CONSERVATION OF BINDANG (AGATHIS BORNEENSIS WARB.) : THE SOIL PHYSICAL EDAPHOLOGY

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CONSERVATION OF BINDANG (*AGATHIS BORNEENSIS* WARB.): THE
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List of Abbreviations and Units

cm = centimeter

\text{dS/m} = \text{decisiemens} / \text{meter}

ft. = feet

g = gram

ha = hectare

H_2O = water

H_2SO_4 = sulphuric acid

i.e. = in example

KCl = kalium chloride / potassium chloride

m = meter

ml = milliliter

mm = millimeter

pH = level of acidity

sp. = species

SOM = soil organic matter

°C = celcius

% = percentage

< = lesser than

> = more than
Conservation of Bindang (*Agathis borneensis* Warb.): The Soil Physical Edaphology

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ABSTRACT

Distribution of *Agathis borneensis* Warb. or locally known as Bindang in Sarawak shows a marked discontinuity. This could be due to factors such as forest destruction, climatic change, illegal logging, species extinction, site development, poor fertility of soils and others. A study was conducted to determine the effects of the soil physical properties on the distribution of Bindang. Two approaches were used in this study, firstly, through the collection of primary data and secondly, through the use of secondary information. Primary data was obtained by making field observations at two sites in the highlands of Sarawak, namely, in Long Seridan and Sabal and laboratory analysis on samples was obtained from these sites. Secondary information was done based on observations from other researchers. The soil physical properties considered in this study were texture, structure, organic matter content, pH, conductivity and organic carbon. The results showed that Bindang is found to thrive well on spodosols and skeletal soils which are highly acidic, good drainage and a shallow soil type.

Key words: Bindang, primary data, secondary information, soil physical properties, thrive well.

ABSTRAK


Kata kunci: Bindang, data primer, maklumat sekunder, sifat fizikal tanah, berkembang subur.
CHAPTER ONE
INTRODUCTION

According to Smythies (1965), Bindang (*Agathis borneensis* Warb.) is more typical of the north temperate regions than of other parts of the world and they are represented by very few species in Sarawak which is commonly found in kerangas or tropical heath forest. Apart from that, it is also found in mixed dipterocarp forest. Kerangas forest, also known as tropical heath forest occurs on allegedly infertile, usually sandy soils or on soil derived from basic igneous or volcanic rocks such as basalts. As in montane forests, leaves in kerangas forest are typically thick, leathery and small characteristics which may be correlated to nutrient deficiency on very acid soils or which could be adaptations to minimize water loss and reduce heat load during periods of drought. Hazerbrock *et al.* (2001) recorded altogether 849 tree species, 133 shrubs, 96 herbs, 100 epiphytes and 55 lianas in Sarawak’s kerangas forests.

Bindang is mainly a montane tree and growing on deep well-drained and leached white sands near the coast but it is also found at low altitude on terrace sands in central and a higher elevation at about 2000 ft. altitude. Smythies (1965) suggested that Bindang is commonly found on deep well-drained leached white podzolized sands near the coast, where it is sometimes the most abundant species. However, it has been heavily logged in the area (Wong, 1981). According to Ipur *et al.* (1998), the tree heights and girths contribute to the various stratification of forests. The trees of Bindang are tall, monopodial and without buttresses. The crown is relatively small, narrow unevenly conical. The bole is typically dapped and light grey in color. The
trees are capable of achieving approximately 50m in height and 1.4m in girth. The seed which is normally winged is usually dispersed by wind and natural regeneration if often fairly plentiful in the forest. The cultivation of Bindang in plantations is hindered by the difficulty of collecting seed and also by the very short period of viability of the seed. Regeneration of Bindang is only successful under a close canopy. The species are distinctive, highly-sought and exploited for valuable timber. Bindang has been established as an excellent joinery timber and for the making of household utensils, pattern-making, shelving and turnery. Bindang became a popular timber for interior finishing and cabinet making because of its fine texture and easy working qualities (Aron, 1999).

