

**DIVERSITY OF *NEPENTHES VEITCHII* AT NEPENTHES CAMP,
MALIAU BASIN CONSERVATION AREA, SABAH**

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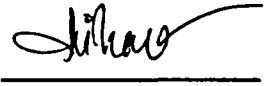
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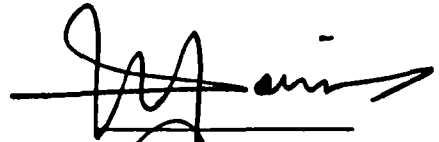
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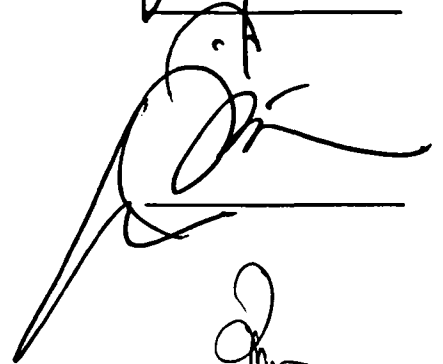
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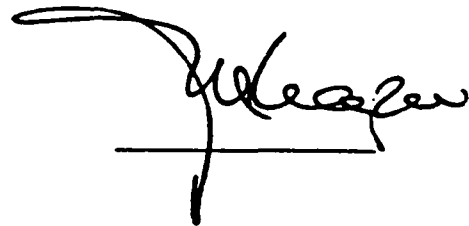
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ABSTRACT

A study on *Nepenthes veitchii* in relation to other species was undertaken at Jalan Babi, Nepenthes Camp, MBCA. The objectives of this study were to identify the abundance of *N. veitchii* in relation to other species found at Nepenthes Camp area, to visualize the distribution of *N. veitchii* in relation to other species by using Geographic Information System (GIS) of *N. veitchii*, and to produce density analysis of *N. veitchii* in relation to other species at Nepenthes Camp area in MBCA by using GIS. Four plots were set along Jalan Babi during the sampling section for field data collection. Global Position System (GPS) device was used to record the location of *N. veitchii* and other *Nepenthes* species found in the plots. The frequency and density of *N. veitchii* in relation to other species were calculated to determine the species abundance. A total number of 138 individuals of *N. veitchii* were found from a total of 937 individuals of *Nepenthes* in all the plots covering a percentage of 14.7%. Satellite image and topography map were produced to visualize their distribution at Nepenthes Camp area, MBCA and lastly, density analysis was conducted through spatial analysis function in GIS. There was no *N. veitchii* found at Plot D1. Plot D2 has 20% frequency and 0.003 density of *N. veitchii*. Plot D3 has the highest frequency and density of 70% and 0.109 respectively. Plot D4 has 30% frequency and 0.023 density of *N. veitchii*. They were distributed at Jalan Babi, Nepenthes Camp, MBCA due to the heath forest vegetation type. *N. veitchii* grow denser in Plot D3 and Plot D4 with greater sunlight exposure rather than shade area at Plot D1 and Plot D2 on nutrient poor sandy ground of heath forest.

ABSTRAK

Ketumpatan *Nepenthes veitchii* di Nepenthes Camp, Maliau Basin Conservation Area, Sabah.

