Faculty of Resource Science and Technology

ASSESSING THE GROWTH PERFORMANCE OF PLANTED NURSING TREES (*Pongamia pinnata*) AT TAKASAGO–UNIMAS EDUCATIONAL FOREST

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Assessing the Growth Performance of Nursing Trees (*Pongamia pinnata*) at Takasago-UNIMAS Educational Forest

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Supervisor: Associate Professor Dr. Mohd Effendi bin Wasli

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Final Year Project Report ☑

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Assessing the Growth Performance of Planted Nursing Trees (*Pongamia pinnata*) at Takasago-UNIMAS Educational Forest

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ABSTRACT

Land degradation has worsened in recent decades, posing new challenges, particularly for living organisms in the ecosystem. Land restoration can be accomplished using proper approaches to recover degraded land caused by human activities such as development and construction. An assessment was conducted to study the survival rate and growth performance of planted *Pongamia pinnata* trees as the nursing tree at Takasago-UNIMAS Educational Forest. In this study, the degraded post-construction areas planted with *Pongamia pinnata* through the box planting method were selected. The study plot had been delineated into three (3) study plots (Plot A with spacing of 5m x 5m, Plot B with spacing of 2.5m x 2.5m and Plot C planted with spacing of 3m x 3m) with 6 smaller subplots within each plot. The survival rate and growth performance in terms of height and stem diameter of planted trees were assessed in all plots. The results showed that the survival rate of planted trees in plot A, B and C were at 62%, 25% and 53%, respectively. The results for growth performance showed that the mean of tree height in plot A (216.76 cm) was significantly higher than in plot B (192.42 cm) and plot C (121.46 cm). Additionally, the mean stem diameter recorded for plot A, B and C were 5.05 cm, 3.88 cm, and 1.79 cm, respectively. Mean annual increment in height (MAIH) and diameter (MAID) of planted *P. pinnata* in Plot C were significantly higher than in both plots A and B. The high survival rate and substantial growth performance of *P. pinnata* indicated that soil conditions and properties along with other limiting factors have affected the survival rate and growth performance of planted *P. pinnata*

Keywords: Growth Performance, *Pongamia pinnata*, Stem Diameter, Survival Rate, Tree Height

Menilai Prestasi Petumbuhan Pokok Kejururawatan (*Pongamia pinnata*) di Takasago-UNIMAS Educational Forest

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ABSTRAK

Kemerosotan tanah telah bertambah buruk dalam beberapa dekad kebelakangan ini, menimbulkan cabaran baharu, terutamanya bagi organisma hidup dalam ekosistem. Pemulihan tanah boleh dicapai menggunakan pendekatan yang sewajarnya untuk memulihkan tanah terdegradasi yang disebabkan oleh aktiviti manusia seperti pembangunan dan pembinaan. Penilaian telah dijalankan untuk mengkaji kadar kelangsungan hidup dan prestasi pertumbuhan pokok Pongamia pinnata yang ditanam sebagai pokok kejururawatan Takasago-UNIMAS Educational Forest. Menerusi kajian ini, kawasan pasca binaan terdegradasi yang ditanam dengan Pongamia pinnata melalui kaedah penanaman kotak telah dipilih. Plot kajian telah dibahagikan kepada tiga (3) plot kajian (Plot A dengan jarak 5m x 5m, Plot B dengan jarak 2.5m x 2.5m dan Plot C ditanam dengan jarak 3m x 3m) dengan 6 subplot yang lebih kecil dalam setiap plot. Kadar kelangsungan hidup dan prestasi pertumbuhan dari segi ketinggian dan diameter batang pokok yang ditanam telah dinilai di semua plot. Keputusan menunjukkan kadar kelangsungan hidup pokok yang ditanam di petak A, B dan C masing-masing pada 62%, 25% dan 53%. Keputusan untuk prestasi pertumbuhan menunjukkan min ketinggian pokok di plot A (216.76 cm) adalah lebih tinggi secara signifikan berbanding di plot B (192.42 cm) dan plot C (121.46 cm). Selain itu, diameter batang min yang direkodkan untuk plot A, B dan C masing-masing ialah 5.05 cm, 3.88 cm dan 1.79 cm. Purata kenaikan tahunan dalam ketinggian (MAIH) dan diameter (MAID) P. pinnata yang ditanam di Plot C adalah lebih tinggi dengan ketara berbanding di kedua-dua plot A dan B. Kadar kelangsungan yang tinggi dan prestasi pertumbuhan yang besar bagi P. pinnata menunjukkan keadaan dan sifat tanah. bersama-sama dengan faktor pengehad lain telah mempengaruhi kadar kelangsungan hidup dan prestasi pertumbuhan P. pinnata yang ditanam