In Sarawak, this species has a marked discontinuous distribution probably because of its unsuitable adaptation such as climate, soil, and environment. However, there is limited information about growing environment of Bindang. Their limited occurrence could be due to certain edaphic factors. Beside that, it is also have to compete with other species such as Meranti, Belian, Selangan Batu and others, which is more productive and highly potential.

Therefore, the study of soil physical properties is important in view of the need to conserve the species. Therefore, the objective of the study is to identify and understand the soil physical properties that have strong influence on the plant growth in order to conserve the species. The properties examined include drainage, pH, depth, texture, structure, presence or absence of special features such as stones and spodic horizon.
CHAPTER TWO
LITERATURE REVIEW

2.1 About Kerangas Forests

Kerangas forests, also known as tropical heath forests are a term used by the Iban people for sites where rice cannot be successfully cultivated. It occurs on allegedly infertile, base-poor, highly acidic and predominantly sandy soils or on soil derived from basic igneous or volcanic rocks such as basalts. In Sarawak, Hazerbroek et al. (2001) recorded altogether 849 tree species, 133 shrubs, 96 herbs, 100 epiphytes and 55 lianas in kerangas forests. Generally, the trees in kerangas forest are smaller and shorter compared to those in mixed dipterocarp forest. The trees produced a low and uniform canopy. Typical kerangas species include Agathis borneensis Warb., Calophyllum spp., Gymnostoma nobile, Myrmecodia tuberosa, Drosera, Tristaniopsis sp., Syzygium sp. and Hydnophyllum formicarium (epiphytes with interconnected ant-inhabited channels developing in their swollen stem base). Wong et al. (1999) suggested that kerangas forest are vulnerable to fire because the effect of drought on plants can be accentuated by the porous sandy substrates and general rooting depth in heath forest soil appeared shallower than in mixed dipterocarp forest. This drought-induced death of plants and plant parts significantly increases the amount of dried matter in the forest that makes the vegetation more susceptible.
2.2 Distribution of Bindang (*Agathis borneensis* Warb.)

According to Soerianegara and Lemmens (1994), *Agathis* is the most tropical genus of the *Coniferae*. The natural distribution of the genus is Peninsular Malaysia, Borneo, Sumatra, Sulawesi, the Philippines, the Moluccas, New Guinea and New Britain. It occurs from low elevations to 1200m in upland rainforest and in dense nearly pure stands on low-lying sandy peat soils in many parts of Borneo and in one area in Peninsular Malaysia. In Sarawak, it is common on deep well-drained leached white podzolized sands near the coast, where it is sometimes the most abundant species. However, it has been heavily logged in the area (Smythies, 1965). The cultivation of Bindang in plantations is hindered by the difficulty of collecting seed and also by the very short period of viability of the seed. However, it is used in enrichment planting and reforestation in various areas within the natural range, especially in Irian Jaya. The trees of Bindang are tall, monopodial, and without buttresses. The crown is relatively small, narrow unevenly conical. The bole is typically dippled and light grey in color. The trees are capable of achieving approximately 50-55m in height and 1-1.4m in girth. The seed which is normally winged is usually dispersed by wind and natural regeneration if often fairly plentiful in the forest.

2.3 Ecology

According to Smythies (1965), Bindang (*Agathis borneensis* Warb.) is more typical of the north temperate regions than of other parts of the world and they are represented by very few species in Sarawak which is commonly found in *kerangas* or tropical
heath forest. Apart from that, it is also found in mixed dipterocarp forest. *Kerangas* forest, also known as tropical heath forest occurs on allegedly infertile, usually sandy soils or on soil derived from basic igneous or volcanic rocks such as basalts. Hazerbroek et al. (2001) recorded altogether 849 tree species, 133 shrubs, 96 herbs, 100 epiphytes and 55 lianas in Sarawak’s *kerangas* forests. Bindang is mainly a montane tree and growing on leached white sands near the coast but it is also found at low altitude on terrace sands in central and a higher elevation at about 2000 ft. altitude. Generally, it is confined to regions with an annual rainfall between 2000 and 4000 mm which is well distributed over the year. On Palawan (the Philippines), several small populations thrive well in a climate with a more marked dry period (Soerianegara and Lemmens, 1994).

