Comparison of Potential Habitat of Genus Rhaphidopora in Kelantan Based on Different Qualitative Methods

By

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DECLARATION

I declare that this thesis entitled Comparison of potential habitat of genus Rhaphidopora in Kelantan based on different qualitative methods 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.

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Date : ____________________________________

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LIST OF ABBREVIATIONS

ENM	Ecological Niche Modelling
MAXENT	Maximum Entropy
SRTM	Shuttle Radar Topography Mission
EOO	Extent of Occurrence
AOO	Area of Occupancy
AUC	Area under Receiver Operating Characteristic (ROC) Curve
IUCN	International Union for Conservation of Nature
HWSD	Harmonized World Soil Data
FRIM	Forest Research Institute Malaysia

LIST OF SYMBOLS

%	Percentage
Ha	Hectares
km	Kilometre
km^2	Kilometre Square
^{o}	Degree

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ABSTRACT

The lowland forest in Malaysia especially in Kelantan has been exploited by logging activity and this can cause land use change. Thus the consequences from this activity can cause habitat loss of flora mostly dipterocarps. The mapping species distribution has become an important tools for conservation because an early prediction can be made using environmental and species occurrence data. This study was conducted to compare potential habitat of selected species of genus Rhaphidopora in Kelantan based on different qualitative methods. Furthermore, the qualitative methods that used in this study is Maximum Entropy (MAXENT), Area of Occupancy (AOO) and Extent of Occurrence (EOO). MAXENT model is widely used as a tool to determine the conservation assessment by using locality data and environmental data such as bioclimatic variable, soil database and altitudinal data. For conservation analysis, Ecological Niche Modelling (ENM) is broadly used because it accuracy. The selected species are *Rhaphidopora falcata*, *Rhaphidopora maingayi* and *Rhaphidopora korthalsii* and the locality data are obtained from the secondary sources. The result shows the comparison of percentage distribution for the selected species. The percentage distribution of *Rhaphidopora falcata* for AOO is 0.32%, EOO is 43.6 % and for ENM is 19.28%. For percentage distribution of *Rhaphidopora maingayi*, AOO is 0.51%, EOO is 62.09% and for ENM is 3.80 %.The percentage of distribution for *Rhaphidopora korthalsii* for AOO is 0.45%, EOO is 62.95% and for ENM is 12.07%. Thus, EOO methods shows the overestimates distribution of the species while AOO shows underestimates the species distribution and MAXENT shows intermediate distribution of the species. Hence, from this study shows that ENM is better compared to AOO and EOO by using MAXENT software which is it more suitable to be used as rapid assessment tool for regional conservation assessment.

Perbandingan Berpotensi Habitat Genus Rhaphidopora di Kelantan Berdasarkan Kaedah Kualitatif yang Berbeza

ABSTRAK

Hutan tanah rendah di Malaysia terutamanya di Kelantan telah dieksploitasi oleh aktiviti pembalakan dan ini boleh menyebabkan perubahan penggunaan tanah. Oleh itu akibat daripada aktiviti ini boleh menyebabkan kehilangan habitat flora kebanyakannya Dipterokarp. Pengagihan pemetaan spesis telah menjadi alat yang penting untuk pemuliharaan kerana ramalan awal boleh dibuat dengan menggunakan data kejadian alam sekitar dan spesies.Kajian ini dijalankan untuk membandingkan potensi habitat spesies terpilih genera Rhaphidopora di Kelantan berdasarkan kaedah kualitatif yang berbeza. Tambahan pula, kaedah kualitatif yang digunakan dalam kajian ini adalah entropi maxima (MAXENT), kawasan penghunian (AOO) dan jauh kejadian (EOO). Model MAXENT digunakan secara meluas sebagai alat untuk menentukan penilaian pemuliharaan dengan menggunakan data lokaliti dan data alam sekitar seperti pembolehubah bioiklim, pangkalan data tanah dan altitud data.Untuk analisis pemuliharaan, Permodelan Nic Ekologi (ENM) secara umumnya digunakan kerana ketepatan. Spesies yang dipilih adalah *Rhaphidopora falcata*, *Rhaphidopora maingayi* dan *Rhaphidopora korthalsii* dan data lokaliti tersebut diperoleh daripada sumber sekunder. Taburan peratus *Rhaphidopora falcata* untuk AOO adalah 0.32%, EOO adalah 43.6% dan bagi ENM adalah 19.28%. Untuk taburan peratus *Rhaphidopora maingayi*, AOO adalah 0.51%, EOO adalah 62,09% dan untuk ENM adalah 3.80% .Peratusan pengagihan untuk *Rhaphidopora korthalsii* untuk AOO adalah 0.45%, EOO adalah 62,95% dan untuk ENM adalah 12.07%. Oleh itu, kaedah EOO menunjukkan taburan anggaran yang berlebihan daripada spesies manakala AOO menunjukkan taburan anggaran yang berkurangan dari pengedaran spesies dan MAXENT menunjukkan taburan pertengahan spesies. Oleh itu, daripada kajian ini menunjukkan bahawa ENM adalah lebih baik berbanding AOO dan EOO dengan menggunakan perisian MAXENT yang lebih sesuai untuk digunakan sebagai alat penilaian pantas untuk penilaian pemuliharaan serantau.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Earth's surface is covered with 30 % of forests which is it known as complex ecosystem consisting mainly of trees that buffer the earth and support all of life forms and there is much biological diversity that can be found on the land such as tropical rainforest. Generally, forests that receive more than 60 inches of rain annually are known as tropical rain forest (Kellyn, 2000). Tropical rainforest are very significance because it has diversity and the abundance of the plant communities which it physically independent of the forest floor for all or part of their life cycle.

Lowland rainforest tree is mainly known as Dipterocarps. Mostly forests in the Malaysia are known as dipterocarp forest because major plants are from Dipterocarpaceae family (WWF, 2016). Habitat loss in lowland forest had more occurred compared to upland/lower montane or ultramafic species (Maycock *et al*., 2012). Example of plants that can be found in dipterocarp forest is aroid from the family of Araceae.

Aroids are the common name for members of the Araceae family. The first and foremost flowering plant, although it classified as strange one is well known as Aroids (Brown, 2000). This is because most people find them unusual because only few of the species that can be categorized that have characteristic of physical terms of flowers.

In fact, Araceae is a plant which have diverse species and known as vascular plant with monocotyledon seed. These plants mostly can be found from tropical sandy loam to temperate pond and wet woodland (Brown, 2000).

1.1.1 Species Distribution Modelling Using Software

Species distribution models can defined as models that are alike species or abundance of data occurred with the information on the environmental characteristics in that area (Elith & Leathwick, 2009). Moreover, earlier prediction can be done by species distribution method based on the pattern or arrangement of biodiversity at geographically scales.

Furthermore, based on the random or stratified field sampling species data can be simple presence, presence absence or abundance observations (Graham *et al*., 2004) and environmental predictor can influence and gives an effect either direct or indirectly on species (Austin, 2002).

Species distribution model also has being used in applied context for setting conservation priorities and have a great potential to support biodiversity conservation where the development of conservation plans and strategies is supported, knowledge of the gaps is identified and tool to examine the potential impact of environmental change is provided (Cayuela *et al*., 2009).

1.2 Problem statement

Conservation of araceae family is needed due to land use changes because of human activities. However, there is less data and information on genus of Rhaphidopora in the State of Kelantan. Hence species distribution is one of the methods to detect the distribution of araceae by using preliminary information to conserve those species.

This study is focused on distribution of Rhaphidopora genus (Araceae) because of this species mostly at lowland area and it habitat mostly exposed to land use change by human activities. Furthermore some of this species are endemic (*Rhaphidopora burkilliana*, *Rhaphidopora corneri* and *Rhaphidopora nicolsonii*) and need to be conserve before it extinct. In the end of the analysis, a map of Rhaphidopora genus will be construct by machine learning technique MAXENT by using ecological niche model.

1.3 Objectives

There are two objectives of this study:

1. To generate potential map of distribution of *Rhaphidopora falcata*, *Rhaphidopora maingayi* and *Rhaphidopora korthalsii* in Kelantan.

2. To compare the percentage of distribution of *Rhaphidopora falcata, Rhaphidopora maingayi* and *Rhaphidopora korthalsii* with MAXENT, Area of Occupancy (AOO) and Extent of Occurrence (EOO).

1.4 Scope of Study

Major finding in Ecological Niche Models (ENMs) is the method of distribution of data identifying non-random associations between species occurrences and ecological features (niche).

In this study it focus more on the niche based model from the presence data obtained from museums and herbarium while for absence data are rarely available for tropical region that have poorly sampled and modelling potentially have most value for conservation (Anderson *et al*., 2002).

CHAPTER 2

LITERATURE REVIEW

2.1 Forest

World land area is covered by 30 % with forest and all individuals depend on the product or services in some form on a same basis. Plus there is many people depend on forest minimally on part of their livelihood and well-being. Forest are one of significance element that are needed for life on the earth and it provide an ecosystem and support life such as birds and animal that lives in there (Keneath *et al*., 2015).

There is significant contribution of forest in our life such as to the economy which provide various product and services that can attribute to livelihoods and can protect the environments (Keenan *et al.*, 2015).

According to Keneath *et al*. (2015) forest that has never been disturb and logged is well known as primary forest and has developed following natural disturbances under natural processes. For secondary forest is a forest that has been logged and has recovered naturally or artificially. Moreover not all secondary forests provide the same value to sustaining biological diversity, or goods and services, as did primary forest in the same location.

2.1.1 Forest in Malaysia

Malaysia is enriched with tropical rainforests where ecosystems that are multiform and unique ecosystem can be found in and fortified with flora and fauna also as a source of high commercial value of dipterocarp species which timbers are well recognize in international marketplace (WWF, 2016).

Generally a rainforest is forested are at that receive 60 inches of rain per year and some rainforest receive in excess of 200 inches which specific type of rainforest are labelled in terms of their elevation and average temperature. Major types forests in Malaysia are dominated by trees from the Dipterocarpaceae family thus explain what is originate term of “dipterocarp forest”. The dipterocarp forest occurs on dry land just above sea level to an altitude of about 900 metres (WWF, 2016).

In 2013, about 18 million hectares of total land under natural forest in Malaysia is estimated that covering almost 54.5% of the land area. The three regions of Malaysia which is Peninsular Malaysia, has 5.81 million hectares of forest covering 44.05% of its land area, while Sabah’s 4.3 million hectares of forest, cover 57.5 % and Sarawak’s 7.89 million hectares of forest, cover 64.04% of the state respectively (FGI, 2013).

Over the past ten years, the conservation of tropical rainforests has received extremely large attention from public and most of everyone either seen or heard about loss of rainforest publicity but those people lack in an understanding he reason why the rainforest is too important to us. (Drinnen, 2000).

2.1.2 Forest in Kelantan

Kelantan is located at northern-most state on the East Coast of Peninsular Malaysia and has an area about 1,502,200 ha which forest covers about 865,017 ha or 57.6 % covered by the wooded area and consist of the Permanent Forest Reserve, which covers an area of 623.849 hectares of forest land with an area of 137.086 hectares, an area of 103.082 hectares of National Park and Forest Farm with an area of 69.696 hectares (Kelantan State Forest Department, 2016).