Satu kajian ke atas *Nepenthes veitchii* berhubungan dengan species yang lain sebagai perbandingan telah dijalankan di Jalan Babi, Nepenthes Camp, MBCA. Objektif bagi kajian ini termasuklah identifikasi kelimpahan *N. veitchii* berhubungan dengan species lain yang terdapat di kawasan Nepenthes Camp, penggambaran taburan *N. veitchii* berhubungan dengan species lain melalui aplikasi Geographic Information System (GIS) dan juga menghasilkan analisis kepadatan bagi *N. veitchii* berhubungan dengan species lain di kawasan Nepenthes Camp, MBCA. Empat plot telah dibina menyusuli Jalan Babi untuk pengumpulan data lapangan. Alat Global Position System (GPS) telah digunakan bagi mendapatkan kedudukan geografi bagi *N. veitchii* serta species yang lain, Frekuensi dan ketumpatan bagi *N. veitchii* serta species lain dikira bagi menentukan kelimpahannya. Sebanyak 138 *N. veitchii* yang bersamaan dengan 14.7% telah dijumpai daripada keseluruhan 937 *Nepenthes* yang terdapat dalam keempat-empat plot. Peta satellite serta peta topografi telah dihasilkan bagi penggambaran taburan *N. veitchii* berhubungan dengan species lain di Nepenthes Camp, MBCA dan akhirnya analisis kepadatan dilakukan melalui fungsi *Spatial Analysis* dalam pakej GIS. Plot D1 tidak mempunyai penumbuhan *N. veitchii*. Plot D2 mengandungi nilai frekuensi 20% dan nilai kepadatan sebanyak 0.003 bagi *N. veitchii*. Plot D3 mengandungi nilai frekuensi yang tertinggi iaitu 70% dan nilai kepadatan tertinggi iaitu sebanyak 0.109 manakala Plot D4 mempunyai nilai frekuensi 30% dan nilai kepadatan 0.023 bagi *N. veitchii*. Didapati *N. veitchii* tumbuh lebih padat di kawasan yang tinggi dengan pendedahan cahaya matahari yang lebih di Plot D3 dan Plot D4 berbanding dengan kawasan teduh di Plot D1 dan Plot D2 pada tanah yang kandungan nutrisinya amat rendah di hutan *kerangas*.

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LIST OF SYMBOLS

%	percent
N	North
E	East
°	degree Celsius
'	minute
''	second
km ²	kilometer square
m	metre
mm	milimetre
cm	centimeter
kg	kilogramme

LIST OF ABBREVIATIONS

IT	Information Technology
ICT	Information Communication Technology
GIS	Geographic Information System
GPS	Global Positioning System
MBCA	Maliau Basin Conservation Area
IUCN	International Union for Conservation for Nature
WCMC	World Conservation Monitoring Centre
CITES	Convention on International Trade in Endangered Species
sp.	species (singular)
spp.	species (plural)

CHAPTER 1

INTRODUCTION

1.1 Background

A precise geographical location is a key to tell people what and where do a feature take place. Spatial information is about the physical location of features and the relationship between features. Due to the dynamic nature of biodiversity, traditional research tools in monitoring and management program has slowly been taken over by the advance development and fast transmission of new technology application like Geographic Information System (GIS) and Global Positioning System (GPS). Spatial information provided by incorporation of GIS and GPS can be used in identifying trends on data, create new relationships from the data and show complex relationships between data producing more integrated and collaborative system approach in academic researches and developments (Nordin *et al.*, 2009).

Maliau Basin Conservation Area (MBCA) also known as Borneo's mysterious Lost World, is one of the untouched wilderness forests remaining in Borneo. It was located at the south-centre of Sabah with the coordinate of latitude $4^{\circ}49'49''\text{N}$ and longitude $116^{\circ}54'01''\text{E}$. MBCA has been declared as Class 1 Protection Forest Reserve in 1997 by the Sabah state government. The present size of MBCA is 588.4 km^2 incorporating



forested land to the east and north of the Basin. This place has become so unique with its natural spectacular scenery like the Maliau Falls, combined with undisturbed flora and fauna like Banteng (*Bos javanicus*), Bornean pygmy elephants (*Elephas maximus*), helmet orchid (*Corybas piliferus*), pitcher plants (*Nepenthes* spp.) and lots more (Hans *et al.*, 2004).

Steiner (2002) wrote that *Nepenthes veitchii* is endemic species to Borneo and only few species exist in Kalimantan. In Sabah, they have not been found on Kinabalu, Trus-Madi or on the Crocker Range. It seems to be mainly a Sarawak species but isolated outlying population found extending into central of Sabah (Phillips & Lamb, 1996). This species from Borneo was recorded as the only known epiphytic species that grow encircling the tree trunk (Clarke, 2001). At Maliau Basin, they were found growing surrounding the huge *Agathis* trees. Some may found grow on the ground too (Hans *et al.*, 2004).

