ALTITUDINAL ZONATIONED MOSS AS BIOINDICATOR FOR POLLUTION

BY

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A thesis submitted in fulfillment of the requirement for the degree of Master of Science (Built Environment)

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ABSTRACT

Placed as the crown of the mountain, Moss forest or tropical montane cloud forest (TMCF) are one of Earth's most imperiled and neglected ecosystems. More than half of these forests are situated within Southeast Asia; those located in Malaysia are considered well studied in the region compared to others. Malaysia is known for its numerous mountains that are exceptionally rich in biodiversity and locally endemic species, but they are also threatened by human expanding activity such are, forestry, agriculture, infrastructure, and global warming. By critically assessing the current state of moist forests—focusing on their biological fingerprints and potentials for a long-term survival—and propose conservation strategies for agricultural, forestry, tourism, and policy sectors of the Biota content as well as the effect that human interference has on it using indigenous moss species as Bio indicators through Bio monitoring, to help conserve these endangered ecosystems. There is no wrong in hoping that decision makers around the region can use the review to evaluate and improve their national strategies related to cloud forest conservation.

خلاصة البحث

لقد تم وصفه تاجا للجبال، فإن غابات موس أو جبل الغابات المدارية الغيمة (TMCF) من بين أكثر النظم البيئية تعرضًا للخطر وإهمالًا. يقع أكثر من نصف هذه الغابات داخل جنوب شرق آسيا؛ وتلك التي تقع في ماليزيا تعتبر مدروسة جيدا مقارنة بغيرها. تشتهر ماليزيا بجبالها العديدة الغنية بشكل استثنائي بالتنوع البيولوجي والأنواع المستوطنة محليًا، ولكنها أيضًا مهددة من قبل الأنشطة البشرية الآخذة في التوسع مثل الغابات، والزراعة، والبنية التحتية التي تؤدي في النهاية إلى الاحترار العالمي. من خلال إجراء تقييم حاسم للحالة الحالية لغابات الطحالب – مع التركيز على بصماتها البيولوجية وإمكاناتها للبقاء على المدى الطويل – واقتراح استراتيجيات الحفظ للزراعة والغابات والسياحة، وقطاعات السياسات لمحتوى Biota وكذلك آثار الإنسان التداخل عليه باستخدام أنواع الطحالب الأصلية مثل Bioindicatorsمن خلال مراقبة الحيوية في محاولة الحفاظ على هذه النظم البيئية المهددة بالانقراض. فلا خطأ في أن يقوم صانعو القرار في المنطقة من استخدام المراجعة لتقييم وتحسين استراتيجياتهم الوطنية المتعلقة بحفظ الغابات السحابية.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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This thesis is dedicated to my parents for laying out the foundation of what I turned out to be in life and as constant strong support source for me to always exist in my life especially during trouble times.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

This chapter presents the background study on the significance of Montane cloud forest within peninsular Malaysia, its physical contributions towards the ecosystem and Moss as one of its dominant biota used as bioindicators as well as its capabilities to be so. This chapter would also include the research background, problem statement, aim, objectives, research questions, research methodology, significance of research, scope of study, organisation of study and the summary.

1.1 BACKGROUND STUDY

Moss Forest is a type of forest ecosystem that typically occurs within 1 500 m to 3,000 m above sea level, situated within a height range of about 300 m but it can also occur at a height of as low as 500 m above sea level depending on the climate (Brunjinzeel et al 1993). Moss forests are known as a forests that are often covered with clouds or mist (Hamilton, 1995). However, the definition of this ecosystem is controversial and unsure, as it is difficult to define the ecosystem between a true moss forest and a montane rainforest. This could be attributed to situations where there is a lack or scarcity of accurate data on the actual moisture input period from the horizontal precipitation of cloud, cloud cover and the tendency to use the term cloud forest or moss forest to describe any of the forested mountains that are sometimes observed to be covered by

clouds. The tropical mountain cloud forest, which is also known as moss forest is made up of forest ecosystems with a structured and distinctive floristic form. It usually appears as a relatively narrow altitudinal Zone where atmospheric environments are characterised by continuous, seasonal or frequent cloud cover at the vegetation level. Clouds or clouds driven by wind suggest more atmospheric connections via reduced sunlight with vapour deficit, canopy wetting, and general evaporation.