### 2.4 Growth and Development

Shading is very important to the seedlings resulted from the difficulty of collecting seed and also by the very short period of viability of the seed. Actually, it shows a slow growth during the first years. As in most typical primary rain forest trees, growth is rapid when released from competition with herbs. Soil characteristics and competition from other tree species influence the development of the tree height. The root system of Bindang is sensitive to lack of oxygen and the trees do not tolerate water-logging. Soerianegara and Lemmens (1994) proposed that many *Agathis* species produce seed cones well before pollen cones appear. At maturity, the seed cones usually shatter on the tree. Seeds are usually carried for only short distances by wind and they often germinate in large numbers near the parent tree. Bindang is
pollinated by wind. The trees are reputed to be an open-grown tree and provenances retain their low branches for some time. The stem form is good. In Java, plantation of this genus starts to produce cones at the age of 15 years but viable seeds are usually not produced before 25 years. However, viable seeds can be collected from February to April and from August to October. In New Guinea, ripe cones appear regularly in November and December, probably with more than 18 months between emergence and disintegration of female cones. Actually, mature trees may produce 200-300 cones and approximately 1 kg of seed per year.

2.5 Planting and Propagation

According to Nainggolan (1981), to establish natural regeneration of *Agathis borneensis*, successfully, continuous maintenance especially during the seedling phase is required. During the different stages of growth, shade should be regulated to provide the necessary amount of light required. Water cannal is built to prevent floods and stagnant pools from occurring during the wet season. Unwanted plants should be weeded out from the area to avoid competition among the plants.

Usually, sowing techniques is used on artificial regeneration. Seed supply is limited by the very rapid decline in viability and the high costs of collecting seed from species whose cones disintegrate. From the research done by Soerianegara and Lemmens in 1994, they found that in Indonesia and Papua New Guinea, cones are collected when they have ripened and become blackish-green. A female cone is very difficult to collect because they produced mainly in the upper parts of the crown at the
ends of the branches. Fallen seed collection is not recommended for planting. The weight of 1000 dry seeds is about 200g.

Seeds must be sown as soon as possible because the viability drops rapidly, from 90-100% initially to zero after a few weeks. A seedling starts to germinate 6 days after sowing, which is 80% of the seedlings emerging within 10 days. Seeds can be stored at temperatures below 0°C and storage time can be extended by quick drying without heating. Air-dried seeds have a germination rate of 40-50% after 14 days, this drop to zero after about 9 weeks. Seeds are directly sown on seed-beds after soaking for 24 hours. It is covered thinly with soil. Seedlings prefer shade and will survive open planting only if the roots are minimally damaged and soil is moist. When more than a year old plants are more resistant to exposure. Potting stock at least 15 cm high, but preferably larger as small stock shows high mortality, is used for planting.

According to Soerianegara and Lemmens (1994), the best nursery seedlings for transplanting are those of 1-1.5 years old and 25-60cm tall. The plant dies if the taproot is bent sharply when transplanting. Mycorrhizal association is easily formed with ubiquitous soil fungi. *Leucaena leucocephala* is used as a nurse tree to provide the necessary shade. Planting during the dormant stage of terminal buds is preferable and the transpiration is reduced by clipping side-shoots.

To overcome lack of seed, vegetative propagation has proved successful for example by root suckers from seedlings from the nursery and by stem and leaf cuttings assisted by auxin applications.
2.6 Effects of Soil Properties on Growth of Bindang (*Agathis borneensis* Warb.)

Soil plays an important role in the growth and development of forests. Therefore, differences in soil properties can influence both composition of forest vegetation and the rate of tree growth. It is important to have knowledge of forest soil physical properties for proper management of the environment and utilization of forest resources.