Botanists, ecologists, and geographers have been interested in studying plant species distribution patterns to insight the processes that facilitate diversification and speciation in closely related plant populations (Cain, 1994; Woodward, 1987). By knowing the appropriate environmental conditions to sustain a species, it allows identifying regions which still not colonized or where the species has become extinct. Beside, judgment upon geographical factors in shaping current distribution of a species can also be made. All these will contribute to the regional conservation planning for instances reintroduction programme (Rosa *et al.*, 2005). Hence, it is now technically possible to produced distribution map by applying GIS to conduct related spatial analyses such as density analysis for *Nepenthes veitchii* to show its current biodiversity status in MBCA.

1.2 Problem statement

Study upon species-based like *Nepenthes veitchii* which is a rare species in Sabah have not much conducted in detail. Thus, the existing species-based information was limited, both in boundary definition and production areas. Moreover, previous studies working on the distribution and density of species were found presented in the wording form. In fact, text may sometimes not an effective means for communicating important subjects particularly when an immediate response is required (Miller, 1994). Limited and difficulty of manual interpretation in performing visual interpretation with complex images can be problematic due to the poor accessibility and the heterogeneous structure of forest for species-distribution study.

1.3 Justification

My study was intended to apply digital mapping approach that have the capability to shows better indication of *Nepenthes veitchii* spatial distribution at Nepenthes Camp, Maliau Basin Conservation Area, Sabah. The data, however can also be used for references in the research or a management purpose since integrated approaches of acquiring information are needed for a modern-day conservation effort.

1.4 Objectives

The aim of this study is to provide some spatial information of *Nepenthes veitchii* at Nepenthes Camp area in MBCA. The specific objectives of the study are as follows:

- a) To identify the abundance of *N. veitchii* in relation to other species found at Nepenthes Camp area in MBCA.
- b) To visualize the distribution of *N. veitchii* in relation to other species at Nepenthes Camp area in MBCA by using Geographic Information System (GIS).
- c) To examine the density analysis of *N. veitchii* in relation to other species at Nepenthes Camp area in MBCA by using GIS.

1.5 Study scope

This study is limited only to the species of *Nepenthes veitchii* growing along the Trail Jalan Babi at Nepenthes Camp area in MBCA, Sabah. However, other *Nepenthes* sp. that growing within the marked site was counted in for aiding in comparison purpose.

CHAPTER 2

LITERATURE REVIEW

2.1 Study of pitcher plant

Pitcher plant is defined as carnivorous plant for their characteristics of attracting, trapping and killing the animal prey following by secreting digestive enzymes and absorption of digested nutrient. Unlike other non-carnivorous plants, they are special because they grow not only depending on the photosynthesis products and nutrition from soil, but they also catch preys mainly insects to digest their proteins for nutrient source.

According to Baffray *et al.* (1989), there are four genera besides the Nepentheceae family grouped as pitcher plants which are *Cephalotus*, *Darlingtonia*, *Heliophora* and *Sarracenia*. This grouping is mainly due to their common feature on the modified leaves or leaf extension that produced jug-shaped vessel called pitcher. The structure, shape, and colour of the pitcher vary from genus to genus. Unlike some other carnivorous plants, pitcher plants do not have any mobile parts (Steiner, 2002). These immobile pitchers thus function as a static pitfall trap for the animal to fall due to their slippery walls into pools of fluid for exodigestion of the prey (Wang *et al.*, 2009).



Capture of preys occurs when small animals mainly insects feeding on the nectar near the opening of the pitcher, slips and falls into the liquid bath in the trap (Juniper *et al.*, 1989). The mixture of rain water and enzymes within the pitcher cup create viscosity, combined with the sharp peristomes making the prey hardly to escape. The struggling prey is reportedly tranquilized by an unidentified agent in the fluid. Acid, alcohol and digestive enzymes produced by pitcher secreted into the liquid, breaking down the captured prey aided by bacterial decomposition and then nutrient will be absorbed by the plant (Wang *et al.*, 2009).