The through falls or average precipitation, without a doubt, highly increases rain contribution through canopies' direct interception of cloud water like horizontal rain or cloud stripping and low water consumption of plants. Comparing the properties of peat and humus (histosol), biodiversity in terms of shrubs, tree species, herbs and epiphytes is sometimes quite high compared to lowland rain forest which are rich with tree species. On a global scale, TMCF is known for having various annual and seasonal rain regimes; for example 500 to 10 000 mm per year. Other than that, what should be kept in mind is the significant difference in altitudinal position of the mountain belt of vegetation, Generally, in a system for large mountains and inlands, TMCF is usually found between 2,000 and 3,500 m of height such as Andes and Ruwenzori, while in the insular and coastal mountains and the Zone may fall to 1,000 m like Hawaii but it does not mean all are similar as that. Under the marine humid exceptional equatorial conditions, the TMCF Zone can develop on an island with small, steeply mountain ridges with elevations as low as 500 m or it could go even lower; for example Micronesia and Gau located in Fiji (Hamilton et al., 1993).

While the additional importance of water inputs from the cloud forest or moss forest is undisputed, quantifying it has proven to be difficult. On the impact of downstream water yield, little fact is known in reality from conversion of moss forests to cattle pastures or land uses, which are other that what they were. For the given amount

of rainfall water yields provided from the forested cloud headwater location and the stream flow tends to be higher than that the ones coming from montane forests that are not affected by low clouds and fog. In addition, during low rainfall periods, the flows from cloud forest areas appear to be more stable. Therefore, there is a good reason to believe that conversion to other land uses of cloud forests can cause significant declines in the flows for the entire season and dry season. (Brown et al., 1996; Bruijnzeel, 2000; Proctor, 1993; Stadtmueller, 1987).

Bioindicators are one of the interesting samples to trace atmospheric pollution and land pollution on a longer time and larger space scale due to their significant low cost of sampling system. Bioindicators are living organisms that can be used to illustrate the condition of the health level of an ecosystem. Certain organisms are very sensitive to pollution produced in their environment or surrounding weather – for a long term or otherwise; so if pollutants are present, the organisms might change their morphology, physiology and behaviours, or in the worst case scenario, they could even die. Living organisms, most of the time, could be used to indirectly measure levels of chemicals within their environments. Thus, population numbers of certain species or organisms can also be tracked over time to notice the changes that may have been the result of the changes in the surrounding environments. The term bioindicator is commonly used referring to organism, or the part or parcel of it which contaminants or pollutants are depicted based on symptoms that are specific reactions and concentrations or morphological changes. It is also generally referred to all organisms that provide the quality of environmental change or specific information about the environment (Poikolainen,2004). Bio monitoring is when the responses of certain or specific individual plant species or plant associations at some stages of the biological organisation are used as a gauge. This will enable people to predict or detect certain

changes in plants due to and because of their environment, following their evolution as a function of time (Kuang, et al., 2007). Bio monitoring with mosses is based on the fact that the terrestrial carpet-like plants have been proven to obtain most of their nutrients in most situations, directly from every aspect of weather deposition, wet or dry, and can reflect clearly the atmospheric deposition, especially in accordance with heavy metal pollution on larger scale of time (Ergebis et al ., 2002; Ergebis et al., 2000). Broadly, and in some cases, cosmopolitan distribution of many species of moss indicates that this gametophyte is the dominant plant among the most easily-adapted to earth taxa. Mosses can be found in every area, continent and in every terrestrial ecosystem, from tropical rainforests to dry desert and at the tundra poles. Preventing soil erosion and maintaining a large amount of water and therefore compiling local water ecosystem budget are some of the moss's important roles (Poikolainen, 2004; Fernandez et al., 2006; Wang et al., 2008; Cui et al., 2009).