Kata kunci : Kadar pertumbuhan, Pongamia pinnata, diameter batang, kadar kelangsungan hidup, ketinggian pokok

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List of Abbreviation

M	-	Metre
cm	-	Centimetre
mm	-	Millimetre
km^2	-	Kilometre square
sq mi	-	Kilometre square
UNIMAS	-	Universiti Malaysia Sarawak
FRST	-	Faculty of Resource Science and Technology
%	-	Percentage
FAO	-	Food and Agriculture Organization
PAH	-	Polycyclic Aromatic Hydrocarbon
P.pinnata	-	*Pongamia pinnata*
°C	-	Degree Celcius
HDP	-	High Density Planting
MAIH	-	Mean Annual Increment of Height
MAID	-	Mean Annual Increment of Diameter

1.0 INTRODUCTION

1.1 General Background

Land exploration for construction, settlement, and development has shown a significant escalation globally since the past decades. Driven by human forces in utilizing land sources for economic growth or even self-priorities, land exploration is highly substantial with deforestation activity which leads to the destruction of natural forest which plays an important role in an ecosystem. The occurrence of forest destruction has deeply impaired biodiversity resilience and bringing up broad and drastic global environmental changes despite the increase in development dimension contemporarily. Southeast Asia has recorded an approximation of 610,000 km^2 (235,500 sq mi) forest lost between 2001 and 2009 which also corresponds to a larger area than Thailand (Cowan, 2021).

Decades of widespread clearing of forest has found to be responsible to land degradation and deterioration of soil quality. Degradation of soil refers to the changes of soil properties and reflected by the increase in soil erosion, decrease in soil fertility and biological degradation of the soils (ITTO, 2002). In 1994, forests in Lordegan, Iran has shown an increment for bulk density at 20%, 50% decrease in organic matter and total nitrogen, a 10 to 15% decrease in soluble ions comparing to the undisturbed forest soil due to subsequent deforestation (Hajabbasi et al., 1994). The substantial impoverishment of soil has eventually impacted on floral growth, development, and survivorship mainly on trees as soil is the fundamental indicator for better tree growth and development. Soil structure influenced plant root distribution, water and nutrient availability, and oxygen infiltration (Johns et al., 2015).

Construction purpose has produced a great scale of degradation in soil properties due to the exposition of undisposed construction materials like rocks, cements, glasses, and trashes that should be cleared up during post-construction period. The accumulation of these materials has created fabricated soils that are heavily compacted, polluted, and unfertile. Construction-damaged soil has negatively influenced tree establishment especially its root growth which support plant growth (Elmendorf, 2017). The implementation of forest rehabilitation is the essential way to improve degraded forest due to post-construction activities. Rehabilitation alters the forest productivity in terms of soil fertility status and restore natural ecosystem.

Forest rehabilitation activity requires a comprehensive understanding and assessment of soil-plant relationship which involve soil properties and fertility, tree planting method and species selection for the progress of rehabilitation techniques in the future (Arifin et al.,2007). Tree planting is found to be the most necessary way in alleviating degraded soil especially in a short period of time. Species selection for planting is undoubtedly important as it gives different growth productivity at degraded forest due to its deteriorated soil quality. Species selection often related to the selection of multi-function species and its tolerance against unfavourable condition. The species characteristics include its ability to be raised in large numbers in nurseries, fast-growing, soil improvement like organic matter development, and nitrogen fixation and coppicing (ITTO, 2002).

While tree planting can vary in methodology, its conjunction with growth performance is apparent. The practice of nursing tree concept which implies the usage of two-storied plantations with fast growing and pioneer nurse trees (Paquette & Messier 2010) is found to be more productive and cost-effective strategy for forest restoration (Löf et al., 2014). Line planting technique is also an effective method as it applies the concept of planting various species in line and is planted under the forest canopy (Pamoengkas, 2010) for enriching forest species as destructed forest before brings an insufficient in natural regeneration. The best-known enrichment planting is line planting which has diversified variants throughout the tropics (Lamprecht 1989). Besides, additional source of valuable timber could be obtained by planting dipterocarps in line (Pamoengkas, 2010).