According to Clarke (1997), *Nepenthes* is the largest carnivorous plant in the world. Besides, they are also the most variable family of carnivorous plant (Steiner, 2002). They have the largest trap of any other carnivorous plants. Although the smallest trap on mature plants may be less than 2ml in volume but the largest may exceed 2000ml. *Nepenthes* is the only genus derived from the family of Nepentheceae and it is the only genus that is dioecious among all the carnivorous plant (Phillips & Lamb, 1996).

Clarke (1997) reported that *Nepenthes* species are being interested and famous because of their carnivorous behavior like real animal. They always presumed to be killers of small animals but it is very likely that pitcher plants actually benefit the prey species by supplying them food. After all, many of the animals that visit pitchers are not caught. The sugars produced by pitcher plants are valuable source for nectar-drinking insects where this nutrition is not available in soil. It also digested by the plant itself (Clarke, 2001). This interaction between animals and plants reveal the current ecological state of affairs and shows that further revisions are sure to follow as more research is done. As the extent appreciation of the undisturbed rain forests of Borneo such as MBCA, the need for research becomes more urgent nowadays (Clarke, 1997).

2.2 Distribution and diversity of *Nepenthes*

Nepenthes is widespread within the Malaysia biogeographical region and it is the center of *Nepenthes* diversity and endemism (Clarke, 2001). Borneo appeared to be a conspicuous part in the world by means of distribution of *Nepenthes* species and because of its isolated region, there may be still many unknown species yet to be discovered (Kurata, 1976). According to Jebb & Cheek (1997), there are about 87 *Nepenthes* species in the world. From a number of 33 species occurred in Borneo, 31 species with two recent undescribed species found at Sabah and 24 of which are endemic (Clarke, 1997). Recent findings in 2009 have recorded that the total number of *Nepenthes* species in Borneo has reached up to 39 species (McPherson, 2009). For example: *Nepenthes rajah* – the king of *Nepenthes* with the largest pitcher-plant in the world was found to grow at Mount Kinabalu, Sabah. *Nepenthes veitchii* – the spectacular and rare epiphytic species found at MBCA, Sabah.

2.3 Morphological description of *Nepenthes veitchii*

Nepenthes veitchii has once been described as the finest and rarest of all pitcher-plants. The most distinctive feature that distinguishes them from other species will be the very much expanded and flaring golden striped peristome with clearly visible teeth and ribs as shown in Figure 2.1 (Phillips & Lamb, 1996). The expanded part of the peristome folds back or points almost vertically upwards. There is a distinct cleft, separating the peristome dorsally rising to the leaf-like lid and continuing to a crest at the underlid in most plants. The lid opens when the plant matures for the purpose of setting a trap and it will not close again (Clarke, 2001).

The mouth of the pitcher is very obvious by its sharp colour and its vertical position. This feature has making it a perfect trap to entice insects into its interior. The showy pitcher, up to 32cm in length is ovoid shaped while the lid is about oblong in shape. All parts of the plant including the pitcher having persistent scurfy brown hairs except for the upper surface of the leaves.

Their colour may be vary from entirely green, through pink and red. The stems can grow up to 10m or more in length. They have broad petiolate leaves up to 25cm long with characteristic of undulating leaf margins, the base claspng the stem (Clarke, 1997).

