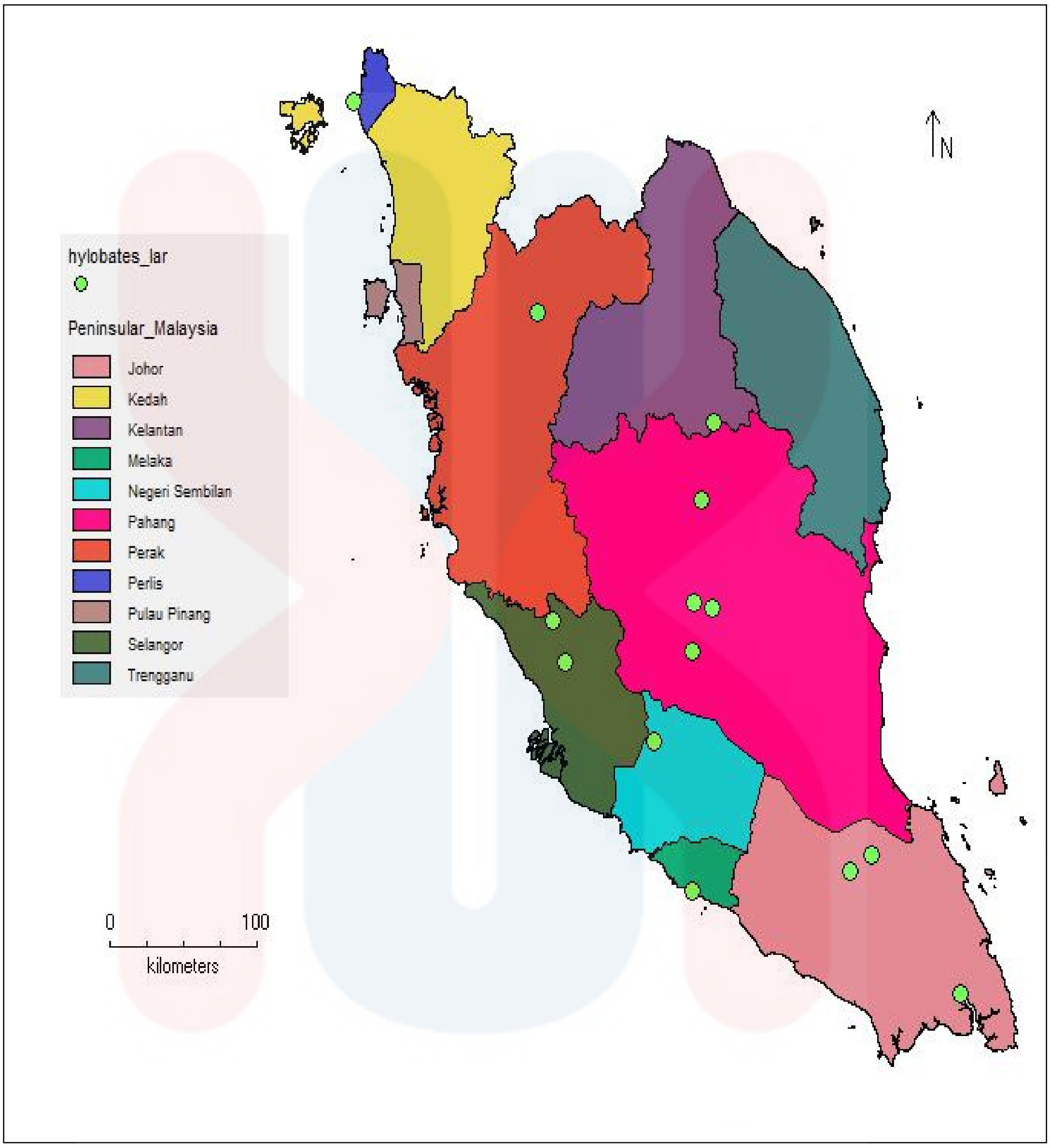


Figure 4.1 localities map of *Hylobates lar* in Peninsular Malaysia

4.2 MAXENT Output

MaxEnt is the main part of this studies where all the data that is the localities data and environmental layer were manipulated. The software predict the potential species distribution using this two key data. 14 localities data of *Hylobates lar* that combined to become one dataset and 19 environmental variables of study area that is peninsular Malaysia was inserted to run the MaxEnt.

First model of this study was to use full set of locality data to ensure maximum accuracy of predicting the species distribution. The random test percentage was set at zero which mean 100% of localities were used as a training dataset and none of it set aside as test point.

The second model was developed using random selections of 75% of the locality data as a training dataset. Whereas, the 25% were reserved for testing the resulting model. The third model was created using random selection of 25% as the training dataset and the remaining 75% as testing data. All these model were set at 100 replication and the average. Each model will brings out different area under the curves (AUC) number which will be used as a validation process. Basically each model different is the test percentage that is 100% , 75% and 25%. Test percentage is the amount of locality data used as a training dataset. The unused training dataset will be used as testing data.