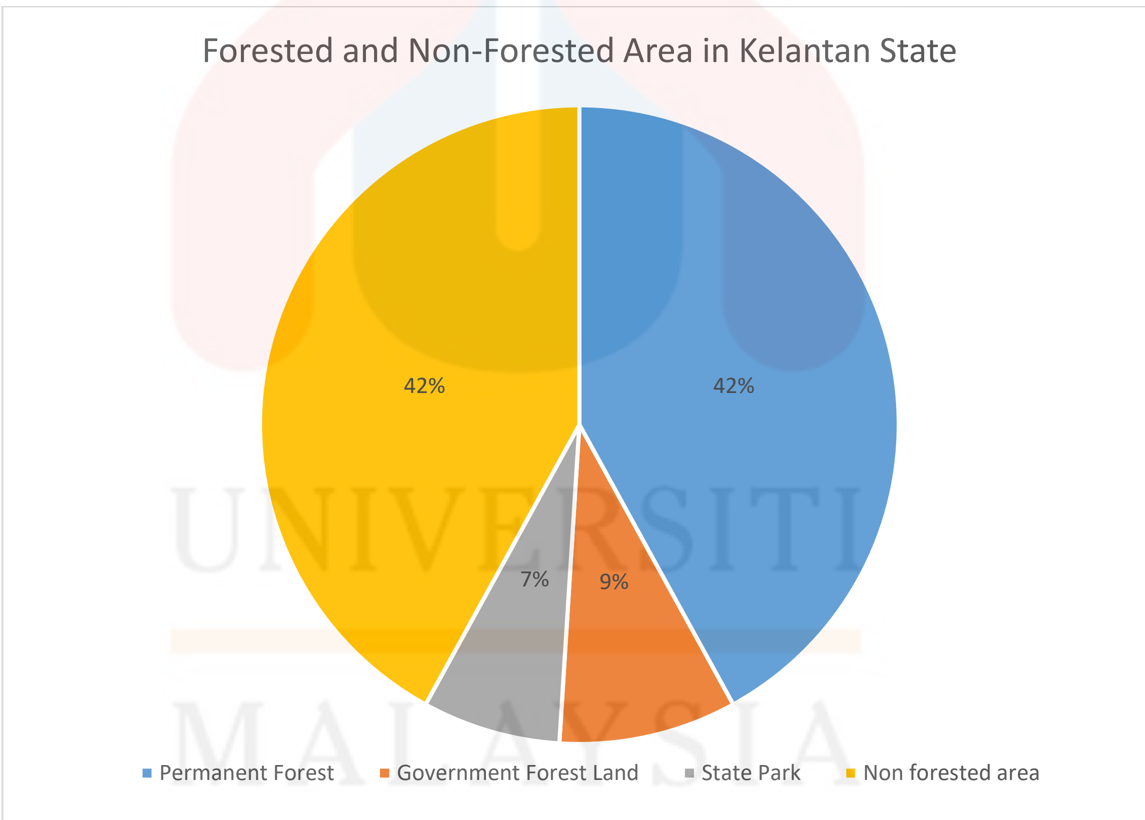

Figure 2. 1: Forested and Non-Forested Area in Kelantan State

Source: Forestry profile (Kelantan State forest Department, 2016)

Moreover, Kelantan is being gift with biodiversity that rich and diverse such as National Park, Virgin Jungle Reserves and limestone hills of Gua Musang. In addition, there is many species like plants and animal that lived and interconnected with those ecosystems (Skidmore, 2009).

Forest in Kelantan mostly are becomes vulnerable and invaded by the people who lives around due to the uncertain of the forest boundaries because they do not aware on how importance of forest biodiversity (Jusoff & Majid, 1995).

2.1.3 Land Use Changes Threats

Human activities or anthropogenic activities are the major contributor to the extinction of flora and fauna. Examples of anthropogenic activity are pollution, habitat destruction over exploitation and introduction of invasive species. Thus see rate of species extinction can be seen which is rise up rapidly (Hogen, 2014) due to accelerated human population growth and expanded scope of agriculture.

Nowadays, there is serious threat to natural ecosystems worldwide due to the rapid and expanding agricultural activities (Tilman *et al*., 2001). In addition, the major causes of land use change is agricultural activity and about 50% land converted to agricultural land. Habitat destruction occurs because of conversion of agricultural land, deforestation and overgrazing urbanization and these are the major reason of biodiversity loss (WWF, 2016).

Currently, oil palm has become one of the crops that mostly expanding in the world (Tilman *et al*., 2001). The two countries that producing largest oil palm is Malaysia and Indonesia (Koh & Wilcove , 2008) Thus by expanding the conversion of lowland rainforest to the oil palm plantation especially in Malaysia can causing the biggest threat to the flora and fauna and due to this ongoing habitat loss can lead to threats to whole ecosystem (WWF, 2016).

2.2 General overview of Araceae

Araceae was found in Southeast Asia from India to Australia with occurring species of Malay Archipelago on all islands where this region has complex geologic history that shaped caused by collision of Indo-Australian, Pacific and Eurasian plate. The changing sea level, uplift and submergence of islands and other tectonic movement was reflecting by the Malaysian flora and fauna.

Approximately there is 121 genera and 6000 species all over the world and in Peninsular Malaysia, there are about 23 genera with 123 species that have been recorded. The species can be found in various habitats from forest, rice field, river, lake, ponds and swamp. For wetland condition, some species are well adapted and most of native and endemic species are recorded as shaded plants (Sulaiman & Mansor, 2001).

In addition, some of aroids species that has medicinal value and widely used as native medicine and this lead to decreases of Aroids population (Sulaiman & Mansor, 2001). *Rhaphidopora korthalsii* has been widely utilized as part of Chinese traditional ways to treat cancer and skin ailment treatment. Previous reports has recorded its immunomodulatory consequences for mice splenocyte and human fringe blood (Yeap *et al*., 2013).

2.2.1 Life forms

Araceae are mostly can be found in the tropical humid rainforest where high percentage of all species of aroids can be found there. The stem of the aroids is short section of green and aerated which land mesophytes are incapacity to endure the dryness, sun exposure and root moisture deficiency. Thus all taxon of aroideae is in high risk of extinction when there is disturbance of forest or land use changes (Mashhor Mansor *et al*., 2012).

Hemiepiphytes aroids are known as the rootclimbers because it has anchor roots and this plant are exist in various size from shortly climbing plants attach or cling to the branches and trunks of trees to big plant that are growing into the forest canopy. This hemiepiphytes is divided into two which is primary and secondary hemipiphytes. Primary hemiepiphytes growth above ground and produce feeder roots that grow down to the ground while secondary hemiepiphytes germinates on the forest floor and growing by climb up the trees and rotting the juvenile stem to separate from the ground (Mashhor Mansor *et al*., 2012).

For epiphytes, the feeder is unfeasible to connect to the forest floor and in asian tropics there are some species that are classified as epiphytes such as *Scindapsus* and *Remusatia*. Then for litophytes, many hemiphytes,epiphytes and geophytes are founded as lithophytes in forested area which these plant are can be found growing on the rocks that provide enough basic need same as tree trunks for attachment such as *Amorphophallus* and *Thyphonium* species (Mashhor Mansor *et al*., 2012).

Rheophytes is known as surge safe plant that growing on the rocks along streams and developing in or along the quick running stream or rivers up to the flood level. The character of the rheophytes is the leaves is tapered and leathered which it firmly attached. Schismatoglottideae is the most genera that have pattern as rheophytes (Mashhor Mansor *et al*., 2012).

Helophytes have unlike taxonomic group of both temperate and tropical genera because the stem may be tuberous,rhizomatous and arborescent,semi-prostrate to aerial, erect and arborescent or merely shortly erect and aerial. The features of the stem which is tuberous associated with the habitats that is noticable as dry and flooded season. In addition, *Cryptocoryne* is the largest genus of aquatic aroids and this species are aquatic or amphibious (Mashhor Mansor *et al*., 2012).

Goephytes include of the genera with tuberous,rhizomatous,subterranean or slightly subterranean stems. Geophytes aroids in certain habitat normally correspond to the winter season and some species from moist and wet tropical forest show development periodicity and dormancy even in non-seasonal climates such as *Amorphophallus* and *Typhonium*.

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2.2.2 Genus Rhaphidopora

The genus Rhaphidophora is in the family Araceae in the major group Angiosperms (Flowering plants).The typical Rhaphidopora habitat is at primary to disturbed secondary lowland to lower montane forest on a variety of substrates including limestone and sandy loam which at 120-180 m altitude. Meanwhile around Peninsular Malaysia Sumatera, throughout Borneo, Java, Nusa Tenggara and Maluku (Boyce, 2001).

In previous study of aroids in Peninsular Malaysia, there are 15 species recorded with two endemic species and one species has been found again (*R. burkillina* Ridl.) also two new records (hitherto Bornean endemic *R. lateviganata* M.Hotta and *R. megasperma* Engl.).Hence there are 18 species include three endemic species recorded in Peninsular Malaysia (Mansor *et al*., 2012).

For this genus, it can be recognize immediately by the short leafy free side shoots bearing clusters of inflorescences subtended and interspersed by prominent chartaceous prophylls and cataphylls and by the spathe drying and persistent into early fruiting. The clustered inflorescences subtended by chartaceous cataphylls recall some New Guinea species, notably *R. versteegii* (Sulaiman & Boyce 2010).

Table 2.1: List of 18 species of Rhaphidopora in Peninsular Malaysia (Mansor *et al*., 2012).

No	Species	Status
1	*Rhaphidopora angustata*	Common
2	*Rhaphidopora beccarii*	Common
3	*Rhaphidopora burkilliana*	Endemic
4	*Rhaphidopora corneri*	Endemic
5	*Rhaphidopora crassifolia*	Common
6	*Rhaphidopora falcata*	Common
7	*Rhaphidopora foraminifera*	Common
8	*Rhaphidopora korthalsii*	Common
9	*Rhaphidopora latevaginata*	Common
10	*Rhaphidopora lobbii*	Common
11	*Rhaphidopora maingayi*	Common
12	*Rhaphidopora megasperma*	Common
13	*Rhaphidopora minor*	Common
14	*Rhaphidopora montana*	Common
15	*Rhaphidopora nicolsonii*	Endemic
16	*Rhaphidopora puberula*	Common
17	*Rhaphidopora slyvestris*	Common
18	*Rhaphidopora tetrasperma*	Common

Moreover, the preference of genus Rhaphidopora is little extraordinary, which has medium sized to very large, thin and rough, rarely neotenic, root climbing lianes and always with creeping not fully develop stage, cut surfaces producing clear , odourless sticky juice either drying (Boyce, 2001).

Genus Rhaphidopora usually can be found in well drained subtropical and tropical per humid to ever wet broadleaf forest at low to mid montane elevations, less often in peat swamp (*R.lobbii* Schott) or freshwater swamp tropical forest (*R. minor* Hook.f.).

The distribution of *Rhaphidopora falcata* can be found at southern peninsular Thailand to peninsular Malaysia. This species can be recognize with medium, slim, seedling, pre-grown-up plants and grown-up shoot which the stems smooth with internodes 1-2 x 0.5- 0.7 cm, isolated by rather very much characterized, marginally slanted leaf scars and stems woody is more develop (Boyce, 1999).

For *Rhaphidopora korthalsii* can be found at primary or secondary dipterocarp forest , lower and upper hill forest , on granite, sandstone, clay and limestone also sometimes in freshwater swamp forest. This species is widespread through southern Thailand through to western Oceania. This species can be identify the leaf lamina of develop plants pinnatisect, the pinnae frequently punctured basally and seeming stilted, lamina constantly glabrous; dynamic shoot apices with scanty to plentiful netted fiber (Boyce, 1999).

Figure 2.2: *The Rhaphidopora korthalsii*

Retrieved from: http:// http://araceae.e-monocot.org/taxonomy/term/3618

For adult *Rhaphidopora maingayi*, the features of this species is apices of dynamic stems with netted prophyll, cataphyll and petiolar sheat and the habitat of this species at open disturbed forest remnants on steep slopes, on sandstone with 755 m altitude and the distribution of this species are mostly at southern peninsular Thailand to peninsular Malaysia and Sumatera (Boyce, 1999).

Figure 2.3: The *Rhaphidopora maingayi*

Retrieved from: http://www.aroidpictures.fr /rhaphmaingayi.html

2.3 Species Distribution Modelling (SDM)

Species distribution model (SDM) is a technique to predict actual potential distribution of species and its environmental characteristic and as a central to both fundamental and applied research in biogeography. Based on data gathered, SDM can be used with enough resources where both presence and absence of species is recorded at an environmentally and spatially representative selection of sites (Cawsey *et al*., 2002).

Species distribution model have become an exceptional in studies of wildlife management, paleo-ecology, ecology conservation biology and studies in biogeography over the 10 years. This model also allows the estimation of species ecological requirements (Guisan, 2006). In addition, huge amount of distributional data include sampling and tracking, herbarium and museum records that is available in national and global biodiversity databases (Soberon & Peterson, 2005).