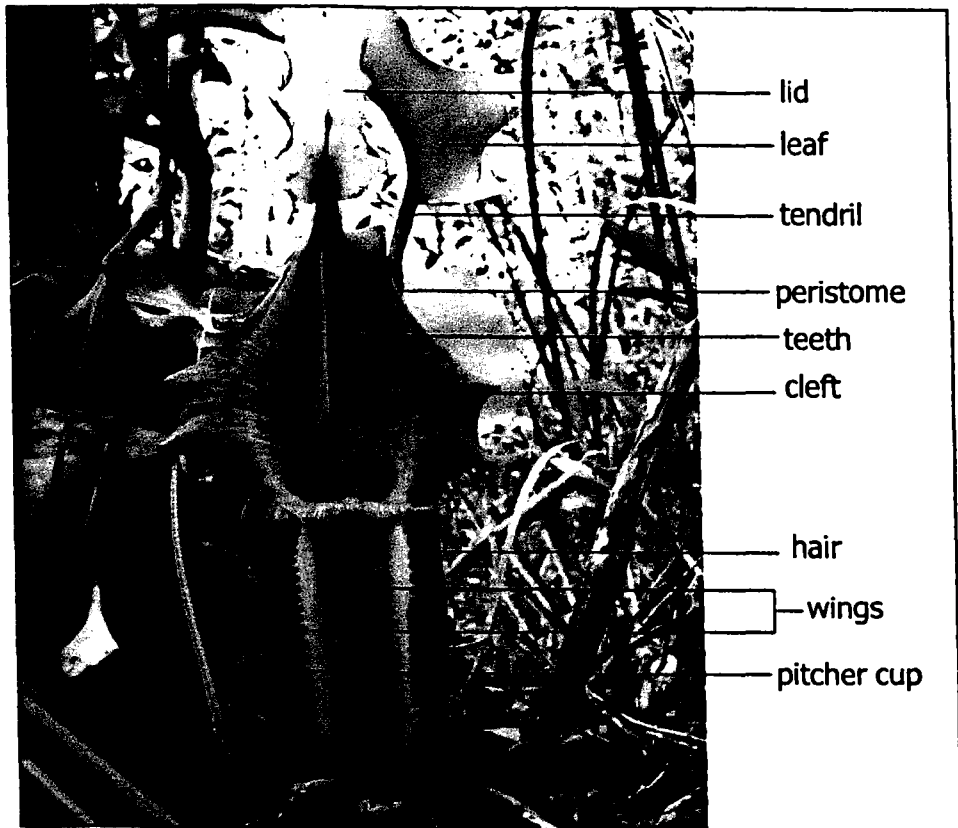


Figure 2.1 Basic morphology of *Nepenthes veitchii*

(Modified from Clarke, 1997)

2.4 Natural habitat of *N. veitchii*

Nepenthes are generally divided into lowland and highland species based much on the altitudes at which they grow (Phillips & Lamb, 1997). Highland *Nepenthes* species occurring at elevation from 1000m or higher with cooler temperatures range from 10-21°C while lowland species confined to the altitudes below 1000m from sea level with temperature range from 21-29°C (James & Pietropaolo, 1986). According to Kurata (1976), 68% of the *Nepenthes* plants are made up of highland species while the remaining 32% are lowland species. Lowland species tend to be more commonly found while highland species are frequently restricted to confined areas.

Nepenthes veitchii from lowland areas below 500m in elevation are usually only found growing in trees which are adjacent to rivers. These varieties tend to have long narrow leaves and generally less colorful pitchers. *N. veitchii* which occur in above 1000m are usually recognized for their spectacular golden or red-striped peristomes. *Nepenthes* habitats may diversified from mossy forest, heath forest, montane forests, and even lowland mixed dipterocarp forest. *N. veitchii* prefer to grow in stunted mossy forest or high-level heath forest (Clarke, 1997).

2.4.1 Montane heath forest

Heath forest or *kerangas* forest (local name) refers to land that cannot used to grow hill rice (Steiner, 2002). Formation of this forest is found on podzolized siliceous sands, drained by characteristic black water streams and is usually found on dip slopes in hilly country in Sarawak, Sabah and Brunei (Whitmore, 1984). At Maliau Basin, montane heath forest is common at lower montane forest elevations, between 900-1600m and it occupies about 21% of the Basin (Saw & Marsh, 1989). It is beautifully developed along

the Agathis Camp-Camel Trophy Camp trail and along the Camel Trophy Camp-Rafflesia Camp trail (Jalan Babi).