High concentrations of sulfur dioxide (SO2) are reflected in mosses used as bioindicator, the accumulation of heavy metals and other pollutants emitted into the atmosphere from anthropogenic and natural sources which have been reported in many studies in some parts of the world including local investigations as well as regional surveys (Giordano et al., 2004; Čeburnis et al., 1999a). In mosses international surveyed reports and scientific articles, it could be found that the most commonly used bioindicator species are *Hypnum cupressiforme, Hyloco-mium splendens,* and *Pleurozium schreberi*. These species are particularly abundant in parts of Europe (Onianwa, 2000). Mosses have many properties that make them suitable for air pollutant monitoring since these species obtain the necessary nutrients for essential processes of wet and dry deposition and have no real roots. Mosses are popular as bioindicator not only due to their environmental characteristics, but also because of their economic

advantages.

Biological indicators are used as one of the simplest and cheapest indicators to monitor the concentration of heavy metal in the atmosphere. The moss analysis technique from the atmosphere to the terrestrial system provides a replacement or surrogate of time-integrated measure of metal deposition. It is easier and cheaper in comparison to the conventional precipitation analysis as it also avoids the usage of large number of precipitation collectors associated with long-term routine sampling and analysis programs. Therefore, unlike conventional precipitation analysis, a much higher sampling densities can be achieved (Harmens, etal., 2008). Furthermore, the plants in regions that are tropically mountainous, in which the rainfalls are often heavy and persistent where precipitation occurs due to the cooling of air laden with moisture where the mountains deflect upwards. Trees in the cloud forest are usually short and bent; for example, climbing ferns, mosses, lichens, and epiphytes or air plants, such as orchids forms thick blankets on branches and tree trunks. It is also known as extremely stunted forest where mosses cover the trees of the jungle occurring in tropical or medium mountainous areas or also known as the Tropical Montane Cloud Forest, thus making moss sampling much less complicated.

Cloud forest worldwide, over the past 20 years, has nearly doubled in the average global destruction rate and is becoming a critical issue whose trends have been recognised by the United Nations Intergovernmental Forum on Forests, stating that "cloud forest is a special concern" primarily within the protected land and catchment areas as well as its conservation in environmentally critical areas for its biological diversity (Aldrich et al., 2001). The causes of loss and reduction of many cloud forest across the globe are plenty; the biggest losses come from these area being converted into grazing land and these precious forests are cleared for wood, cattle or crops, the

loss cause "cloud stripping" capacity to reduce water revenue which is now mostly utilised for domestic and irrigation purposes. At the same time, topsoil erosion that is caused by some or most of these activities causes sedimentation in the rivers, blocking up reservoirs and lakes.

Nevertheless, cloud forest continues to be purged for new agricultural land when the population pressure is growing and the existing farmlands become poor. Other important causes for losing regional cloud forest includes conversion to vegetable crops in tropical regions, gathering wood for charcoal production, wood harvesting, mining, non-timber forest products unsustainable extraction (for example, the orchids and bromeliads), the introduction of foreign species and construction of telecommunications installation in the cloud forest at the top of the mountain. Considering all of the abovementioned factors, it may not be impossible that this type of forest would be lost forever in the years to come.

1.2 Problem Statement

Three issue that will be discussed is: how TMCF existence influences the environment and the species of mosses dominant to the local. The Tropical Montane Cloud Forests (TMCFs) are situated highly in the list of the world's most endangered or threatened ecosystems. To achieve the rest of the remaining area conservation, there is an urgent need for information on the location, socioeconomic situation, extent of protection status, current threats on site-by-site basis, and biological importance.