For example, prediction of current and future potential distribution of species is essential for understanding the impact of future climate change (Beaumont *et al*., 2005). Species distribution method also can be applied in order to strengthening available data identify the gaps by prioritizing areas for the field survey (Cayuela *et al*., 2009).

In addition, species distribution modelling (SDM) act as tool for conservation planning and policy development and implementation in tropical region and there is two tropical studies which application of species distribution modelling is being applied in order to support conservation planning (Cayuela *et al*., 2009).

2.3.1 Ecological Niche Modelling (ENM)

Ecological niche can be defined as the set of condition of and resources where all of the species is live with the environmental variables and ecological interaction of the species distribution is controlled. Major finding in Ecological Niche Models (ENMs) was the method of distribution of data identifying non-random associations between species between species' occurrences and ecological features (Anderson *et al*., 2002).

In this study, it focus more on the niche based model from the presence data obtained from museums and herbarium while for absence data are rarely available for tropical region that have poorly sampled and modelling potentially have most value for conservation.

Ecological Niche Modelling can be used as a rapid assessments tool where it is not only tools for dipterocarp but also to other endangered species. This study was important in order to determine the endangered species status either plants or animal. Hence by using modelling technique, identification of current species conservation status can be used for conservation activity itself at the same time can reduced time provided (Phillips *et al*., 2006) and in ecological niche modelling distribution is used to predict related species, invasive species, distribution shifts due to changing climate and undiscovered species.

2.4 Modelling Method

Numerous number of algorithms has been used in species distribution modelling such as extent of occurrence (EOO) and area of occupancy (AOO). EOO defined as area that contained within a polygon drawn which to create solution of the shortest boundary encompassing all known sites of occurrences of a species (Maycock et al., 2012).

AOO measured area within EOO occupied by given species. IUCN Red list assessment using extent of occurrences EOO or area of occupancy EOO technique in estimate s species extinction because it's currently accepted (IUCN Standards and Petition Subcommite, 2010).

Howeever, the EOO overestimates the distribution of species with multiple proposition of distribution because it fails to account the for the patchy distribution of habitat whereas the AOO underestimates species distributions because of sampling constraints (Solano & Feria, 2007). In addition there is some modelling method that commonly used presence-only which is GARP and BIOCLIM.

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2.4.1 Maximum Entropy (MAXENT)

MAXENT is for modelling species geographic distributions with presence only data where general purpose is method with a simple and precise mathematical formulation, and well suited for species distribution modelling (Phillips *et al*., 2006) and this modelling can help researcher identify distribution of species in poorly sampled areas such as the tropics and can be applied to describe the distribution or potential habitat of certain species (Nazeri *et al*., 2012).

Table 2.2: Advantages and disadvantages of MAXENT software (Phillips *et al*., 2006).

Advantages	Disadvantages
1.All environmental information of whole area needs only presence data.	1.Less guideline for general use
2.Maximum entropy probability distribution efficiency are have been develop and guaranteed.	2.Prediction area can be wide in range
3.The Maxent probability distribution has a concise mathematical definition.	3.This software is not available in standard statistical packages.
4.By using logarithm regularization over fitting can be avoided.	4.Further study needed for amount of regularization.
5.No issue on bias sampling because probability distribution of MAXENT depend on localities occurrence.	
6. The difference of suitable area of distribution of model because output is continuous.	
7. By using presence/absence data of species, MAXENT can be run by using conditional model.	
8.MAXENT can be run with limited data.	
9.Can be readily applied in active research area in statistic and machine learning.	
10.A flexible statistical method to be used in niche based model.	
11.Continuous and categorical data can be utilize and incorporate with interactions between different variables.	

2.4.2 Area under Receiver Operating Characteristic (ROC) Curve (AUC)

AUC is generally a method to determine and estimate the accuracy of predictive distribution model that are derived from the presence absence data. Hence, from the output that are derived from different modelling technique, continuous probabilities of presence, (P) generated from the variables used AUC is mostly used in many application to measure the quality of a classification algorithms and it design to minimize error rate of AUC values. (Lobo *et al*., 2008).

According to Table 2.3, there are ranges and classification in determining the value of AUC.

Table 2.1: Range of AUC and its classification (Arau'jo *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

CHAPTER 3

MATERIAL AND METHOD

3.1 Study Area

The state of Kelantan is located in the East Coast of Peninsular Malaysia, neighbouring with Thailand, Perak, Terengganu and Pahang at 5.2500 ˚ N latitude and 102.0000 ˚ E longitude. The total number of district in Kelantan State are ten which is cover an area of 1,502,200 ha/ 150, 22 km² (Kelantan State Forest Department, 2015). Figure 3.1 shows the map of Kelantan state.

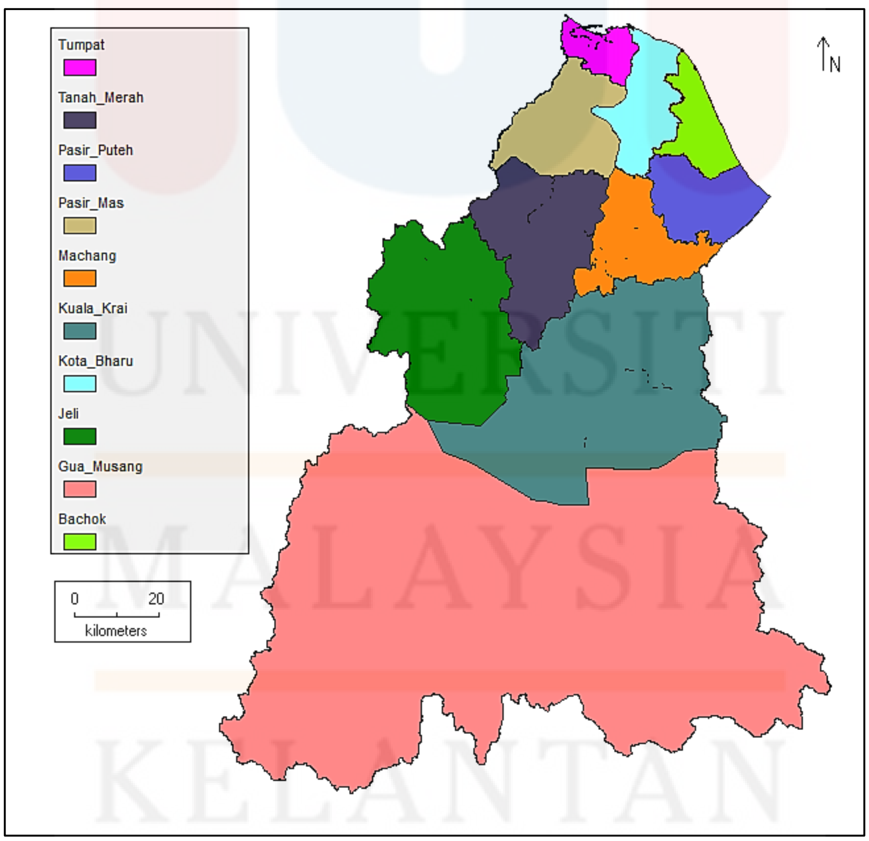

Figure 3.1: The map of Kelantan

3.2 Sources of Data

3.2.1 Locality Data of Study Species

In this study, locality data is very important in the secondary data. The localities data is needed to determine the distribution of species. In this study the selected species are *Rhaphidopora falcata, Rhaphidopora maingayi* and *Rhaphidopora korthalsii*.

Secondary data is acquired from herbarium data of study species which discover species point location data. All the datasets were obtained from the Forest Research Institute of Malaysia (FRIM) that located in Kepong, Kuala Lumpur. Moreover, all specimens were collected from year 1950s to 1960s in order to avoid imprecise distribution data (Maycock *et al.*, 2012).

Thus, secondary datasets is regarding the availability and information of genus Rhaphidopora and in Kelantan. Additional data is obtained from Zulhazman Hamzah (unpublished data) that is collected from all over Kelantan state.

3.2.2 Environmental Data Layers

3.2.2.1 WORLDCLIM Data

The environmental data we will use consist of climatic and elevational data. Generally, in order to identify the genus Rhaphidopora environmental data is needed by obtained from WORLDCLIM (http://WorldClim.org/bioclim) (Hijamans *et al*., 2005). Moreover, to generate more biologically variables there are 19 bioclim layer that derived from the monthly temperature and rainfall values. Next, from WORLDCLIM also can download climate data for:

1 Current conditions (interpolations of observed data, representative of 1950-2000).

2 Future conditions: downscaled global climate model (GCM) data from CMIP5 (IPPC Fifth Assessment).

3 Past conditions (downscaled global climate model output).

Table 3.1: Bio- Climatic Variables downloaded from (http://WorldClim.org/bioclim)

Codes	Description
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

3.2.2.2 Harmonized World Soil Database (HWSD)

The Harmonized World Soil Database (HWSD) is the soil related variable contains the soil data. Selected soil parameters such as organic carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class, and granulometry can be obtained at (http://www.iiasa. ac.at/web/home/research/modelData/HWSD/HWSD.en.html) (IIASA,2012) HWSD is a global database, framed within a Geographic Information System (GIS), that contains up-to-date information on world soil resources .

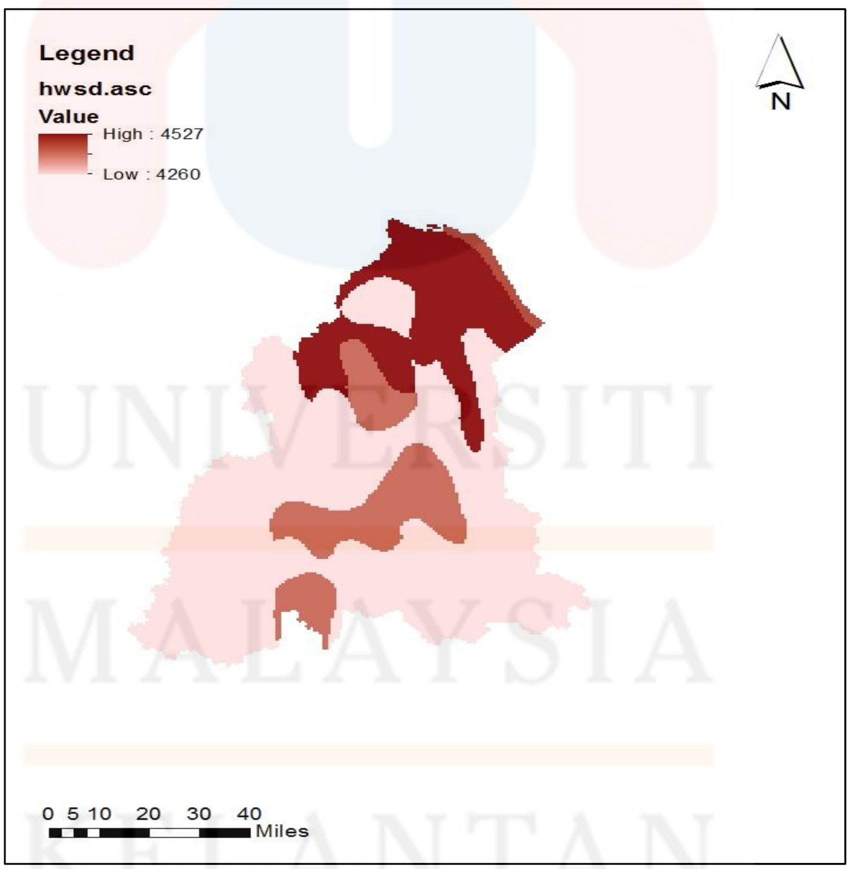

Figure 3.2: Map of altitudinal (SRTM)

3.2.2.3 Shuttle Radar Topography Mission (SRTM)

Shuttle Radar Topography Mission (SRTM) is an elevation model on a near globe scale from 56° S to 60° N which to generate most complete high resolution digital topographic database of Earth. Index map of newly available with full resolution data can be download from the (http://USGS EROS Data Center) (Ramirez, 2016).