Table 4.1: Area under the curve (AUC) for each model

Species		AUC
Hylobates lar	Full Run Training Data	0.795
	25% Testing Data	0.759
	75% Testing Data	0.837

The table above displays the AUC values for *Hylobates lar* species that had been projected using each different model run in MAXENT which is Full Run Training Data, 25% Testing Data and 75% Testing Data.

The next table shows the range of AUC and its classification where it becomes an indicators for our model. Two models that is the first and second model range above 0.7 but does not exceed 0.8 so these model can be classify as fair. While the third model sit at good classification with AUC values of 0.837.

Table 4.2: Range of AUC and its classifications (Araújo *et al.*, 2005)

RANGE	CLASSIFICATION
≤ 0.6	Fail
0.6-0.7	Poor
0.7-0.8	Fair
0.8-0.9	Good
≥0.9	Very good

4.3 Distribution models

Figure 4.2, 4.3 and 4.4 shows the average possible distribution of *Hylobates lar* generated using MaxEnt for model 1, 2, and 3 respectively. The color that is moving towards red show the highest possibilities of species to be available in that region whereas the colors moving towards blue indicates that the region has lowest chance of containing that species.

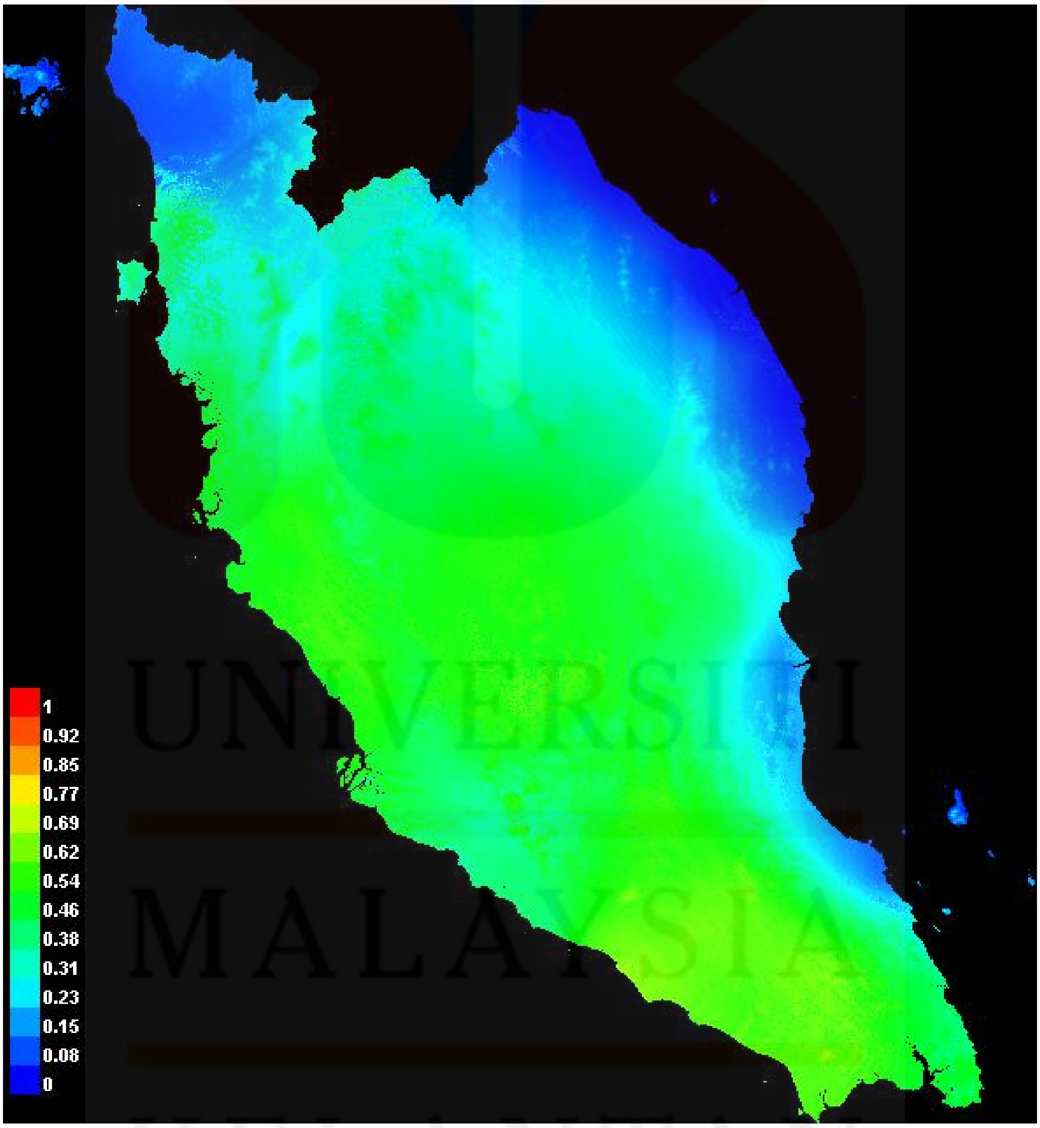
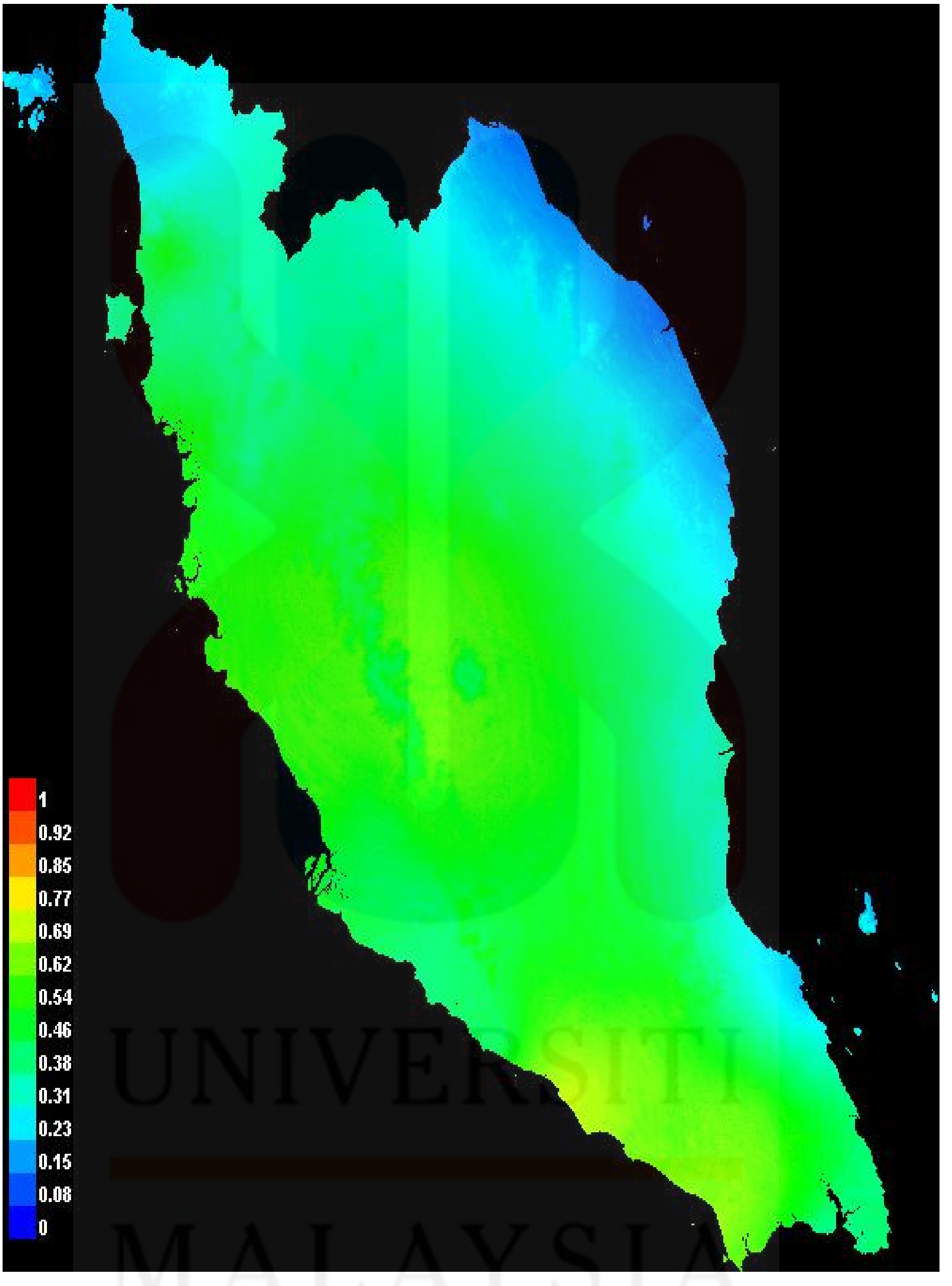
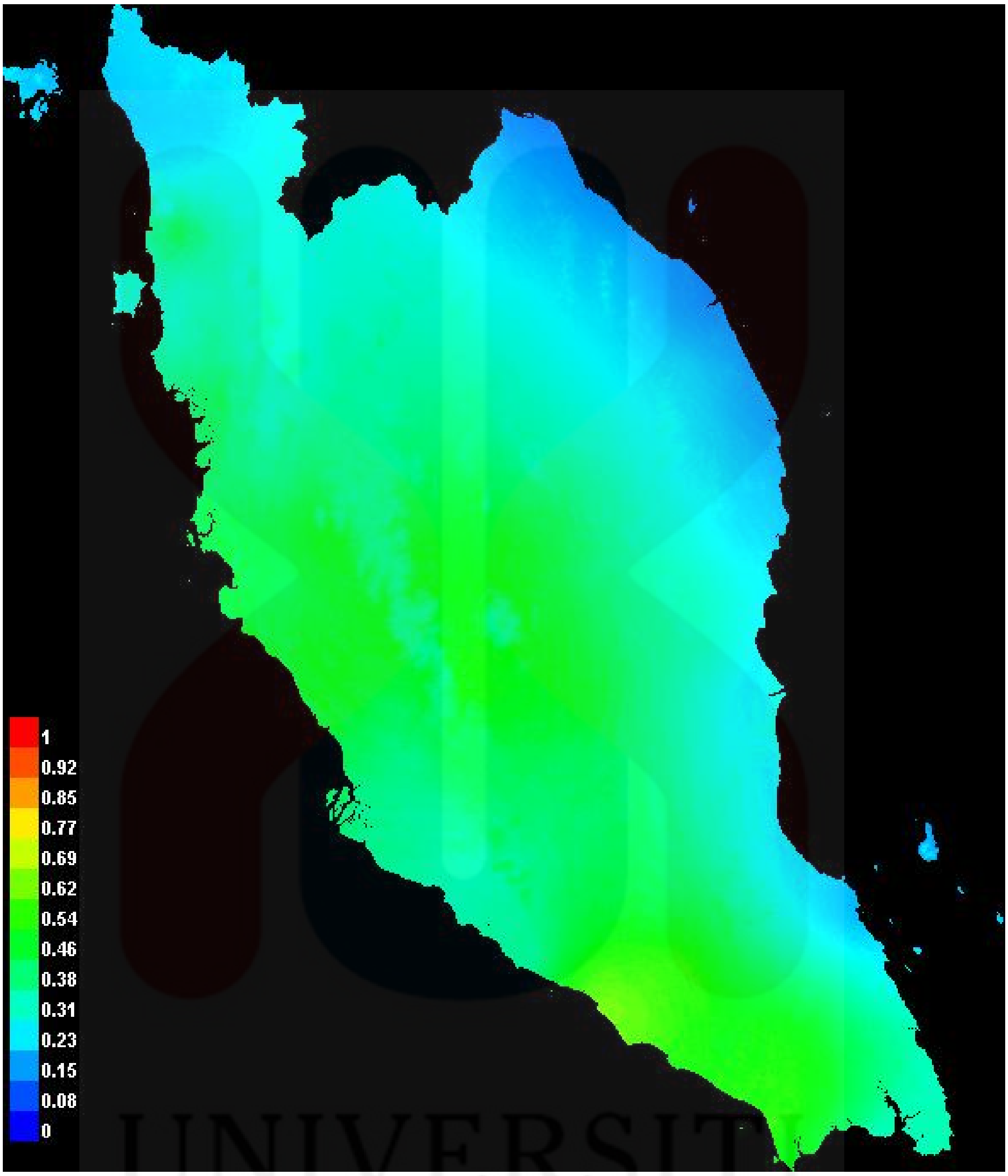