1.2 Problem Statement

The success of forest rehabilitation depends on the ability of the forest in contributing to provide a balance ecosystem after restoration process for a long-term. The effectiveness of nursing tree concept in rehabilitating degraded land should be tested through the assessment on growth performance and the survivorship rate of the nursing trees as it is the key indicator for the success of forest rehabilitation project. The nursing trees is influenced by mainly biotic and abiotic factors which is essential to the growth performance of nursing trees. The effectiveness on tree planting measures and the suitability of selected trees can be evaluated through the assessment.

1.3 Objectives

The objective of this research is to assess the growth performance and rate of survivorship of planted nursing trees, *Pongamia pinnata* at three different planting spacing. Besides,this study will determine the effect of different planting spacing on the growth performance of *P. pinnata* as nursing tree at Takasago-UNIMAS Educational Forest. This study will also indicate the suitability of *P. pinnata* as nursing tree at Takasago- UNIMAS Educational Forest.

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2.0 LITERATURE REVIEW

2.1 Importance of Rehabilitation on Degraded Land

The natural forests have been diminished at an unprecedented rate by human activities due to overexploitations in the forest areas that damage the land environment resulting in land degradation (ITTO, 2002). According to FAO (2020), between the year 2005 and 2010, Malaysia's total forest area dropped by 434 000 ha which indicates a huge loss of natural forest. The occurrence of deforestation of tropical forest could lead to global warming at which it accelerates the greenhouse gases emission and increase the accumulation of carbon dioxide, CO_2 due to low density of trees presence in the natural forest to undergo photosynthesis process (Kobayashi, 1994). Therefore, it is important to implement forest rehabilitation as forest rehabilitation activities are considered as an important element from a global perspective in terms of wood, ecosystem resources and eco-friendly environment services (Arifin et al., 2007).

The existence of the protected forests where no logging is allowed is insufficient to protect the endangered species in Malaysia. Hence, the effort of enriching the species and establishing biodiversity is necessary. The richness and high diversity of plants can turn the degraded areas into green environment at which it will eventually turn into a conservation area for biodiversity and can also be used as green lung, park, or botanical garden. The essentials in rehabilitation projects should also focused on the planting of the endangered plant species as it will ensure the survival of the species (Krishnapillay et al., n.d.). In some cases, the habitat restoration of the endangered species may need to follow some specialized condition to avoid naturalized predators from the mainland.

Restoration will prevent the protected area from being a source of weeds or pests. Protected areas may have boundaries with great populations of invasive pest and weeds species. Restoration can improve the functionality and effectiveness of these buffer areas and perimeters. While conserving a significant biodiversity is the primary focus of the rehabilitation, restoration of trees with various species will improve soil properties and microclimates. Soil organic matter is a main component of soils because of its effect on soil chemical and physical properties (Jamaluddin et al.,2013). In some decking sites and skid trails, the productivity in growing plants may occur at less due to inconducive soil properties. Therefore, rehabilitating these degraded sites can only be successful if the proper species is selected according to its land suitability followed by intensive site preparations (Krishnapillay et al., n.d.)

On the other hand, restoration can help to maintain the Soil Organic Carbon (SOC). An increase organic carbon may lead to the improvement of the soil and yield production and quality. Furthermore, higher SOC can develop soil structure or tilth which brings to greater physical stability. Soil aeration and water drainage and retention will get improved as well and reduces the risk of erosion and nutrient leaching (Corning et al., 2016). Forests are important source of medicinal compounds in wild organisms, including those that are common foods, drinks and drugs for example cocoa, ginger, and cola nut. Forests are a rich ecosystem reserve of compounds that can be used as pharmaceuticals and nutraceuticals. Back in the past decades, people who are living in or near forest often get the medicinal benefits of the source available near them especially the natural medicinal values (Gruca, 2018).

2.2 Previous studies on the techniques in land rehabilitation at degraded area

The method of implementation and the selection of tree species play a vital role for a successful rehabilitation of degraded logged-over forest (Maswar et al., 2001). Throughout the past years and decades, a lot of studies related to rehabilitation process have been made by various researchers around the world. The studies analysed involve the importance of the implemented techniques and trees selection in relation with the land suitability of the rehabilitation in the degraded area.