Shuttle Radar Topography Mission (SRTM) data was generated using ArcGIS version 10.1 to produce altitudinal map of Kelantan State. Figure 3.2 shows the map of altitudinal for Kelantan state. The blue brown show low value of altitude while the color tends to blue shows the value of altitude increases.

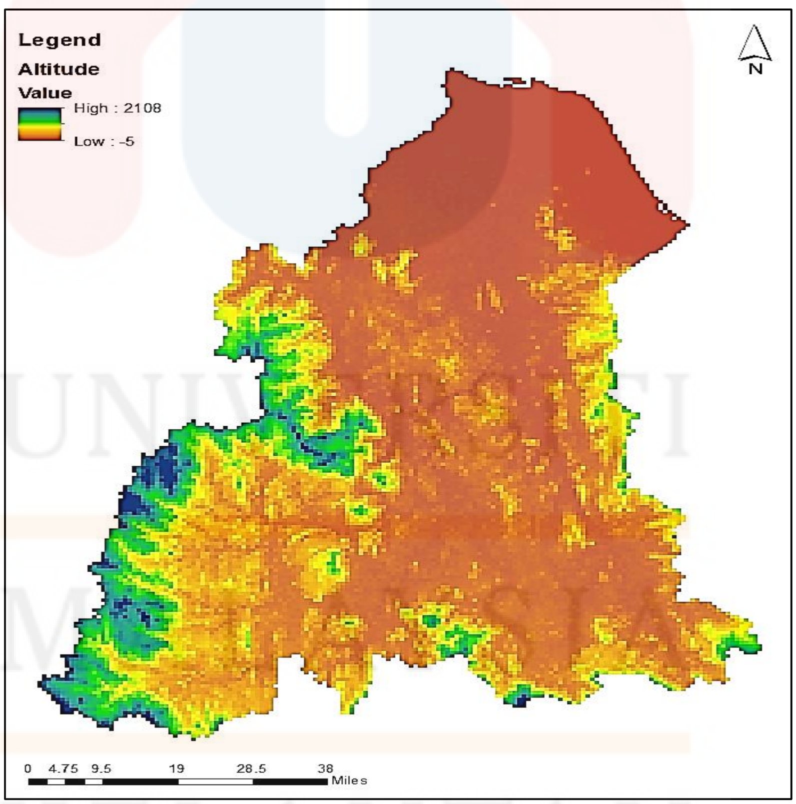

Figure 3.3: Map of altitudinal (SRTM) in Kelantan State

3.3 Data Analysis

Analysis of the data was done by using MAXENT software that downloaded free and from this software data will be obtain and estimation modelled map of current distribution is produced. This model run using distributional data which are environmental data and locality data. Thus, based on the basic need of the plants such as water, oxygen, temperature, light, soil is met so elevation MAXENT can computed the model minimally with the condition above.

MAXENT software showed the best among others compared to other modeling software (Elith *et al.*, 2006). The three species with more than 12 localities data were needed to run two separate models were run (Maycock *et al*, 2012). The first model was developed using full run test and the second models was developed using a random selection of 75 % of locality data as training data and 25 % of locality data remaining was reserved as testing data (Maycock *et al*, 2012).

. For Area of Occupancy (AOO) and Extent of Occurrence (EOO), the species point distribution maps will be used to construct convex polygon to measures EOO and generate grids to obtain values for AOO. Then by overlaying the output the species distribution can be predicted. All locality data were used to develop EOO and AOO by using ArcView GIS 3.3. EOO was estimated by the minimum convex polygon method using Conservation Assessment Tools (CATS) extension.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Distribution of Selected Genus Rhaphidopora

The localities data is needed to determine the distribution of species. In this study the selected species are *Rhaphidopora falcata*, *Rhaphidopora maingayi* and *Rhaphidopora korthalsii*. Figures 4.1, 4.2, and 4.3 represent the spots of the selected genus Rhaphidopora in Kelantan and this map are generated by using Arc GIS version 10.1.

Figure 4.1 shows the locality data for *Rhaphidopora falcata* and recorded the map that has been generated, it shows that the distribution of *Rhaphidopora falcata* is mostly in Gua Musang and there are several spots in Jeli, Machang, Tanah Merah and Kuala Krai.

Figure 4.2 shows the locality data of *Rhaphidopora maingayi* in Kelantan. The total locality data for *Rhaphidopora maingayi* are recorded with 28 points. The distribution of *Rhaphidopra maingayi* are highly distributed in Gua Musang and the rest are scattered in Kuala Krai, Machang, Tanah Merah, Jeli and Pasir Putih.

Figure 4.3 show the *Rhaphidopora Korthalsii* localites with 23 points. The distribution map of *Rhaphidopora Korthalsii* in Kelantan, are scattered in Gua Musang, Jeli, Tanah Merah, Kuala Krai and Pasir Puteh.

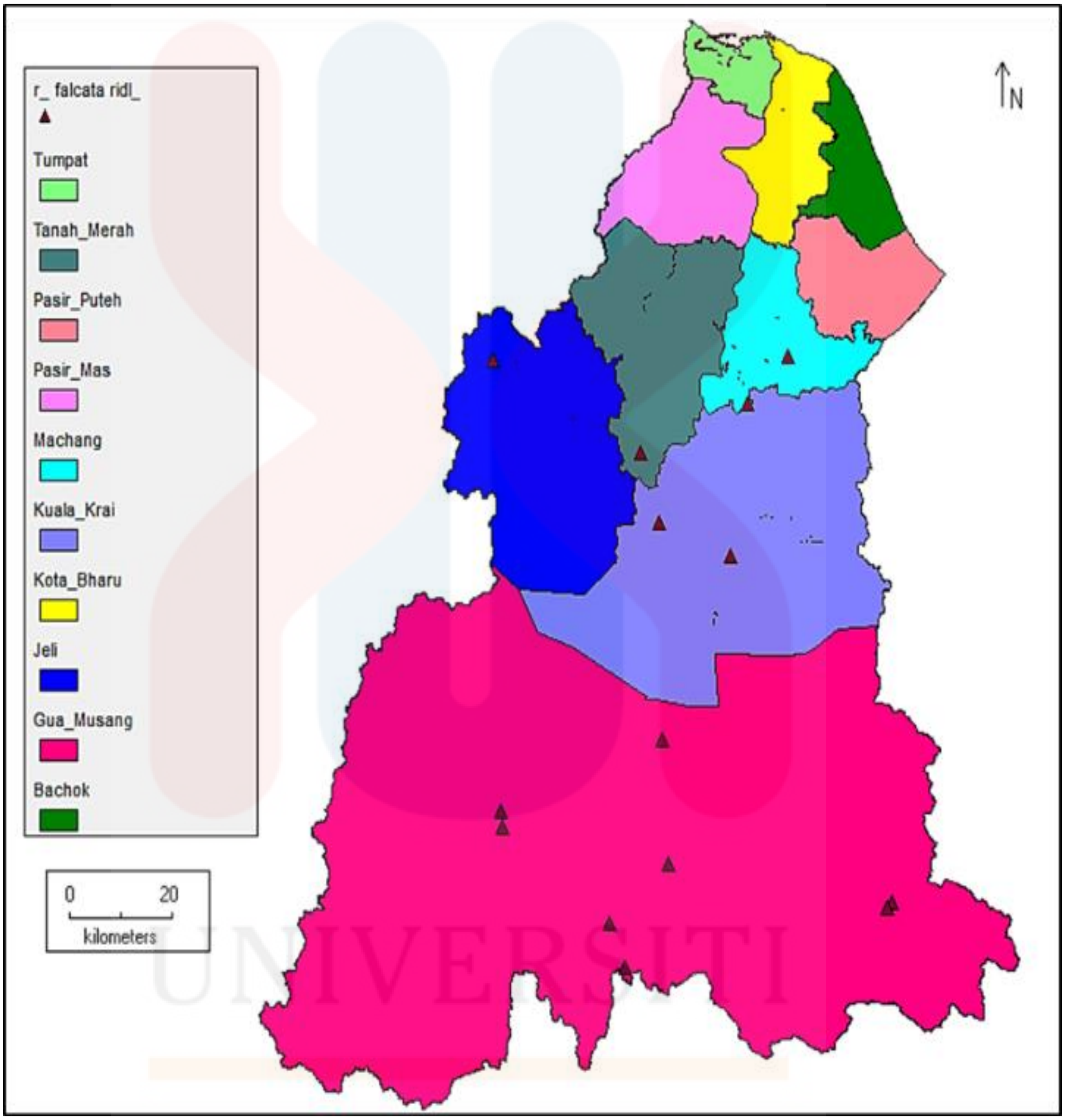

Figure 4.1: Localities data and habitat distribution of *Rhaphidopora falcata* in Kelantan

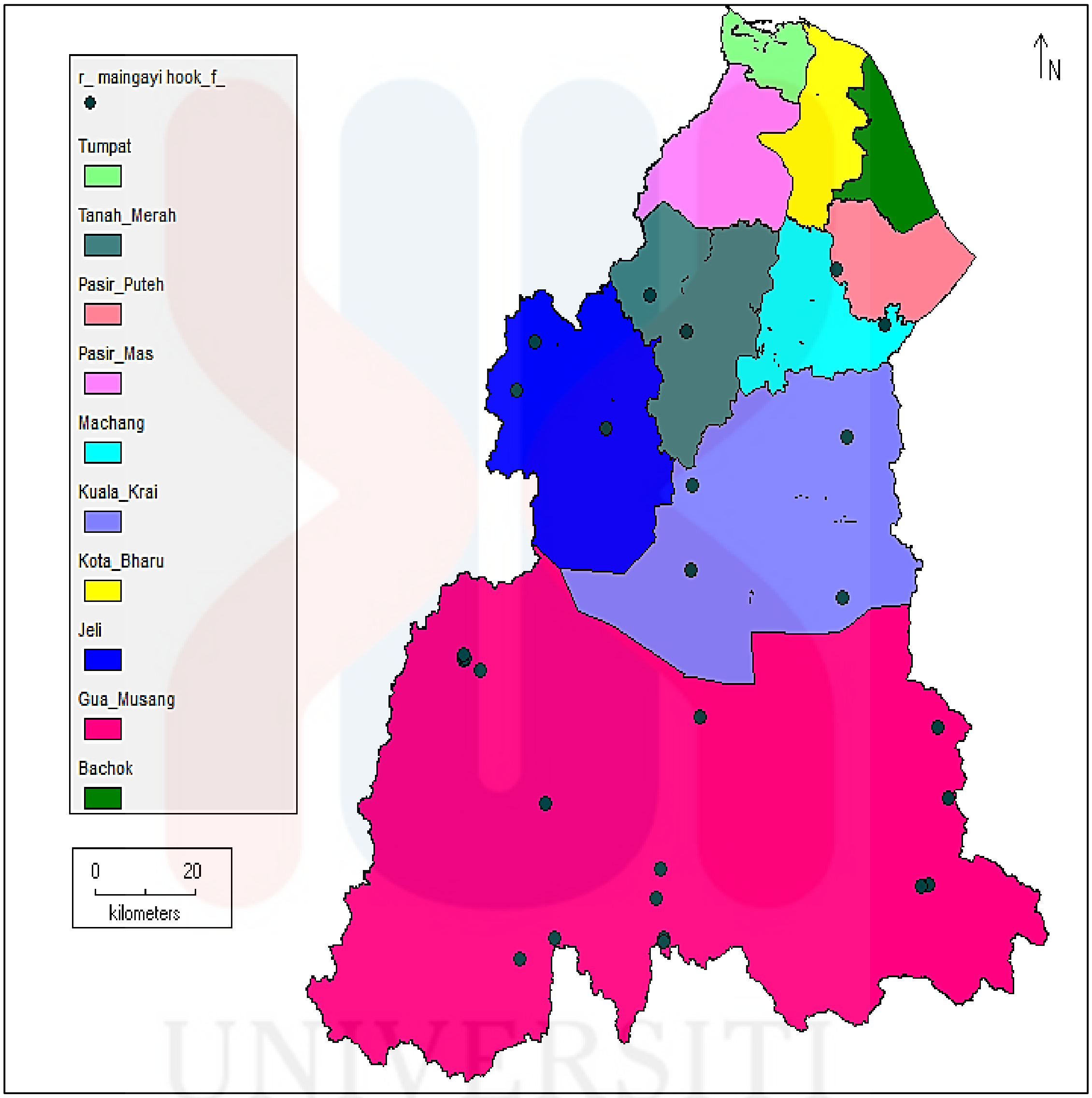

Figure 4.2**:** Localities data and habitat distribution of *Rhaphidopora maingayi* in Kelantan