Figure 4.2 the average possible distribution of *Hylobates lar* generated using MaxEnt for model 1.

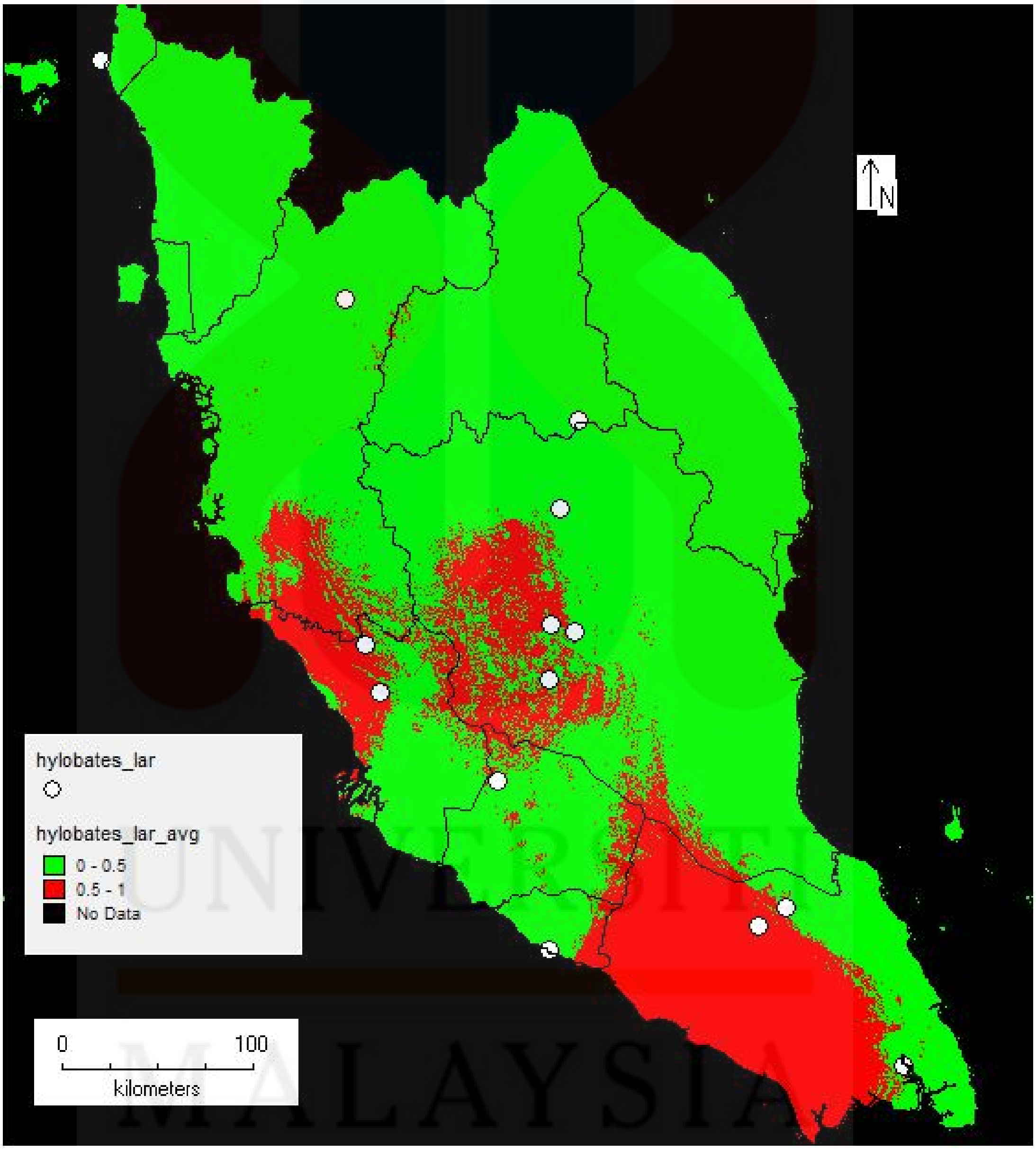


Figures 4.3 the average possible distribution of *Hylobates lar* generated using MaxEnt for model 2.