The parent material of heath forest soil is sandstone and the rock is a member of Plateu Sandstone Formation which is low in bases and coarse-textured (Shiego *et al.*, 1991). Tropical heath forest developed on leached, highly acidic, white sandy soils that are intrinsically poor in nutrients. Jordan (1985) points out that the nutrient contents are in critical condition in tropical rainforest with an overlying humus layer entirely absent and there is no humus-enriched horizon in mineral soil. Therefore, the nutrient content of the soils in tropical rainforest is usually extremely low. In heath forests on sandstone the nutrient content is even lower than in tropical rainforest (Whitmore, 1991). This habitat of very poor in nutrients supports growth of common *Nepenthes* species (Juniper *et al.*, 1989; Clarke, 1997; Steiner, 2002). Until now, there were eight species and one hybrid discovered as component of Maliau's heath forest included *N. gracilis*, *N. hirsuta*, *N. stenophylla*, *N. lowii*, *N. reinwardtiana*, *N. tentaculata*, *N. mirabilis*, *N. veitchii* and *N. stenophylla* × *N. veitchii* (Hans *et al.*, 2004).

2.4.2 Montane forest

Montane forests are covered with cloud at much of the time so the climate is cooler than lower altitudes. The soils are humus-rich and generally form a layer over rocky base. Mosses accumulation is not as rich as in heath forests (Webb & Sidkan, 2002). They tend to be peaty and acidic and able to hold high volume of water. If there is no cloud, the temperature rises and humidity drops. They may soak with rain for days but can be also subjected to sudden dry periods. Though mountain submits and ridges are harsher tropical environment, they are home for many highland *Nepenthes* species such as *N. tentaculata* and *N. lowii* (Clarke, 1997).

2.4.3 Peat swamp forest

In Borneo, these forests are extensive occurring on deposits of peat. According to Anderson (1964), the waterlogged condition, the high level of acidity and organic materials, the low input of nutrient and the lack of soil or firm ground within the forest have resulted in different forest structures but their communities are still less diverse than heath forests. There is one particular species of dipterocarp, *Shorea albida* which does not grow anywhere else but in peat swamp forests. Lowland *Nepenthes* are usually growing in this type of forests (Clarke, 1997).

2.5 Growth habit of *N. veitchii*

Nepenthes are not all jungle plants and shade-loving but they rather grow at open and sunnier area (James & Pietropaolo, 1986). Instead of climbing over shrubs and bushes like other species do, *N. veitchii* climbs straight up the trunks and branches of trees as epiphytes in a spiral fashion making the most spectacular sights among all of the pitcher plants (Figure 2.2). This has made it potentially become nature tourism's attraction (Hans *et al.*, 2004). In the absence of supporting tree, they scramble along the ground (Figure 2.3). The leaves encircle the trunk of the host tree and the pitchers are produced in two columns on the opposite side to the main stem of the plant (Phillips & Lamb, 1997).

In taller forest along streams or river banks especially in the lowlands, *N. veitchii* is completely epiphytic. Their epiphytic way of life gives them advantages by allowing them to access to more direct sunlight, a greater number of canopy animal pollinators, and the possibility of dispersing their seeds via wind in the rainforest that are often harsh conditions of the canopy (Phillips & Lamb, 1996). This epiphytic species of