In a study conducted by Maswar et al. (2001), four rehabilitation methods were implied and evaluated under the process of rehabilitation of logged-over lowland tropical forest in Pasoh Forest Reserve, Negeri Sembilan, in Peninsular Malaysia. The methods involved were line planting (T1) and gap planting at which gap planting method varies in its gap differences; 10m x 10m x 5 ha^{-1} (T2), 20 m x 20 m x 5 ha^{-1} (T3) and 10 m x 10 m x 9 ha^{-1} (T4). The selected planted species were *Hopea odorata, Azadirachta excelsa* and *Vitex pubescens*. The percentage of survival recorded differs according to the planted species withall the survival rate under different planting techniques and species are more than 70%. From this study, it is suggested that both planting methods were suitable under the rehabilitation process of the forest. The most practical method is gap planting method as it is found to be the most cost-effective technique and produce great efficiency for especially for high density planting. *Hopea odorata*, *Azadirachta excelsa* and *Vitex pubescens* are suitable species for plantation under rehabilitation of the forest.

On the other hand, a study conducted by Mohd Zaki & Nik Muhammad (2001) focused on the effectiveness of the pot-hole planting techniques and its feasibility for the usage in establishing indigenous tree species under the rehabilitation project of degraded land area in Bintulu, Sarawak. Pot-hole planting can be explained as a low-cost planting technique that involves open planting with minimum site preparation such as clearing of weed species and digging of planting holes. A total number of 270 seedlings of *Barringtonia* sp., *Cotylelobium burckii, Durio zibethinus, Eugenia* sp., *Eusideroxylon zwageri, Shorea macrophylla, S. ovata* and *S. maaxwelliana* were selected as the planted species and were raised in nursery for 12 months before transplanting. These seedlings produced a survival rate ranging from 91 to 100%. From the result obtained, it is found out that pot-hole technique produced a better overall survival and growth performance (height and basal diameter) of the planted seedlings compare to the more intensively prepared sites. Therefore, this method can be used to rehabilitate a large area of degraded land.

A study of the rehabilitation of degraded forests in lowland Kutai, East Kalimantan, Indonesia was carried out by Mori (2001). This study focused on planting dipterocarps and avoiding the plantation of dipterocarps in single species in most cases except for the plantation of few species such as *Dryobalanops aromatica* and *Shorea robusta*. In this study, two main components for rehabilitation success are light control and species selection. It was stated that light control should correspond to the light requirements in various growing stages of a species. The pre-existing trees or fast-growing trees is useful for the utilization of light control. From this study, it is suggested that species with wide adaptability should be planted, and mixed planting species is recommended. A study carried out by Dong (2014) focused on the plantation of *Acacia* as a nurse crop for re-establishing native-tree species plantation on degraded lands in Vietnam. *Acacia* species offered two key benefits as nurse- crop species which are shading and enhanced nutrient cycling (Padilla & Pugnaire, 2006). The study evaluates the potential of the *Acacia* species specifically *Acacia mangium* and *Acacia auriculiformis* especially their tolerance and adaptation to a wide range of sites on nourishing the plantation site such as improving soil conditions on degraded gravelly and sandy soils in Central Vietnam, the ability to fix atmospheric nitrogen, landscape recovery and the ability to replace the high demand for quality timbers harvested from natural forests. The study concluded that *Acacia* species is a potential species for recovery degraded forest.

2.3 Nursing Tree Concept

Nursing tree concept implements the method of planting fast-growing trees which provide shelter to target trees that is smaller than the nursing trees for improving their growth productivity (Löf et al., 2014). The method of nursing tree concept is seen to be a crucial method especially when involving land restoration process as this method can help to improve the degraded land. Moreover, this concept is beneficial especially towards the public community and environment as it ecologically sound, easily accepted by the public, cost-effective and has a great ability in ameliorating the harsh environment (Wasli et al., 2021). Therefore, plantations of target tree species could be more productive through the implementation of nursing tree (Paquette & Messier 2010).