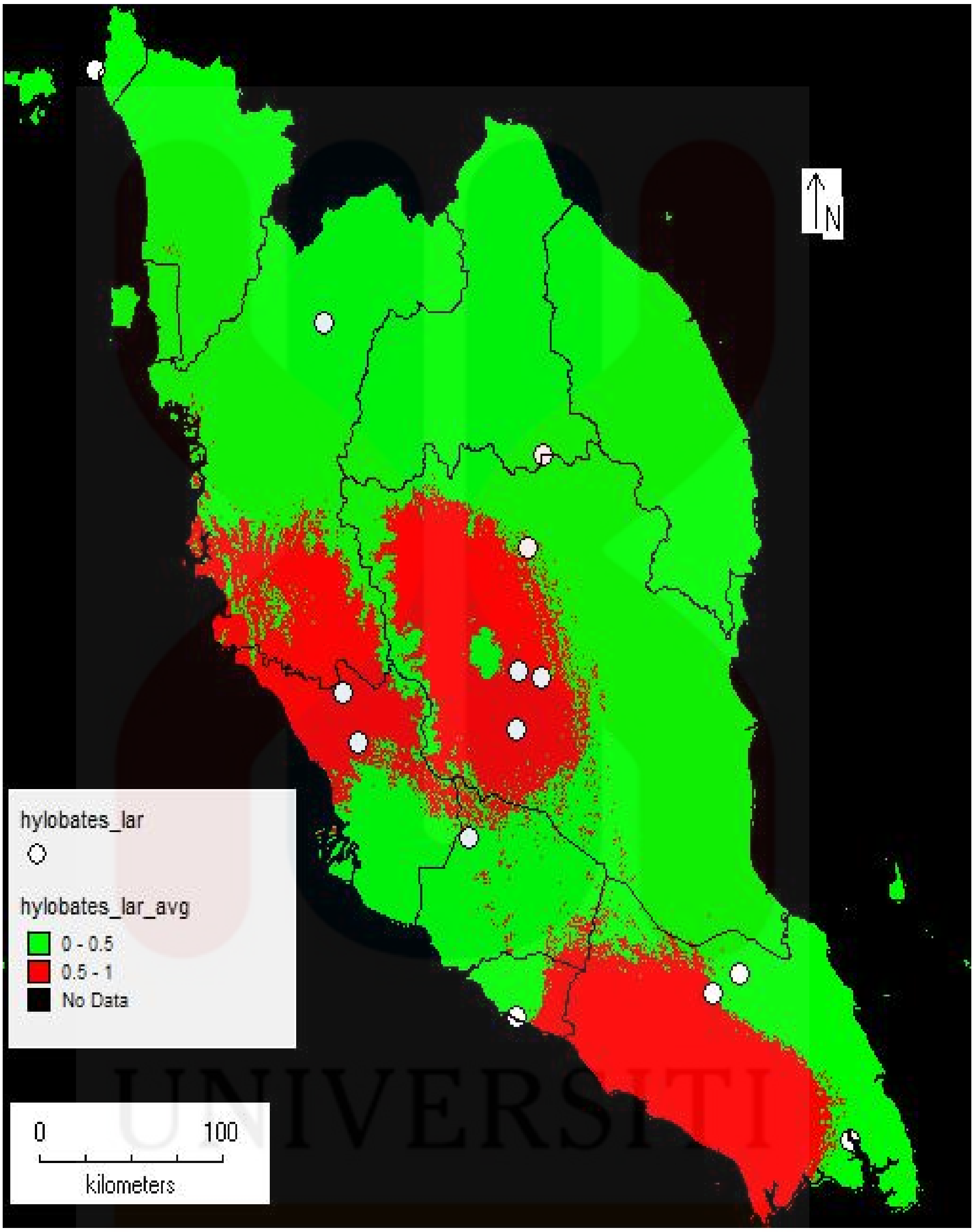


Figures 4.4 shows the average possible distribution of *Hylobates lar* generated using MaxEnt for model 3.

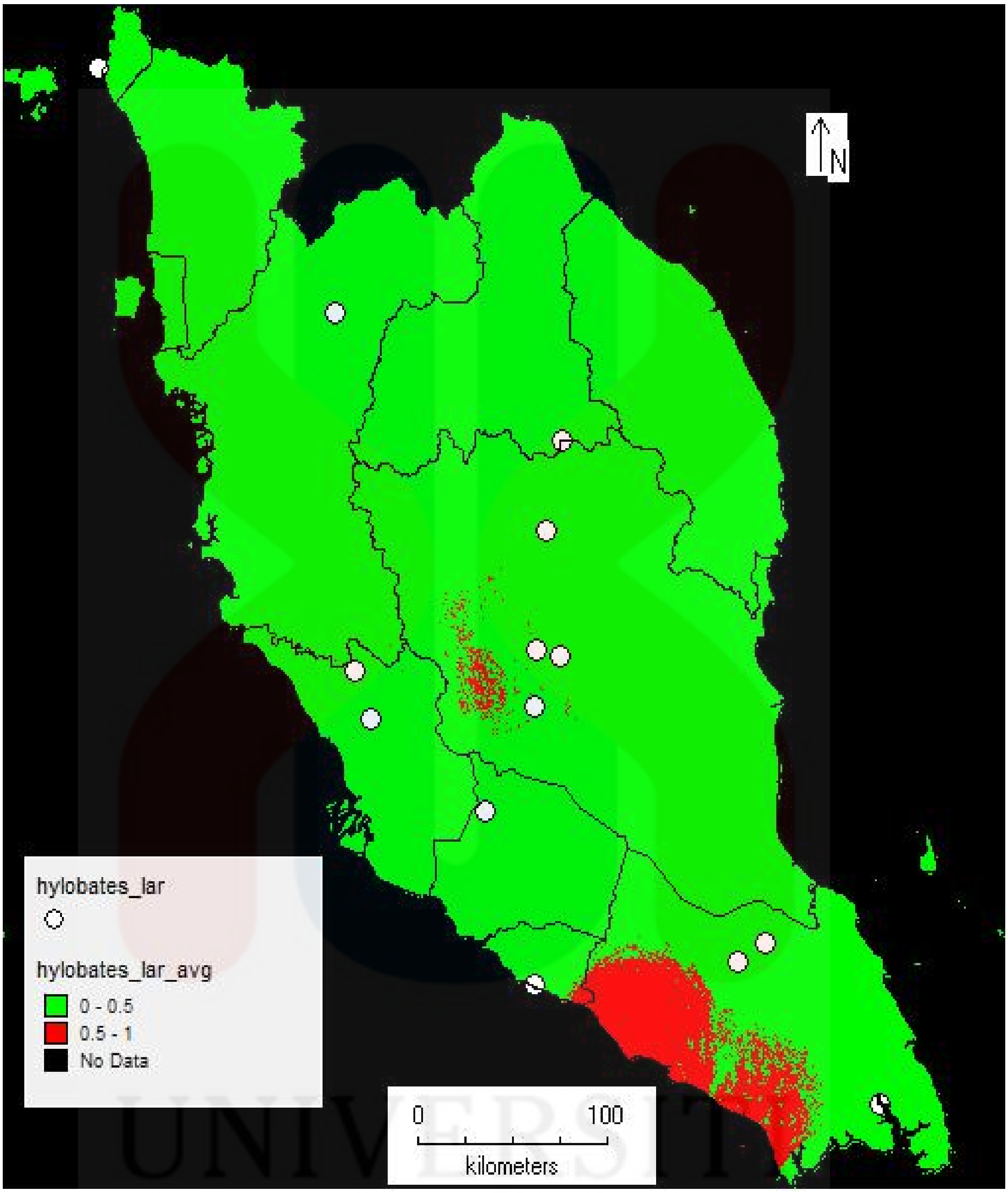
These three model output then was manipulated in DIVA-GIS to shows the potential distribution map. Area with green color has lowest probability of species distribution while red area has highest probability that the species may be found. Belows are the figures 4.5, 4.6 and 4.7 according to models respectively.