A. Types of species

Types of moss found to be used as bioindicators and its physical attributes as lower latitude tropical moss forests, standing characteristics includes generally, increased stem density and reduced tree stature. Gnarled trunks and branches, compact dense crown and small, thick, as well as hard (sclerophyll) leaves are usually exhibited. TMCF is also characterised by having high biomass as epiphytes such as bryophytes, filmy ferns and lichens and at the same time, the reduction in woody climbers. Soil is wet and often waterlogged and highly organic in the form of humus and peat (histosol). Biological diversity in plant species, shrubs, herbs and epiphytes can be quite high given the small extent of size compared to the low rainforest that is rich with tree species. In addition, endemism in TMCF is often very high (Hamiltonet al, (1993).

B. Altitudinal Zonation

Altitudinal zonation refers to the changes in the plant and animal community structures along an altitudinal gradient determined by abiotic factors marked by a well-defined layering of ecosystems corresponding to the horizontal zonation along the latitudinal gradient. Main environmental factors that determine the boundaries of altitudinal layers of ecosystems in the mountains are temperature, humidity, soil composition, solar radiation, latitude, wind velocity, direction, disturbance, frequency, topography and competition.

C. Level of Pollution

To find the level of pollution of local areas using bioindicators, this includes sulfur oxides and nitrogen oxides but also heavy metals that are airborne such as lead, cadmium and nickel. To achieve this aim with the existing technologies is difficult because they are not accurate or very expensive while living plants that take and accumulate pollutants are already being utilised as biological indicators. Mosses are particularly well-suited to act as a bioindicator for air pollution because they have no roots and have a very high surface to mass ratio.

1.3 RESEARCH AIM

The intention behind the conduct of this research is to further understand the relationship between human interaction or activity and the ecosystem of Tropical Montane Cloud Forest using moss as bioindicators through Bio Monitoring.

1.4 RESEARCH OBJECTIVES

The objectives of the research on this topic are as provided below, which were recognised and derived during the problem statement and problem questions:

i. To study the physical aspects and characteristics of the Tropical Montane Cloud Forest;
ii. To carry out a moss research on the level of heavy metal contents in the ecosystem by moss; and
iii. To explore the ways of using moss as bioindicators as tools of precautions and control in biomonitoring instead of mechanical methods.

1.5 RESEARCH QUESTIONS

Referring to the objectives, the research questions were created:

i. What are the landscape characteristics and ecosystem of Tropical Montane Cloud Forest (TMCF) or "Moss Forest"?

ii. What are moss and using it as bioindicators?

iii. What are the types of pollution that exist and their effects?

iv. What are the environmental impacts of the disappearance of the Moss Forest Ecosystem?

1.6 RESEARCH SIGNIFICANT

Cloud forest values show that majority of the areas are highly important habitats for endangered and endemic species of flora and fauna – many tree species included and plants such as the Cyatheaceae and Orchidaceae orchids. Many species of birds and mammals in large quantities such as the spectacled bear (*Tremarctos Ornatus*) and howler monkey (*Alouatta spp*.) depend on the cloud forest habitats for their survival. In addition, these forests have a high socio-economic value for locals, particularly as building materials, source of fuel and food, but also on a larger scale, for protection of catchment areas and climate regulation. At the same time, over-logging for firewood, agriculture clearance, grazing animals' encroachment and the spread of fires from the combustion of adjacent grasses have been identified as major local threats to the fragile ecosystems and their inhabitants. In addition, many areas are under the pressure of mining companies and large scaled road construction projects which are often against the will of the local people.

If managed in a sustainable way, TMCFs can provide other valuable service networks to locals living in or adjacent to the forests. In addition to being a source of wood and small dimension timber, they can provide a wide range of non-wood forest products including honey, medicinal plants and bush meat.

1.7 RESEARCH METHODOLOGY

The data and information for this study were collected through various sources such as primary data and secondary data such as books, journal, thesis and internet as well as the relevant articles.

1.8 ORGANISATION OF STUDY

This study consists of five chapters. The first chapter is the introduction of the study. In Chapter 2, the literature review on interior Tropical Montane Cloud Forest or moss forest is presented. The research methodology and case study are discussed in Chapter 3. Chapter 4 presents the findings of the research. Finally, in Chapter 5, the conclusion and recommendations are presented. Figure 1 shows the flow of the study.