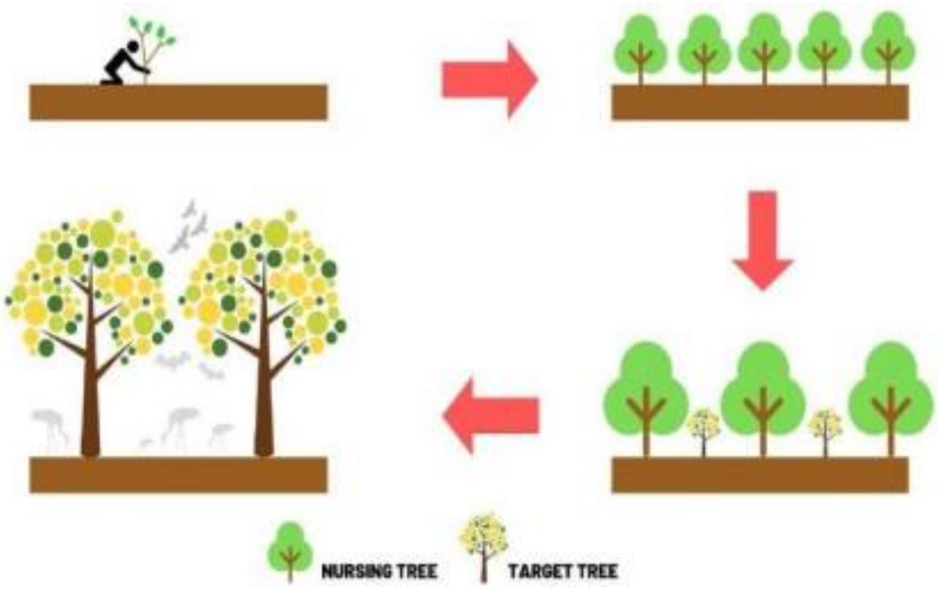

Figure 1: The Nursing Tree Concept

One of the major limiting factors for the growth of target trees is light and moderate shading from fast growing nursing trees may reduce interference from ground vegetation and regenerating woody plant species naturally. Moreover, the target tree species may exhibit weak apical dominance and apical control in open conditions that may result inpoor stem form and thick lateral branches near ground due to less light competition for the trees that will reduce the timber value (Löf et al., 2014). The selection of the nursing tree is often related with few characteristics and adaptability at which the tree needs to be a fast-growing tree and able to adapt to various soil types and conditions. Other than that, the tree needs to have a high productivity on degraded land and able to provide various ecological function to the environment (Wasli et al., 2021).

2.4 General Information of *Pongamia pinnata*

Pongamia pinnata is a medium-sized evergreen tree with a fast-growing ability that can reaches up to 40 feet in height and 60 cm in its straight or crooked trunk diameter size with glabrous, deciduous, smooth bark and dropping branches forming a spreading canopy for a moderate shade in the area planted (Sangwan et al, 2010). *P. pinnata* belongs to the family family Leguminosae and subfamily Papilionaceae or Fabaceae and the genus *Pongamia* (Chopade et al., 2008) derived from the Malabar local name called pongam (Sangwan et al,2010). *Pongamia* is a genus known for having only one species which is *P.pinnata* also called *Derris indica* and *Pongamia glabra* (Chopade et al., 2008). The name *Derris indica* is derived from Greek word which brings the meaning of 'leather covering orskin' and the specific name 'indica' obviously means of India.

P. pinnata grows naturally in lowland forest and is suitable for growing in limestone and rocky coral outcrops on the coast, along the edges of mangrove forest and along tidal streams and rivers. It is a shade bearer and can grow well under the shade of other trees. Apart from that, *P. pinnata* is not a shade demander as it still can grows well under a direct overhead light. This species can withstand waterlogging and slight frost conditions due to its adaptability. It is a well-adapted species to wide climatic conditions and soil moisture conditions and has the resistance towards drought situations, but a prolonged drought may however kill seedlings. In its natural habitat, the species tolerates a wide temperature range as its mature trees can tolerate temperatures of up to 50 °C. Moreover, it is highly tolerant of salinity and alkalinity (Orwa et al., 2009).