Figures 4.5 the species distribution map for model 1 using DIVA-GIS



Figures 4.6 the species distribution map for model 2 using DIVA-GIS



Figures 4.7 the species distribution map for model 3 using DIVA-GIS

Apart from giving out map of possible species distribution, MaxEnt also show which environmental variables out of 19 variables used that has the highest influence on the prediction made. Tables below shows the 19 variables and percentage of each variables contributed to MaxEnt algorithm in running the prediction.

Tables 4.3 19 environmental variables with their percentage contribution

Variable	Percent contribution
Bio 15	43.6
Bio 3	20.2
Bio 19	7.6
Bio 13	5
Bio 18	4.8
Bio 4	4.8
Bio 2	3.4
Bio 17	2.3
Bio 9	1.8
Bio 14	1.8
Bio 6	1.6
Bio 7	0.9
Bio 12	0.8
Bio 1	0.5
Bio 5	0.3
Bio 16	0.2
Bio 8	0.2
Bio 11	0.2
Bio 10	0

Table 4.3 shows the 19 variables according to their influential percentage in MaxEnt modelling. The most influential variables is bio 15 that is the precipitation seasonality that takes up 43.6%. Precipitation seasonality means the Coefficient of Variation (C of V) which is the standard deviation of the monthly precipitation estimates expressed as a percentage of the mean of those estimates. Second most with 20.2% percentage contribution is bio 3 that is isothermality. Bio 3 is basically the mean diurnal range (bio 2) divided by the annual temperature range (bio 7). The lowest contribution at 0.2% was shared by 3 bio that is bio 16, bio 8 and bio 11. The unused bio which contribute zero percent in this 0% test percentage model was bio 10 that is the mean temperature of warmest quarter.

Based on this model the potential distribution of this *Hylobates lar* species is mainly located at the southern of peninsular Malaysia that is the state of Johor. This is because states of Johor has the most red region which indicates high possibility of species available at that location. Second most abundant species distribution region is situated at Pahang. The red region at Pahang state is mainly at the west side while the east side shows low probability of species distribution. Terengganu, Kedah and Pulau Pinang shows no red region available in their country which means probability of species distribution is low in their states. Perlis meanwhile has a locality data at their states but no red region. Kelantan has the lowest red region area which is located close at the borders with Perak.

4.4 EOO and AOO Output

Figures 4.8 shows the contrast between Ecological Niche Modelling (ENM), Extent of Occurrence (EOO) and Area of Occupancy (AOO) methods in predicting species distribution. The ENM which is MaxEnt predict that *Hylobates lar* species was mainly located at southern of peninsular Malaysia with the values of 12642.59 km sq total area on the peninsular Malaysia.

Second method that is the EOO estimates the area of this species within the polygon drawn in order to gives the shortest-boundary solution encompassing all known site of occurrence of a species. The output values given when this method was run is 68396.37 km sq. This method predict the species status based on the area calculated. The species is predicted as least concern (LC).

Third method is the Area of Occupancy (AOO) which means the area is determine by counting the number of occupied cells in uniform grid covering the species range and then multiplying the number of occupied cell by the size of the grid cell adopted. This method also predict the species status based on the resulted areas estimation. The result gives area estimated of 50746.78 km sq and placed this species as least concern.