REFERENCES

- Aiba, S. & Kitayama, K. 1999. Structure, Composition, and Species Diversity in an Altitude-Substrate Matrix of Rain Forest Tree Communities on Mount Kinabalu, Borneo. *Plant Ecology*, **140**:139-157.
- Adam, J. H., Wilcock, C. C. & Swaine, M. D. 1992. The Ecology and Distribution of Bornean *Nepenthes*. *Journal of Tropical Forest Science*, **5**(1):13-25.
- Anderson, J. A. R. 2006. The Structure and Development of Peat Swamps of Sarawak and Brunei. *Journal of Tropical Geography*, **18**: 7-16.
- Aronoff, S. 1989. *Geographic Information Systems: A Management Perspective*, Ottawa. WDL Publications.
- Ashton, P. S. 1971. The Plants and Vegetation of Bako National Park. *Malayan Nature Journal*, **24**:151-162.
- Baffray, M. F. B., Danton P. & Fournier. 1989. *Nature at Culture des Plantes Carnivores*. Ed. Edisud, Aix-en-Provence, France.
- Burrough, P. A. 1986. *Principles of Geographical Information Systems for Land Resources Assessment*. Oxford University Press, New York.
- Cain, S. A. 1994. *Foundations of Plant Geography*. Harper and Bros, New York.
- Chai, P. & Radcliffe, G. 1984. Ant Plants and Carnivorous Plants of Kerangas Scrub Vegetation in Bako National Park. *Nature Malaysian*, **9**(2): 18-27.
- Cheek, M. & Jebb, M. 2001. Nepenthaceae. *Flora Malesiana*, **15**(1).
- Clarke, C. 1997. *Nepenthes of Borneo*. Natural History Publications in association with Science and Technology Unit, Kota Kinabalu, Malaysia.
- Clarke, C. 2001. *A Guide to the Pitcher Plants of Sabah*. Natural History Publications (Borneo) Sdn Bhd, Malaysia.
- D'amato, P. 1998. *The Savage Garden*. Berkeley: Ten Speed Press.
- Danser, B. H. 1928. The Nepentheceae of the Netherlands Indies. *Bulletin Jardine Botanique Buitenzorg*, **9**(3): LIVR: 3-4: 249-435.
- Elia, G. 2009. Not to scale map. GIS Laboratory Institute of Tropical Biology, Universiti Malaysia Sabah.

- Gillbert, C. 1994. Testing the Attribute Collection Capabilities of A GPS-Based Data capture system. *Earth Observation*, 45-46.
- Green, S. 1967. Notes on The Distribution of *Nepenthes* in Singapore. *The Garden's Bulletin Singapore*, 91(8): 10-14.
- Greer, J. D. 1993. The View from Above – An Overview of GPS and Remote Sensing Options. *Journal of Forestry*, 22: 53-65.
- Handayani, T., Latifah, D. & Dodo. 2005. Diversity and Growth Behavior of *Nepenthes* (Pitcher Plants) in Tanjung Puting National Park, Central Kalimantan Province. *Biodiversitas*, 6(4): 251-255.
- Hans P. H., Tengku Z. A., Waidi S. & Wong K.M. (eds). 2004. *Maliau Basin Sabah's Lost World*. Natural History Publications (Borneo) Sdn Bhd, Kota Kinabalu, Sabah.
- Holtum, R. E. 1940. Malayan Pitcher-Plants. *Malayan Nature Journal*, 1: 35-44.
- James & Pietropaolo, P. 1986, *Carnivorous Plants of the World*. Timber Press, Portland, Oregon.
- Jebb, M. H. P. & Cheek, M. 1997. A Skeletal Revision of *Nepenthes* (Nepenthaceae). *Blumea*, 42(1): 1-106
- Juniper, B. E., Robins, R. J. & Joel, D. M. 1989. *The Carnivorous Plants*. Academic Press, London.
- Jordan, C. F. 1985. Nutrient Cycling in Tropical Forest Ecosystems. Chichester: John Wiley & Sons.
- Katagiri, S., Yamakura, T. & Lee, S. H. 1991. Properties of Soils in Kerangas Forest on Sandstone at Bako National Park, Sarawak, East Malaysia. *Southeast Asian Studies*, 29(1).
- Kennedy, M. 1996. *The Global Positioning System and GIS: An Introduction*. Ann Arbor Press. Chelsea, MI. p.268.
- Kurata, S. 1976. *Nepenthes* of Mount Kinabalu. Sabah Natinonal Parks Trustees, Kota Kinabalu.
- Kok, R. D. 2008. Darwin Initiative Annual Report 3: *Assessing and Conserving Plant Diversity in Commercially Managed Tropical Rainforests*. Yayasan Sabah Group, Sabah Forestry Department, RBG Kew, Department for Environmental, Food and Rural Affairs. Darwin Initiative, Sabah.
- Kook, W. C., Tarmizi. A. & Wahid O. 2000. Advances in Fertilizer in the Oil Palm Industry. Malaysian Palm Board. *Proceeding Conferrence of OFIC 2000*, Kuala Lumpur.