Bindang is mainly a montane tree and found to thrive well on poor *kerangas* soil. As in montane forests, leaves in *kerangas* forests are typically thick, leathery and small. These characteristics may be correlated to nutrient deficiency on very acid soils or which could be adaptations to minimize water loss and reduce heat load during periods of drought. Wong *et al.* (1999) suggested that the nutrient deficiency on these very acid soils appears to be restrictive for many plant species and the ability of such plants to supplement their nutrient status through associating with ant or trapping insects seems to be an advantage. Streams draining *kerangas* forests have been described as “black water” due to the high amounts of humic acids that leach through *kerangas* soils easily.

Type of soil which could be due to the preponderance and occurrence of Bindang is spodosols. Spodosols are acid soils characterized by a subsurface accumulation of humus that is complexed with aluminium (Al) and ferum (Fe). These photogenic soils typically form in coarse-textured parent material and have a light-coloured E horizon overlying a reddish-brown spodic horizon. The process that forms these horizons is
known as podzolization. According to Fanning and Fanning (1989), spodosols occur on coarse-textured acid parent materials in humid regions from the arctic to the tropics although the main tropical region spodosols appear to be the aquods. They occur only in moist to wet areas and are most common where it is cold or temperate. Forests are the natural vegetation under which most of these soils have developed. The formation of spodosols is correlated with certain vegetation associations. Species like Biodox trees and pine trees which is low in metallic ion contents, seem to encourage the development of spodosols. Strong acidity develops as the litter from these low-base species decomposes. Percolating water leaches acids down the profile and the upper horizon succumb to this intense acid leaching. Most minerals except quartz are removed.

Spodosols is actually a mature soil, typically of the sandy leached soils of cool coniferous forests. Spodosols are not naturally fertile (Brady, 1990). It is also found in humid tropics when the erosion is conducive to the heavy leaching and illuviation of organic matter and sesquioxides (i.e. on sandy organic matter and forest environment). Soils can become quite productive when properly fertilized. The low native fertility of most spodosols makes them unsuitable for tilled crops. They are covered mostly with forests, the vegetation under which they originally developed. Pritchett and Fisher (1987) explained that the debris returned to the surface under conifers is usually low in nitrogen and the essential bases. It decomposes very slowly, consequently, the ground is covered with a thick blanket of mosses growing on needles and decaying wood over very acid humus.
The vegetation that naturally occurs on spodosols is tolerant of the environment (acid-loving) and provides the organic matter involved in cheluviation. McKeague *et al.* (1983) identified a number of different groups of plants, including coniferous-deciduous forest with shrubs and mosses. It is needed much longer time to form spodosols. In many forested areas where spodosols occur, the soils with the whole podzols morphology are not continuous over the landscape because of tree-throw. Based in the chemical analysis, it points up strong to excessive acidity (pH$_{1/20}$ 3.5-4.5 on surface and 4.6-5.0 in subsurface horizon) with low nutrient status and aluminium (Al) concentrations reaching toxic levels. Slightly more favourable conditions are found on lower slopes and valley floors.

Soil has an important effect on seedling mortality. In flooded and unflooded areas, sandy soils have an adverse effect on the survival of *Agathis* seedlings because of the lack of nutrients. Seed germination is also negatively influenced by the litter and organic matter covering the soil. The density of *Agathis* prior to logging and the degree of soil wetness have a significant influence on the composition of seedlings, poles and trees.

In relation to the forests, *kerangas* forests are vulnerable to fires because the effect of drought on plants can be accentuated by the porous sandy substrates and general rooting depth in heath forest soil appeared shallower than in mixed dipterocarp forest. Death of plants can be induced by this drought and plant parts significantly increases the amount of dried matter in the forest that makes the vegetation more susceptible. According to *Wong et al.* (1999), in a visit to the drought-stricken *Agathis*-dominated
kerangas forest in Badas Forest Reserve in April 1998, such mortality was observed even in unburnt patches of forest, especially among the smaller, more shallowly rooted *Agrostistachys longifolia* and *Erythroxylum latifolium*, both of which are common in that forest.