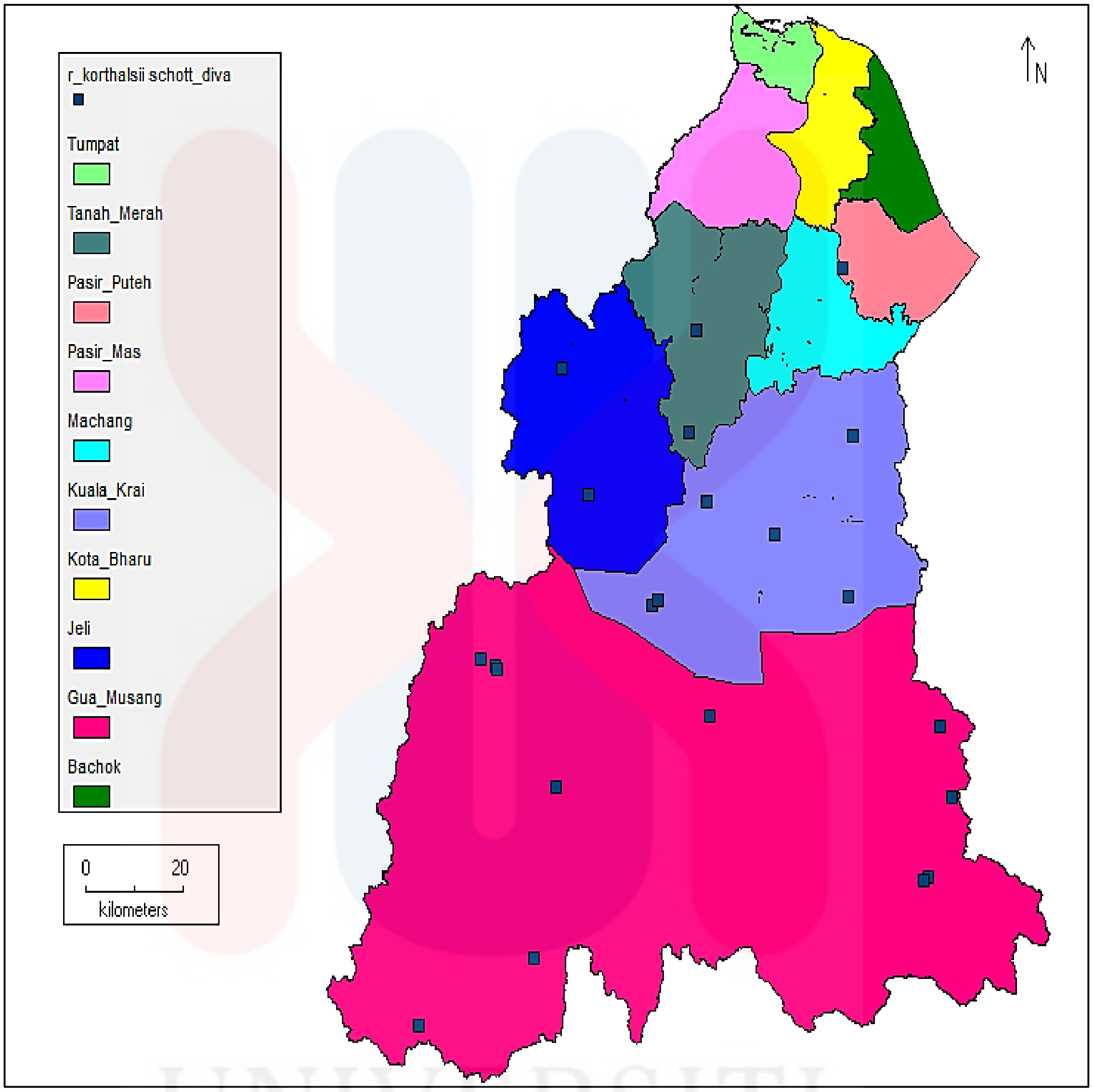

Figure 4.3: Localities data and habitat distribution of *Rhaphidopora korthalsii* in Kelantan

4.2 MAXENT output

The prediction of distribution of the selected species which is *Rhaphidopora falcata*, *Rhaphidopora maingayi* and *Rhaphidopora korthalsii* is constructed by MAXENT modelling software. In this study the average raw output data is produced by 100 replicated model per species is run and all the localities data are more than five.

In this study the prediction of genus Rhaphidopora was construct with two different set of data which is the first set were run with localities data and environmental variables that is consist of 19 bioclimatic data and HWSD. The second set were run by using localities data and environmental variables which is include of 19 bioclimatic data but without HWSD.

4.2.1 Model Validation

In this study, this model was set up with full run training data, 75% training dataset and 25% testing dataset. Then, to ensure that the potential distribution estimated accurately, the first model was evolve with using full set of localities data which it can be used for percentage for presence localities to be set aside as randomly as test point or Area under curve (AUC).

The 75% training dataset which is the second model, set up with random selection and the rest which is 25 % as testing data. The validation of the data can be done by working on training and testing data. Area under curve (AUC) value is used to validate the result from MAXENT software.

The probability and suitability for species distribution can be shown by the colour of the map generated from the MAXENT software. High probability for growth if the colour towards red and green colour indicates typical condition and probability of predicted species occurred low if the colour towards blue.

Table 4.1: Value of the training AUC for three selected Rhaphidopora species in Kelantan.

Species		Include HWSD	Without HWSD
	Full run training data	0.826	0.814
Rhaphidopora falcata	25%	0.831	0.813
	75%	0.841	0.829
	Full run training data	0.892	0.891
Rhaphidopora maingayi	25%	0.884	0.883
	75%	0.721	0.689
	Full run training data	0.866	0.871
Rhaphidopora korthalsii	25%	0.865	0.876
	75%	0.706	0.660

Table 4.1 shows the value of Area under Curve (AUC) for each selected species of Rhaphidopora and different value of data run in MAXENT which is 100% or full run training data, 75% testing data and 25%.testing data. All the species show the excellent and good value of AUC which is more than 0.75. This validation model is needed to remove the sample biasness when used the MAXENT software.

4.3 Distribution of *Rhaphidopora falcata*

Table 4.2 shows the percentage distribution of the species and the predictive distribution of *Rhaphidopora falcata* in Kelantan is influenced by the environmental variables.

The percentage of contribution for *Rhaphidopora falcata* with HWSD shows that Bioclim 5 (max temperature of warmest month) has the highest contribution and effect which is 27.5% respectively. Bioclim 8 contributes the highest amount of effect to Rhaphidopora falcata without HWSD data which is 29.1 % respectively.

The lowest contribution effect for *Rhaphidopora falcata* with HWSD data is Bioclim 6 (min temperature of coldest month) at 0.1 % while for *Rhaphidopora falcata* without HWSD also 0.1% which is Bioclim 6 (minimum temperature of the coldest month).

Figure 4.4 shows the predicted distribution of species is generated by using MAXENT software. For figure 4.4 (a) shows the prediction distribution of species by using 22 environmental layer including Harmonized World Soil Database (HWSD) and for Figure 4.4 (b) shows the predicted distribution of species by using 22 environmental layer and exclude HWSD.

Table 4.2: Environmental variables and their percentage for *Rhaphidopora falcata* contribution in MAXENT Modeling

Environmental Variables	Percentage Include HWSD	Distribution (%) Exclude HWSD
Bioclim 1	1.6	2.3
Bioclim 2	1.7	2.7
Bioclim 3	0.1	0.3
Bioclim 4	0.2	0.3
Bioclim 5	**27.5**	15.3
Bioclim 6	0.1	0.1
Bioclim 7	2.2	2.5
Bioclim 8	9.5	**29.1**
Bioclim 9	1.0	1.3
Bioclim 10	0.7	0.7
Bioclim 11	3.5	2.8
Bioclim 12	11.2	8.4
Bioclim 13	1.8	1.6
Bioclim 14	0.7	1.2
Bioclim 15	3.1	8.1
Bioclim 16	2.6	5.0
Bioclim 17	0.8	0.6
Bioclim 18	0.1	1.1
Bioclim 19	0.1	0
HWSD	11.5	-
SRTM	20	16.5

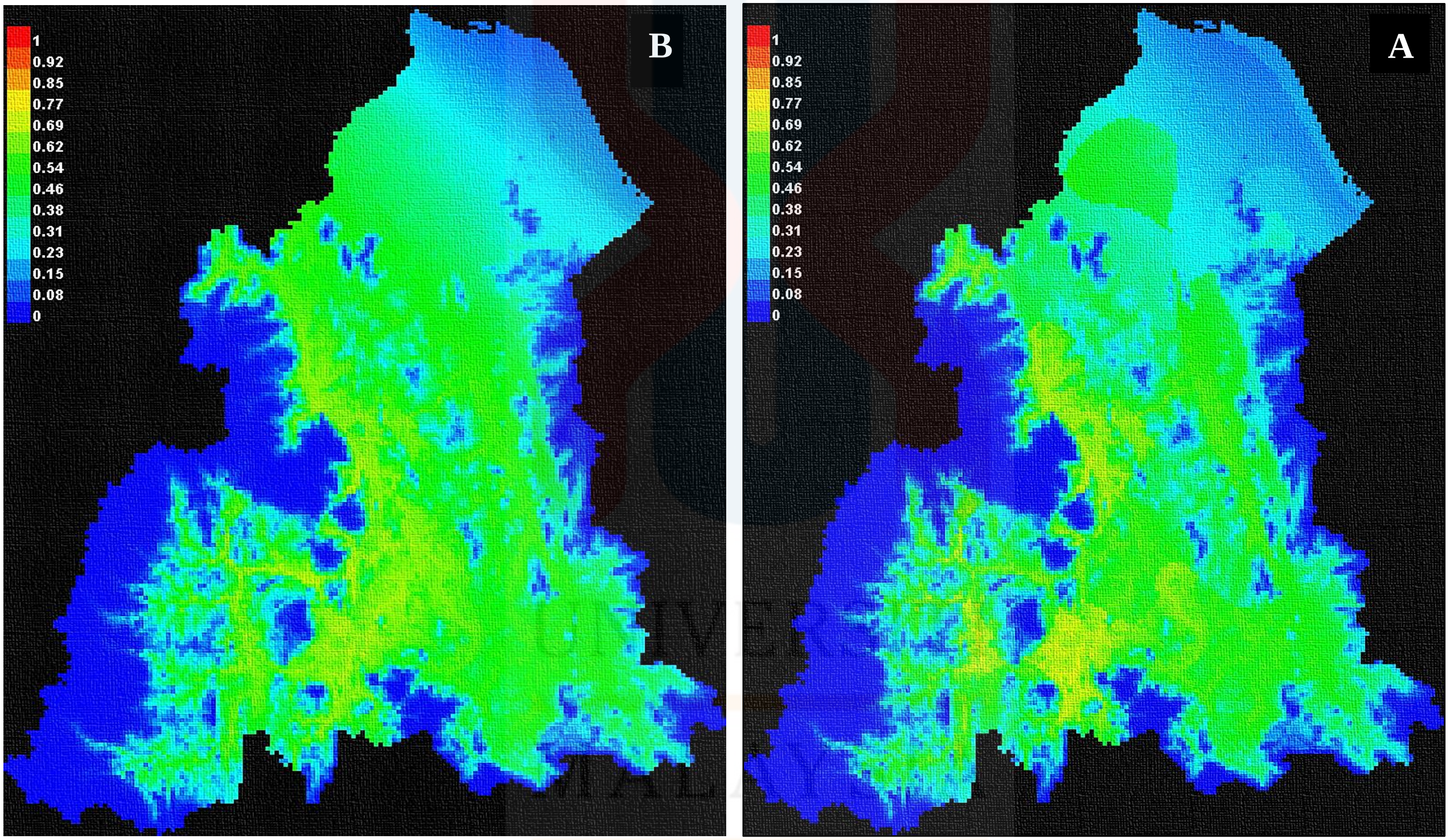

Figure 4.4 (A) and (B): Predicted distribution of *Rhaphidopora falcata* include (A) and exclude (B) HWSD data

4.4 Distribution of ***Rhaphidopora maingayi***

Table 4.3 shows the percentage distribution of the species and the predictive distribution of *Rhaphidopora maingayi* in Kelantan is influenced by the environmental variables.