- Langley R. B. 1997. The GPS Error Budget. *GPS World*, March, p.51-56
- Mazrimas, J. 1979. *Nepenthes*. *Carnivorous Newsletter*, **8**(1): 24-29.
- McPherson, S. R. 2009. Pitcher Plants of the Old World. Part II. *Annals of Botany*, **7**: 403-458.
- Miller, R. I. (eds). 1994. *Mapping the Diversity of Nature*, Chapman & Hall, London.
- Nordin, S., Aliakbar, G. & Mohammad T. M. 2009. *Penginputan Data Geografi & Analisis Asas Geografi: Satu Pendekatan Mesra Pengguna*. Program Geografi, Sekolah Sains Sosial, Universiti Malaysia Sabah.
- Phillips, A. & Lamb, A. 1996. *Pitcher Plants of Borneo*. Natural History Publications (Borneo) Sdn Bhd, Kota Kinabalu, Sabah.
- Rosa, M. C., Joaquin, H. & Jorge, M. L. 2005. Potential Distribution Modelling, Niche Characterization and Conservation Status Assesment Using GIS Tools: A Case Study of Iberian *Copris* Species. *Biological Conservation*, **122**: 327-338.
- Saw, L. G. & Marsh, C. 1989. Vegetation Classification and Mapping. In: Marsh, C.W. (eds). *Expedition to Maliau Basin, Sabah, April-May 1988: Final Report*. Yayasan Sabah, Kota Kinabalu. 117-125.
- Shiego. K., Takuo, Y. & Lee S. H.. 1991. Properties of Soils in Kerangas Forest on Sandstone at National Park, Sarawak, East alaysia. *Southern Asian Studies*, **29**(1): 35-47.
- Steiner, H. 2002. *BORNEO: Its Mountains and Lowlands with their Pitcher Plants Trekking from 1992 to 2002*. Toihaan Publishing Company, Kota Kinabalu.
- Smythies, B. E. 1965. The Distribution and Ecology of Pitcher-Plants (*Nepenthes*) in Sarawak. *UNESCO Humid Tropics Symposium*, Kuching.
- Theodore, W. S. & Beazley, R. 1960. Frequency Calculations From Several Different Forest Ecological Sampling Methods. *The Ohio Journal of Science*, **60**(2): 100-105.
- Viuex, B. E. & Needham, S. 1993. Non Point Pollution Model Sensitivity to Gridcell Size. *Journal Water Resources*. Planning Management. ASCE **119**(2): 141-157.
- Wang, L. X., Zhou, Q., Zheng Y. J. & Xu, S. Y. 2009. Composite Structure and Properties of the Pitcher Surface of the Carnivorous Plant *Nepenthes* and Its Influence on the Insect Attachment System. *Natural Science*.
- Welch, R. & Remillard, M. 1992. Integration of GPS, Remote Sensing, and GIS Techniques for Coastal Resource Management. *Photogrammetric Engineering and Remote Sensing*, **58**: 1571-1578.

- Webb, C.O. & Sidkan, A. 2002. *Plant and Vegetation of the Maliau Basin Conservation Area, Sabah, East Malaysia*. Yayasan Sabah, ICSB, Research & Development Division, Sabah.
- Whitmore, T. C. 1984. *Tropical Forests of the Far East*. 2nd ed. Clarendon Press. Oxford.
- Woodward, F. I. 1987. *Climate and Plant Distribution*. Cambridge Univ. Press, Cambridge, United Kingdom.