Figure 2: *Pongamia pinnata* tree

This species can grow on most soil types ranging from stony to sandy to clayey, including verticals. The highest growth rates are observed on deep well-drained sandy loam with assured moisture. However, this species still has the potential to grow well on other types of soil as it tolerates saline conditions, alkalinity, and waterlogged soils (Orwa et al., 2009). The other important adaptive description of *P. pinnata* is its nitrogen fixing ability. In some common biofuel crops, namely, sugarcane, canola, sweet sorghum, and maize deprive soils of nitrogen rather than contributing to the increment of nitrogen content. A study related to quantification by gas chromatography of ethylene in acetylene, C_2H_2 reduction assays, where C_2H_2 serves as a substrate for bacterially encoded nitrogenase shows the ability of *P. pinnata* as nitrogen fixing plant (Leksono et al., 2021). *Pongamia s*pecies can form functional spherical nodules with a broad range of rhizobia which belongs to the *Bradyrhizobium* tribe (Scott et al., 2008). Besides, this species is valuable for the enrichment of soil fertility.

P. pinnata trees are usually planted along the highways, roads, and canals to stop soil erosion. The species can develop a dense lateral network of roots which is preferred for controlling soil erosion and binding sand dunes (Usharani et al., 2019). *P. pinnata* can tolerates wide range of abiotic stresses and improve the soil nutrient status especially on a degraded land as it can be productive on degraded land. *Pongamia* is promoted as being able to produce oil on poor, degraded or saline soils (Murphy et al., 2012). *Pongamia* trees have been used for soil reclamation around coal mines and revegetation in India (Maiti, 2012). *P.pinnata* can act as a phytoremediation. Due to its high adaptability and fast-growing ability, *P. pinnata* can become as a nursing tree. A nursing tree plays a role to provide shelter to improve the growth productivity of the target trees (Löf et al., 2014).

3.0 MATERIALS AND METHOD

3.1 Study Area

This study was conducted at Takasago-UNIMAS Educational Forest sites, West Campus, Universiti Malaysia Sarawak (UNIMAS), Kota Samarahan, Sarawak (Figure 3). This study area is located approximately 14 km from Kuching, Sarawak with the latitude and longitude reading (1˚27'51.53" N, 110˚25'25.32" E). The average annual precipitation recorded is around 3900 mm per year (Wasli et al., 2021), with the monthly maximum precipitation recorded in the area exceeding 300 mm in January (CustomWeather, n.d.). While, the annual temperature ranges between 24°C (75.2 °F) as its minimum temperature and rises to around 33°C (91°F) for its maximum temperature (Malaysian Meteorological Department, 2019).

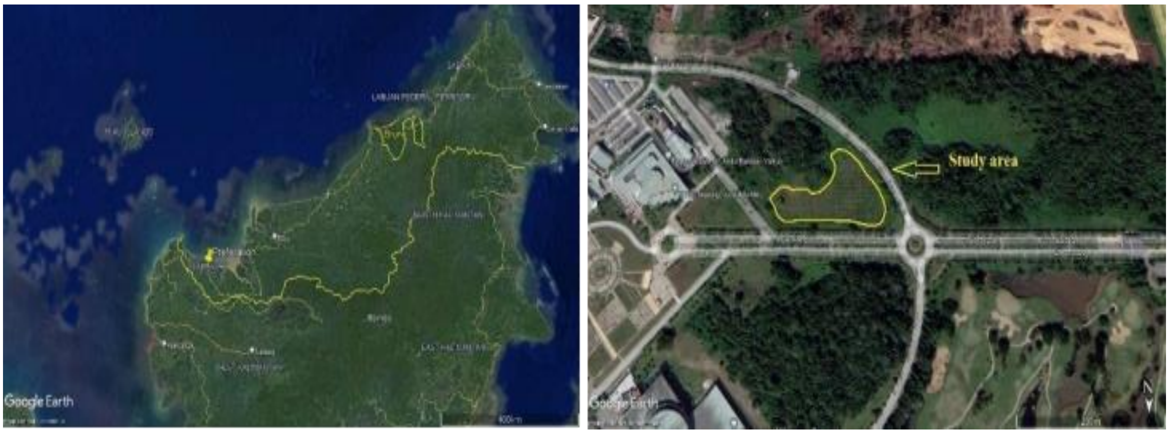

Figure 3: Location of Universiti Malaysia Sarawak (UNIMAS) & Takasago-UNIMAS Educational Forest (Google Earth Pro, 2021)

The origin of the study site is an open area from the post-construction site of the construction of UNIMAS previous years ago (Wasli et al., 2021). In term of the soil in the study area, soil's constituent is derived primarily as abandoned soil resulting from the construction process where the construction waste like rocks, deposited cements and brickscan be found on the soil surface. Takasago-UNIMAS Educational Forest sites is