For *Rhaphidopora maingayi* with HWSD data, it shows that the highest contribution of environmental variables is Bioclim 13 which is precipitation of wettest month at 21 % respectively same goes with *Rhaphidopora maingayi* without HWSD, where it contributes 19.7 % at precipitation of wettest month which is Bioclim 13.

Meanwhile for least contribution factor for *Rhaphidopora maingayi* with HWSD data is Bioclim 9 which is mean temperature of driest quarter at percentage of distribution is 0.3 % also same with *Rhaphidopora maingayi* without HWSD data at percentage of distribution is 0.3 %.

Figure 4.4 shows the predictive distribution that are generated by the MAXENT modelling software. Figure 4.6 (a) shows the predicted distribution by using 20 environmental layers including the Harmonized World Soil Database (HWSD) and Figure 4.6 (b) shows the predicted distribution by using same environmental layer but without HWSD data.

Table 4.3: Environmental variables and their percentage for *Rhaphidopora maingayi* contribution in MAXENT Modeling

Environmental Variable	Percentage Distribution %	
	Include HWSD	Exclude HWSD
Bio 1	3.8	6.3
Bio 2	4.2	2.5
Bio 3	0.9	1.0
Bio 4	2.4	2.2
Bio 5	3.0	4.0
Bio 6	1.1	1.7
Bio 7	1.3	1.6
Bio 8	3.2	1.6
Bio 9	0.3	0.3
Bio 10	7.8	11.0
Bio 11	1.1	1.0
Bio 12	17.3	19.5
Bio 13	**21.0**	**19.7**
Bio 14	1.7	1.6
Bio 15	5.8	7.3
Bio 16	4.2	3.6
Bio 17	4.6	3.2
Bio 18	0.9	1.3
Bio 19	3.1	2.5
HWSD	3.9	-
SRTMSRTM	8.3	8.1

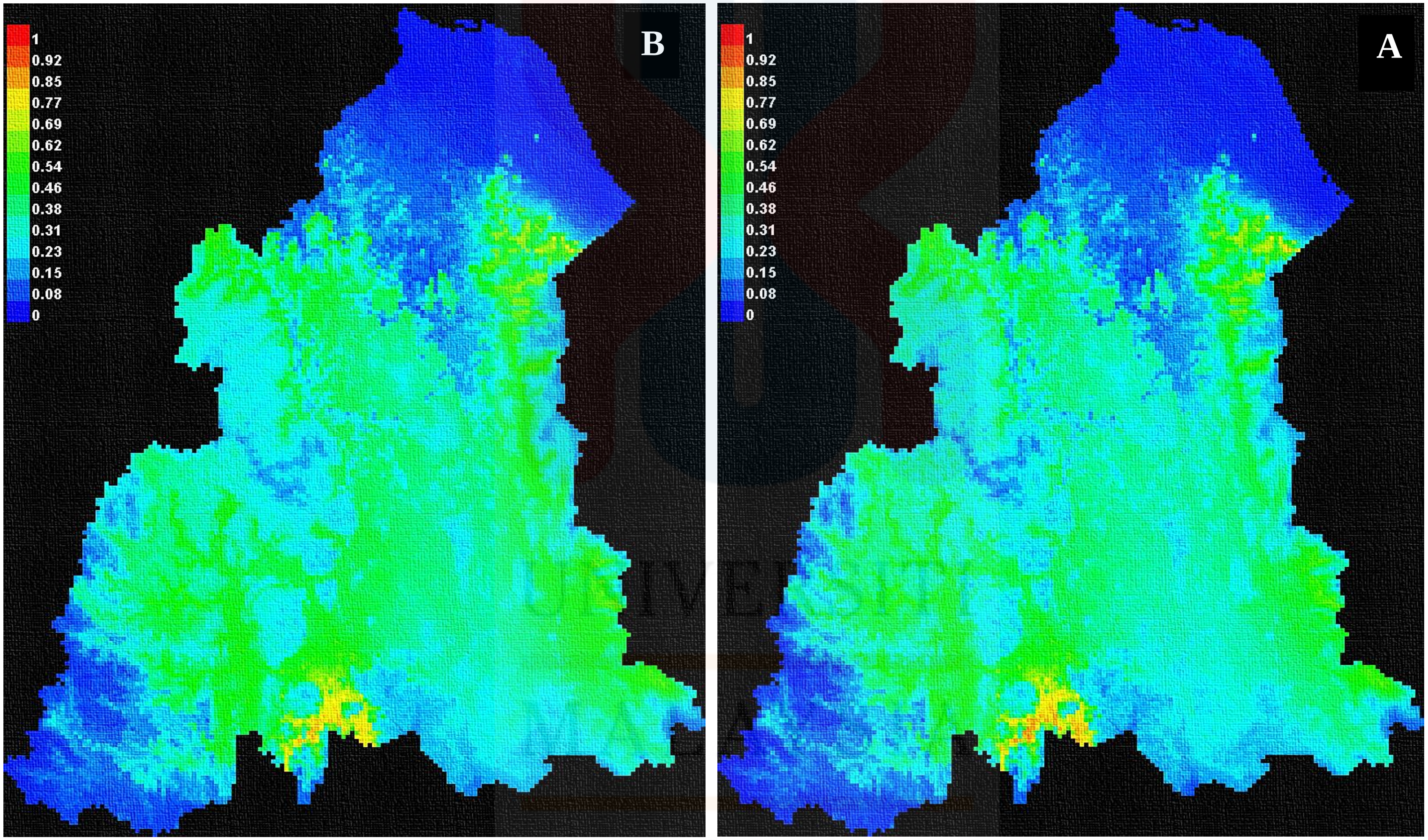

Figure 4.5 (A) and (B): Predicted distribution of *Rhaphidopora maingayi* include (A) and exclude (B) HWSD data.

4.5 Distribution of *Rhaphidopora korthalsii*

Percentage contribution of the environmental variable that devote to the percentage contribution of *Rhaphidopora korthalsii* in Kelantan is shown in Table 4.5. It is found that the *Rhaphidopora korthalsii* with HWSD data, the SRTM data gives the highest amount of effects on *Rhaphidopora korthalsii* predicted distribution which is 28 % respectively. For *Rhaphidopora korthalsii* without HWSD data, it is found that SRTM data also gives the highest percentage that effect the predicted distribution which is at 25.5 % respectively.

Meanwhile for the least amount percentage contribution of *Rhaphidopora korthalsii* with HWSD is 0.1 % which is Bioclim 18, precipitation of warmest quarter. The lowest amount of effect on *Rhaphidopora korthalsii* predicted distribution without HWSD data is Bioclim 9, mean temperature of driest quarter which is at 0.2 %.

Figure 4.5 shows the predictive distribution that are generated by the MAXENT modelling software. Figure 4.7 (a) shows the predicted distribution by using 20 environmental layers including the Harmonized World Soil Database (HWSD) and Figure 4.7 (b) shows the predicted distribution by using same environmental layer but without HWSD data.

Table 4.4: Environmental variables and their percentage for *Rhaphidopora korthalsii* contribution in MAXENT Modelling

Environmental Variables	Percentages Distribution %	
	Include HWSD	Exclude HWSD
Bio 1	9.5	9.8
Bio 2	6.2	11.7
Bio 3	3.5	2.0
Bio 4	1.1	1.2
Bio 5	7.0	7.1
Bio 6	0.1	0.4
Bio 7	1.1	0.9
Bio 8	1.6	1.3
Bio 9	0.5	0.2
Bio 10	3.2	2.6
Bio 11	0.3	0.3
Bio 12	5.9	8.9
Bio 13	6.4	5.2
Bio 14	4.1	5.7
Bio 15	7.7	6.7
Bio 16	4.4	4.8
Bio 17	2.2	2.5
Bio 18	0.1	0.3
Bio 19	3.6	2.9
HWSD	3.6	-
SRTM	**28.0**	**25.5**

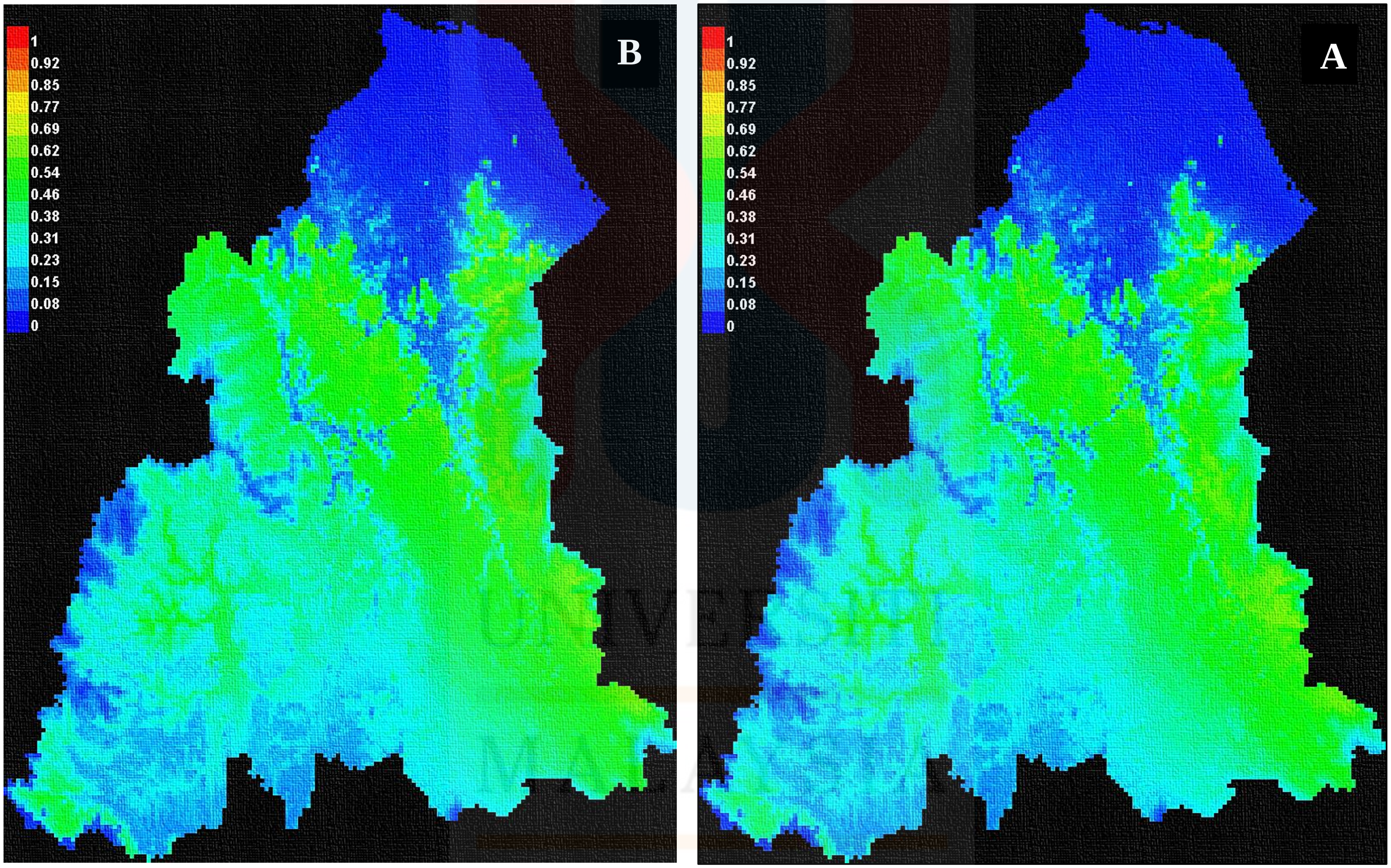

Figure 4.6 (A) and (B): Predicted distribution of *Rhaphidopora maingayi* include (A) and exclude (B) HWSD

4.6 Comparison on Area and Percentage of Distribution of ENM, AOO and EOO

Figures 4.7, 4.8 and 4.9 shows the comparison of distribution area of selected species of Rhaphidopora in Kelantan by using Ecological Niche Modelling (ENM), Area of Occurrence (AOO) based on cell size of 2 x 2 km ($4km^2$) endorsed by IUCN and Extent of Occurrence (EOO) convex polygon. The prediction process of EOO and AOO were generated from ArcView 3.3 while ENM generated by using MAXENT software. Table 4.9 shows the comparison for AOO, EOO and ENM on percentage and area of distribution of *Rhaphidopora falcata*, *Rhaphidopora maingayi and Rhaphidopora korthalsii*.