### 2.7 Environmental Conditions of Spodosols

a) **Climate**

Spodosols may have any soil temperature regime. They are largely confined to humid areas that extend from high latitudes to the tropics especially extensive in cool-humid, mid to high latitudes (i.e. Canada, Alaska, New Zealand etc.).

b) **Time**

Spodosols are relatively mature soils. A cemented spodic horizon takes longer time periods to form (approximately 3,000 to 8,000 years).

c) **Parent material**

Typically, spodosols are formed in very coarse silty or coarser (i.e. increased in sand) textured material, i.e. sandy loam, loamy sand, sand. Siliceous or leached carbonaceous parent materials favor the development of spodosols. Some were originally calcareous, but carbonates were leached before the spodic horizon developed. It also forms in weathered material from rocks poor in Ca and Mg (i.e. sandstone, granite). The content of iron-bearing minerals in
the parent material influences the kind of spodic horizon that will develop and the degree of development of an E horizon.

d) Relief

Spodosols form on slopes ranging from nearly level to very steeply sloping and on surfaces in which the water table ranges from very deep to fluctuating near the surface. They do not seem to form in a soil that is permanently saturated with water. The iron content of spodic horizons depends on the water table levels whereby the spodic horizons that are saturated with water for prolonged periods may be depleted of iron because it is reduced and mobilized.

e) Vegetation

The occurrence of spodosols is correlated with certain vegetation associations. It is used for forestry, pasture, hay and for cultivated crops. Management can decrease acidity by adding lime and raise nutrient level by fertilization.
CHAPTER THREE

MATERIALS AND METHODS

Two approaches were used in this study, firstly through field collection of primary data and secondly through the use of secondary information.

3.1 Primary data

The study was conducted in Long Seridan and Sabal Forest Reserve. These locations are on dissected terrains with large tracts of mixed dipterocarp forests, *kerangas*, sub-montane and montane forests. According to Sarawak Land Capability Classification, the soils are in class 4-5. They are relatively infertile, highly acidic, therefore, poor in bases, predominantly sandy soils and subject to erosion hazard because of their occurrence on steep slopes. The activities takes place during the collection of primary data are such as augering observations, samples collection and preparation (air-drying, grinding and sieving).

3.1.1 Augering observations

Augering is done every 20cm to 1m depth or less. Observations were made of the horizon change, soil texture, structure, colour, odour, thickness and permeability.
3.1.2 Samples

Samples were taken near the location of the Bindang trees (within 10m). This could be at the hill top, mid-slope or bottom of slope.

There are 21 representative soil samples at different depths collected from three locations in Long Seridan and four locations in Sábal Forest Reserve. For each sites, samples are taken at different depth according to horizon or to auger depths such as 0-20cm, 20-40cm and 40-100cm. The soil sample is placed in the plastic bags before it is analyzed in the laboratory practices.

3.1.3 Sample preparation

a) Air drying

According to Tan (1996), air drying is the most accepted procedure of sample preservation. Drying in the air may reduce the rate of possible reactions in the disturbed soil sample. Additionally, a sample should not be allowed to stay moist for extended periods of time. Air drying is done before any analysis on composite soil samples brought back from the field is conducted. It is also sieved to the required size range.

Firstly, the soil sample spread on a piece of brown paper or plastic sheet in a wooden or plastic tray and air-dry at room temperature. Large clumps are broken up into smaller ones to hasten up drying. As in field conditions, the clumps are easy to break
when compared after they become air dry. Air drying took several days to a week or more depending on the initial moisture content of the sample.

b) Grinding and sieving

The purpose of grinding is to reduce heterogeneity and to provide maximum surface area for physical and chemical reactions. Meanwhile, sieving is an essential part of homogenizing the sample after grinding operation. In this research study, the air-dry sample is ground with a pastel and mortar, then sieve manually. The first sieving is done using a 2mm (opening) sieve. The sieved sample is stored and labeled in a bottle or plastic container.

3.2 Secondary information

Secondary information was obtained through direct consultation with other researchers who have undertaken surveys on the species in Sarawak. Locations where the species had been found by these researchers were identified. The probable soil types were then identified using the detailed reconnaissance soil map at 1:50,000 scale.