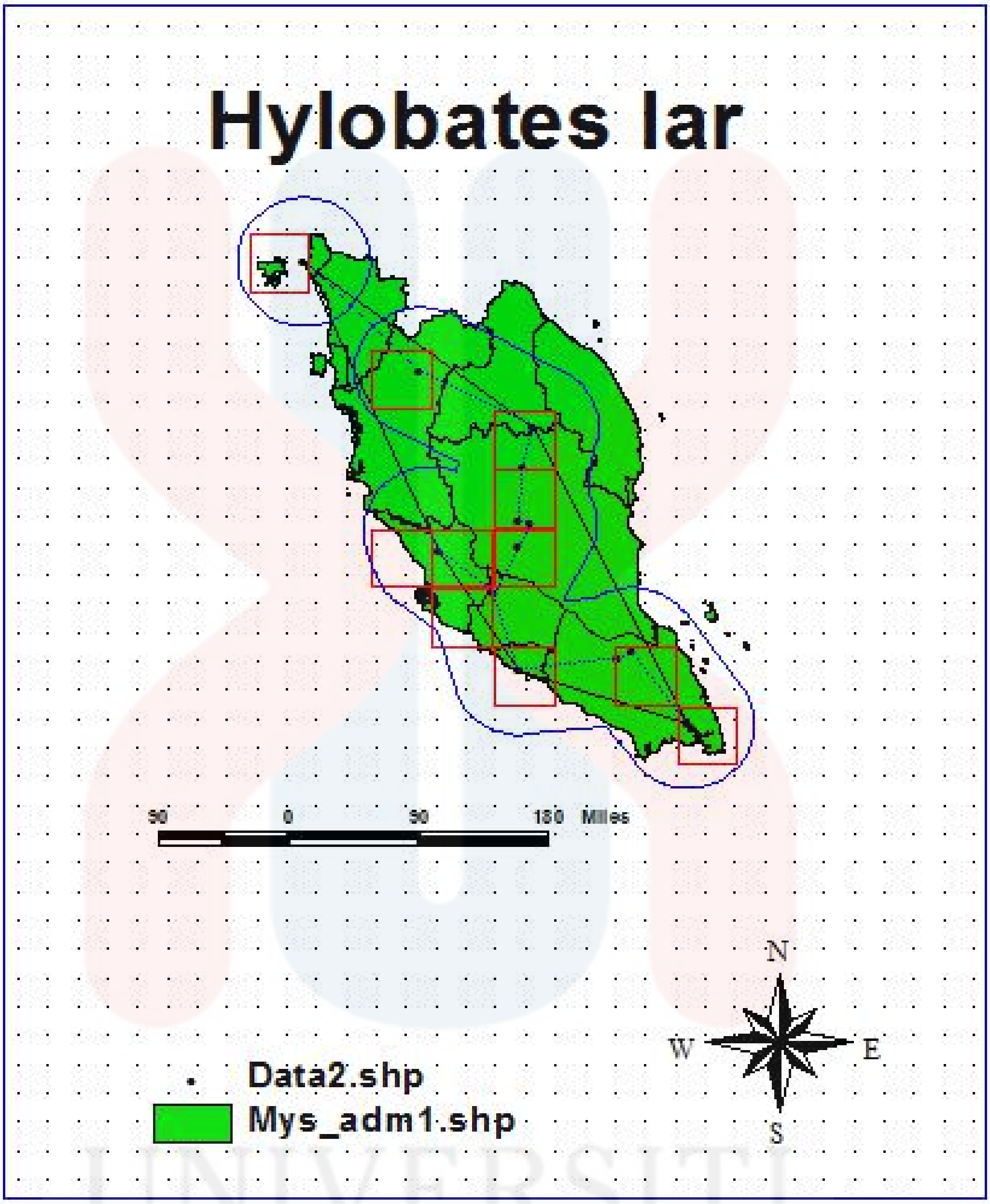


Figure 4.8 : Potential Distribution of *Hylobates lar* by Using EOO and AOO.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Hylobates lar is the species of primates that chosen in carried out this research. This research is to estimate the potential distribution of *Hylobates lar* seems they are one of endangered species in the world. These species distribution modelling is to compare the modelling method in effort to obtain the potential distribution of the species.

The method to construct the potential species distribution can be any way of method, as long as the data obtained from the result are correct, unbiased and have numbers of record. Then, it will produce a map of the potential distribution of the species in the study area.

From this research, MAXENT is the best method to construct the species distribution because it can produce correct result with a small sample size. Maxent result also show specifically the potential distribution by showing the suitable place on the map using color as a range where 0 to 0.5 set at green and 0.5 to 1 is set at red. Green indicate the lowest possibility whereas red indicate the highest probability. The outcome shown red region majority is found located in southern of peninsular Malaysia. Thus it can be said that *Hylobates lar* can be found mainly at the southern peninsular Malaysia.

5.2 Recommendation

As for recommendation, the potential distribution of the species needs to identify through collecting sampling in the study area. The collection of sampling based on the data obtained from MaxEnt.

In addition, the data obtained need to share or publish to government and private sector who acts as conservationist sectors in order to save the *Hylobates lar* Besides, the data obtained also for education purpose which can help other people who doing research about this species in the future.

Last but not least, more research regarding the potential species distribution need to be done in the future. This is to increase the data on locality of species distribution.

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APPENDIX A

BIOCLIM	Environmental Variables
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3	Isothermally (BIO2/BIO7/)(*100)
BIO4	Temperature Seasonality (Standard deviation *100
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range (BIO5-BIO6)
BIO8	Mean Temperature of Wettest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO10	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation of Seasonality (Coefficient of Variation)
BIO16	Precipitation of Wettest Quarter
BIO17	Precipitation of Driest Quarter
BO18	Precipitation of Warmest Quarter
BIO19	Precipitation of Coldest Quarter