Table 4.5: Comparison on percentage and area of distribution for AOO, EOO and ENM

	AOO		EOO		ENM	
	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)	Area (km^2)	Percentage (%)
Rhaphidopora falcata	48	0.32	6562.59	43.96	2896	19.28
Rhaphidopora maingayi	76	0.51	9327.17	62.09	571	3.80
Rhaphidopora korthalsii	68	0.45	9456.93	62.95	1813	12.07

4.6.1 *Rhaphidopora falcata*

The prediction of species by EOO form a convex polygon from the localities data. Then overestimation and bias is occurred because it include irrelevant habitat which include river, road urban areas and others. With number of collections used which are 14 that are consisting of 14 localities, the distribution area for *Rhaphidopora falcata* are in Gua Musang and there is several distribution in Jeli, Machang, Tanah Merah and Kuala Krai.

The estimated value for *Rhaphidopora falcata* EOO area of this species is about 6562.59km^2 with 43.96% of distribution in that area. The area of distribution for AOO is 48km^2 with 0.32% percentage of distribution. For ENM which shows intermediate prediction, the area of species is about 2986 km^2 with 19.28% distribution of the species in that area.

4.6.2 *Rhaphidopora maingayi*

Figure 4.8 shows the comparison of distribution area of *Rhaphidopora maingayi* in Kelantan by using Ecological Niche Modelling (ENM), Area of Occurrence (AOO) and Extent of Occurrence (EOO). The distribution area for *Rhaphidopora maingayi* are at Gua Musang, Kuala Krai, Machang, Tanah Merah, Jeli and Pasir Putih. The number of collections that used in *Rhaphidopora maingayi* is 27 which it consisting of 27 localities for the prediction of the distribution.

The estimated EOO area is 9327.17 km^2 with 62.09% of distribution .The result for area of *Rhaphidopora maingayi* for AOO is about 76km^2 and 0.51% distribution in that area For ENM, the distribution area is 571km^2 with 3.80 % of distribution.

4.6.3 ***Rhaphidopora korthalsii***

Figure 4.9 shows the comparison of distribution area of *Rhaphidopora korthalsii* in Kelantan by using Ecological Niche Modelling (ENM), Area of Occurrence (AOO) and Extent of Occurrence (EOO). The distribution area for *Rhaphidopora korthalsii* are at in Gua Musang, Jeli, Tanah Merah, Kuala Krai and Pasir Puteh.

With number of collections that are used in the predictive distribution of *Rhaphidopora korthalsii* which is 22 localities, the estimated value EOO area of this species is about 9456.93 km^2 and the percentage of distribution is 62.95%.The estimated area for AOO is 68 km^2 with 0.45 % of percentage of distribution. For ENM, the estimated area is1813km^2 with 12.07 % of percentage of distribution.

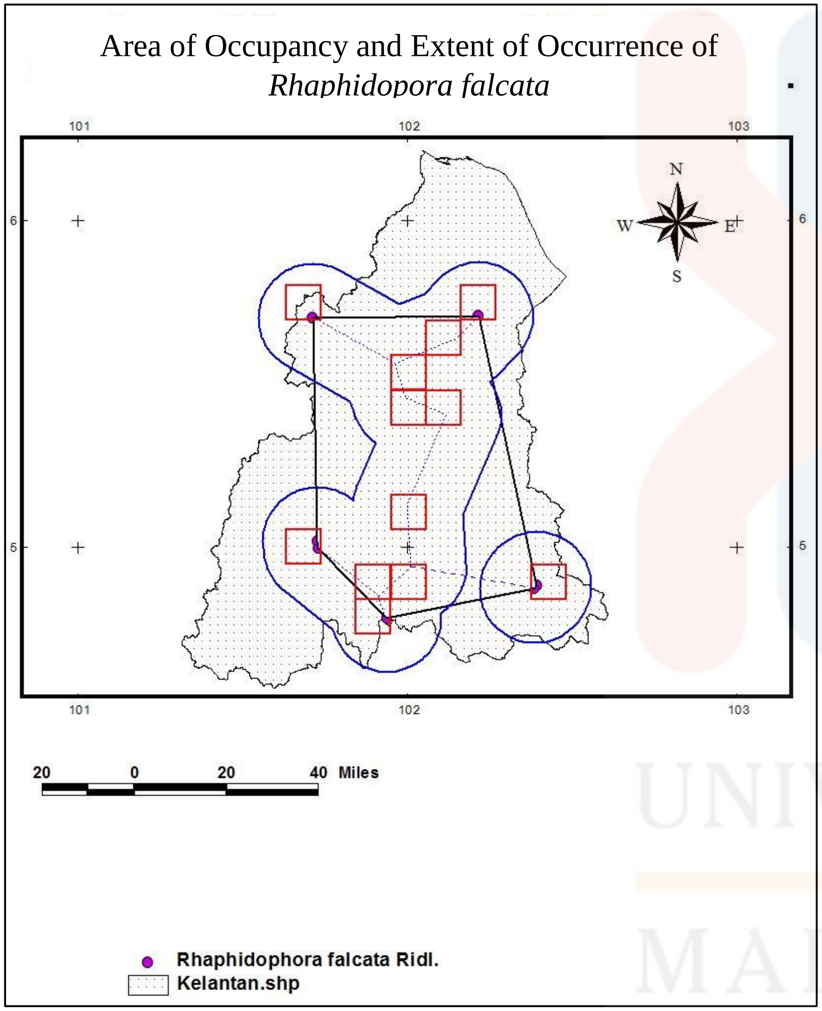

Figure 4.7 (a)

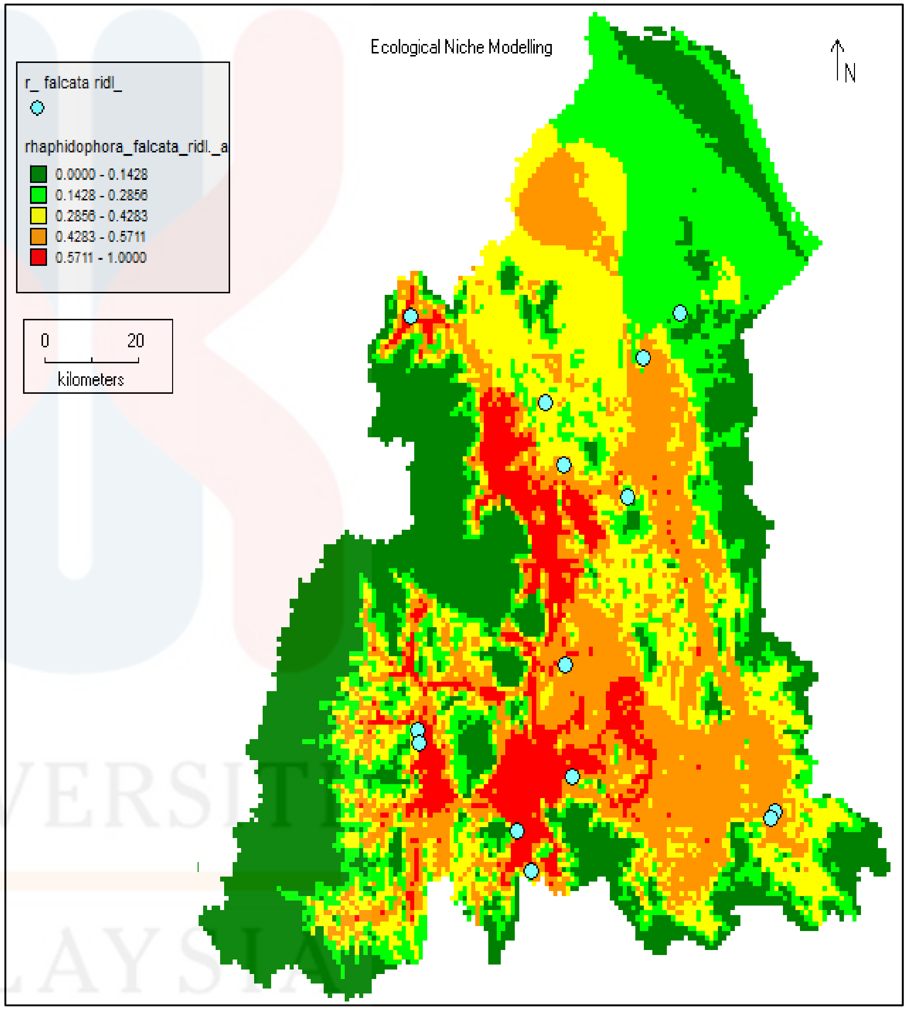

Figure 4.7 (b)

The comparison of distribution area of *Rhaphidopora falcata* in Kelantan using Extent of Occurrence (EOO) and Area of Occupancy (AOO) (a) and Ecological Niche Modelling (b)

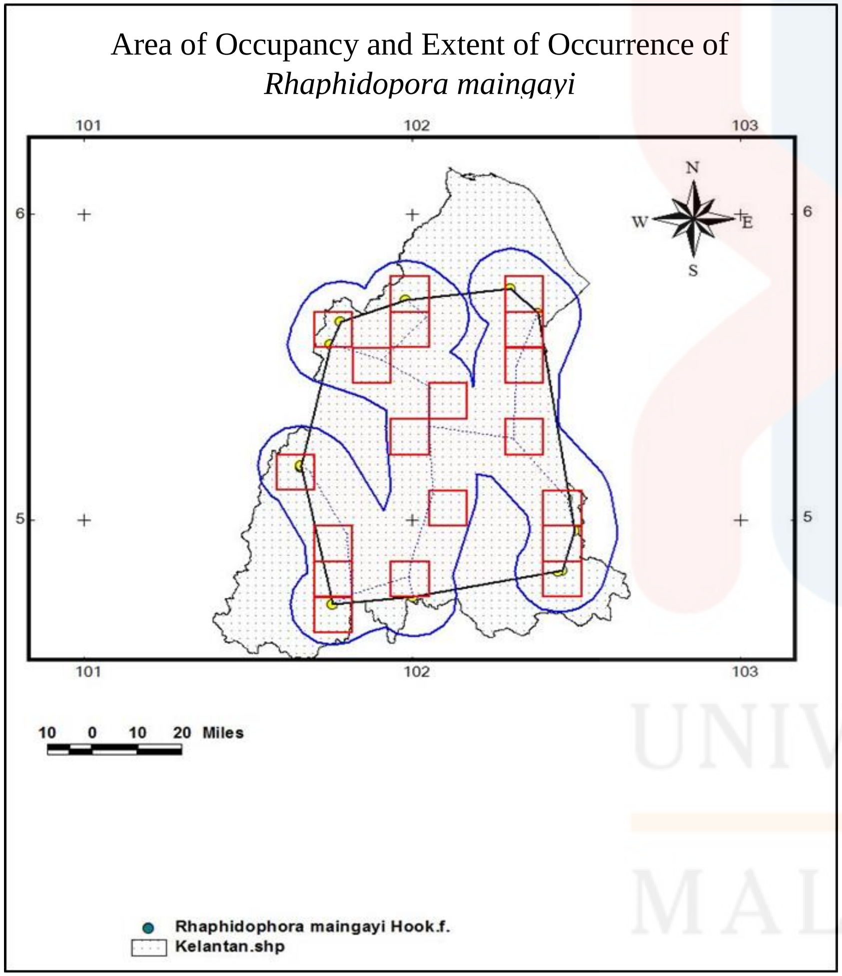

Figure 4.8 (a)

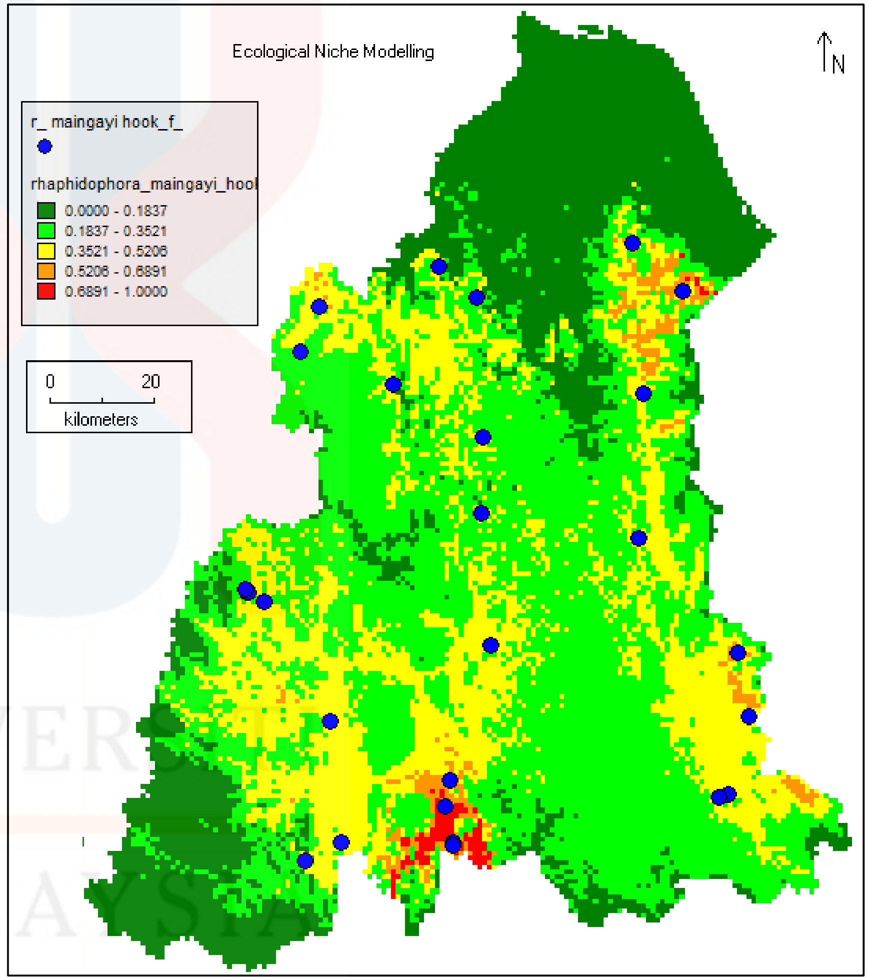

Figure 4.8 (b)

The comparison of distribution area of *Rhaphidopora maingayi* in Kelantan using Extent of Occurrence (EOO) and Area of Occurrence (AOO) (a) and Ecological Niche Modelling (b)

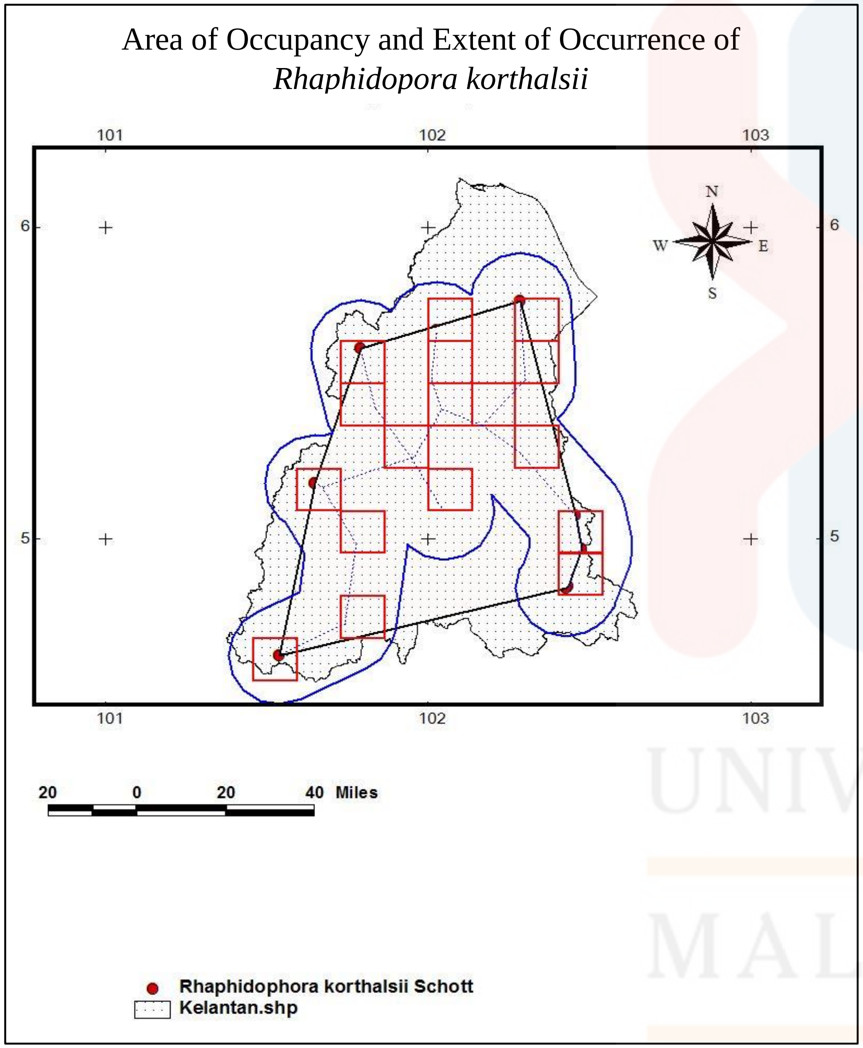

Figure 4.9 (a)

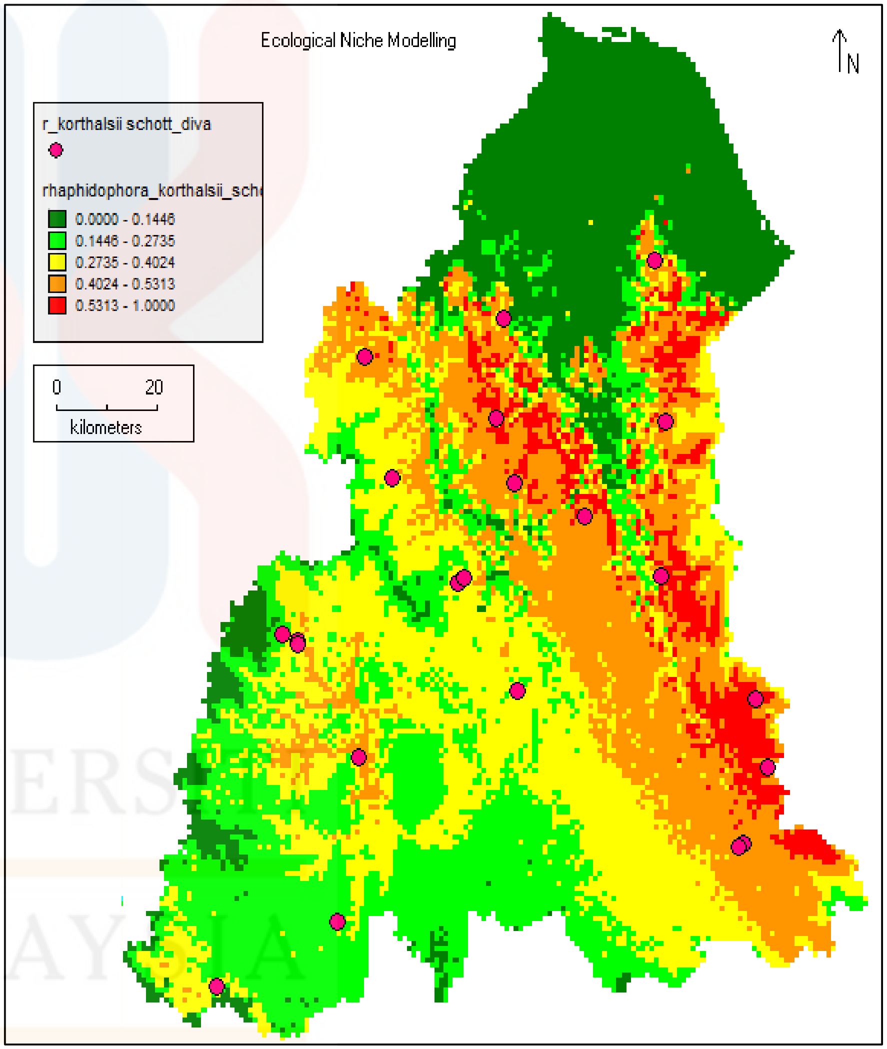

Figure 4.9 (b)

The comparison of distribution area of *Rhaphidopora korthalsii* in Kelantan using Extent of Occurrence (EOO) and Area of Occurrence (AOO) and Ecological Niche Modelling.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

According to the output of map that are generated from the MAXENT software, it seems that the distribution of three selected species from genus Rhaphidopora which of *Rhaphidopora falcata*, *Rhaphidopora maingayi* and *Rhaphidopora korthalsii* are scattered all over Kelantan.

The factors that affect the Rhaphidopora species in Kelantan growth is determined by the MAXENT software. For *Rhaphidopora falcata* it is shown that mean tempereature of wettest quarter influence the growth of that species. The precipitation of wettest month affected the growth of *Rhaphidopora maingayi* species and for *Rhaphidopora korthalsii*, the growth effect and distribution of this species is maximum temperature of warmest month.

Besides that, it show that HWSD data also contributes to the effect for the growth of the selected species compared to 19 bioclimatic data and altitude. In addition, model validation is done and shown that all value for selected species more than 0.75. Thus, it is proved that by using MAXENT modelling for all species is accepted.

The Area of Occurrence (AOO) and Area of Occupancy (EOO) were determined by using ArcView GIS version 3.3. In this study, the comparison between ENM with AOO and EOO can be clarify which is ENM modelling used localities and environmental data to computed map meanwhile for AOO and EOO methods used localities data from herbarium and additional data from the previous research.

Moreover it shows that ENM provide a useful technique as it able to predict the potential distribution of Rhaphidopora in Kelantan by characterizing the suitable environment condition for the genus and identify where the suitable environment are distribution in space and estimate important factors of limiting species distribution while MAXENT algorithm approach in estimating the species distribution using secondary data. In a nutshell, it shows that ENM predict the distribution better by using environmental data compared to EOO and AOO.

5.2 Recommendation

Ecological niche modelling is a suitable tool to calculate the percentage of habitat loss and accurate result will be produce and determination of conservation status can be done without biasness. In addition, interpretation and analysis of data in remote sensing should be added because this activity is very important and helpful in using MAXENT software.

Then, by using ecological niche modelling, the assessment of habitat loss can be done with addition of land use change data and type of soil data and surrounding area in accessing the habitat loss of the species. This modelling also must be verified by ground truth activity based on the map of predicted distribution and ensured that data used for modelling is the latest one.

For further study, MAXENT modelling should be applied for guidance and support conservative plan because by using this method it is cost effective and this software can be downloaded freely from the web. Furthermore, the assessments of habitat loss can be done by using the same method by identifying effect of habitat loss to distribution of araceae family at global scale.

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