SOIL EDAPHIC CONDITION IN PEAT AFFECTING THE GROWTH PERFORMANCE OF SAGO PALM

Roland Yong Chiew Ming

Master of Environmental Science
(Land Use and Water Resource Management)
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Thesis submitted in partial requirement for the Master of Environmental Science (Land Use and Water Resource Management)

FACULTY OF RESOURCE SCIENCE AND TECHNOLOGY
UNIVERSITI MALAYSIA SARAWAK
2014
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ABSTRACT

Sago palms (*Metroxylon spp.*) planted on shallow and deep peat, adhering to good agricultural practice showed good growth performance at early stage of its development i.e. less than 4 years after planting (Fariza, 2008). However, several researchers have reported that the characteristics of peat soils play an important role in the period for development of growth of sago palm. It has been reported that the trunking stage of sago palm cultivated in deep peat soils begins to deteriorate after few years of cultivation due to high incidences of tapering mother palm and poor growth of succession palms. Moreover, sago cultivated in deep peat soils exhibited distinct elemental deficiency symptoms in the leaves which correspond likely due to inefficiency of nutrient uptake after fertilizer application. It is evitable that soil properties play an important role in determining the growth performance of sago in peat area which later affects the growth pattern of sago palms. A preliminary study was conducted at Sebakong Sago Plantation (SSP), Mukah and Sungai Talau Research Station (STRS), Dalat in order to identify the effect of soil physicochemical properties that contributed to the growth performance in terms of trunking formation of sago palm. The study also involved in determining the inter relationship between characteristics of the peat soil in relation with the root distribution of cultivated sago palm within the study area. Based on the initial findings, although soil physicochemical properties provide significant relationship with the growth pattern of cultivated sago palm, it was distinctive that the growth performance in term of the trunking formation of sago palm cultivated in shallow peat and mineral soil are better than those cultivated in deep peat soils. Moreover, the decomposition rate in the peat soils plays an important role in determining the growth performance of cultivated sago palm. It was observed that the peat soils with sapric-hemic-fibric conditions and with low percentage of undecomposed woody materials promote better condition rooting medium, anchorage and efficient adsorption as compared to fibric peat soils which is very raw and dominant with woody residues.
ABSTRAK

Pokok sagu (Metroxylon sagu spp.) yang ditanam di kawasan tanah gambut cetek dan dalam
dengan sokongan amalan pertanian yang baik menunjukkan pertumbuhan yang subur pada
peringkat awal iaitu dalam tempoh 4 tahun pertama selepas penanaman (Fariza, 2008).
Walaubagaimanapun, beberapa hasil penyelidikan telah melaporkan bahawa sifat-sifat tanah
gambut memainkan peranan penting bagi pertumbuhan pokok sagu. Laporan turut menyatakan
bahawa pertumbuhan pokok sagu di tanah gambut mula merosot pada peringkat berbatang
dimana berlakunya pembentukan batang mengunci ke atas dan pertumbuhan sulur turunan yang
tidak memuaskan. Penanaman pokok sagu di tanah gambut dalam juga menunjukkan simptom
kekurangan elemen pada daun yang amat ketara disebabkan oleh ketidakberkesanan
pengambilan nutrien selepas pembajaan. Keadaan ini jelas menunjukkan bahawa ciri-ciri tanah
memainkan peranan yang amat penting dalam menentukan corak pertumbuhan pokok sagu.
Kajian telah dijalankan di Ladang Sagu Sebakong, Mukah dan Stesen Penyelidikan Sungai
Talau, Dalat untuk mengenalpasti kesan ciri-ciri fizikal dan kimia tanah dalam menyumbang ke
atas pembentukan batang pokok sagu. Kajian tersebut turut menentukan hubungan di antara
sifat-sifat tanah gambut dengan penyebaran pertumbuhan akar pokok sagu. Berdasarkan
penemuan, ciri-ciri fizikal dan kimia tanah mempunyai hubungan yang amat ketara dengan corak
pertumbuhan pokok sagu dimana pembentukan batang pokok sagu di tanah gambut cetek dan
tanah mineral adalah lebih baik berbanding di tanah gambut dalam. Tambahan pula, kadar
pereputan di tanah gambut turut memainkan peranan penting. Berdasarkan pemerhatian, tanah
gambut berkeadaan sapric-hemic-fibric yang mengandungi peratusan yang rendah bahan kayu
belum terurai menjadikan ia media pengakaran yang lebih baik bagi cengkaman dan penyerapan
nutrien dibandingkan dengan tanah gambut berkeadaan fibric dimana ia sangat kasar dan masih
dominan dengan bahan-bahan kayu belum terurai.
1.0 INTRODUCTION

1.1 BACKGROUND

Sago palm (*Metroxylon spp.*) is one of the few tropical crops which can tolerate wet growing conditions including peat swamps. It has been suggested that sago palm can grow on natural deep peat swamps with none or minimal drainage (Kueh, 1987). It had been observed that sago on peat exhibited distinct deficiency symptoms in the leaves reminiscent of potassium deficiency (Kueh, 1995). Data derived from destructive analysis of the palm also pointed to the fact that nutrient removal is of high magnitude and fertilizer application is a must in order to sustain yields (Flach, 1990). The comparison of the growth rates of sago palm grown on deep and shallow peat (Yamaguchi. Et al., 1997) showed that there were considerable variations. Sago palms grown on deep peat have significantly smaller perimeter size, fewer fronds as well as poorly developed canopy which is called tapering symptom compared to those in shallow peat. The poor growth in deep peat may be caused by poor absorption of nutrients as the peat itself was low in nutrients.

Study on the effect of nitrogen (N), phosphorus (P) and potassium (K) fertilizers on the growth of the sago palm in undrained deep peat was conducted by the Department of Agriculture Sarawak. The assessment by means of frond production rate of leading palm, trunk girth and rate of trunk elongation showed no response to N, P, and K applications (Kueh, 1995). The lack of response was probably due to fertilizer being lost as peat has poor capacity to hold nutrients and any fertilizer taken up by the palms being distributed throughout the cluster, since sago palms produce suckers. In general, nutrient removal from soil by palms is of high magnitude and fertilizer application is thus considered essential to sustain yield (Flach, 1990).
With the establishment of the plantation and research station, some problems that has not been realized before were now being experienced in these areas. It was found that sago grown in deep peat suffered stunted growth. This is characterized by small crowns, low number of fronds and no sign of trunking after having been planted for more than 10 years (CRAUN, 2010). Therefore it is important to look into a detailed study on the suitability of peat soil to comprehend the earlier findings on the factors that contributed to the growth performance of sago palm.

1.2 PROBLEM STATEMENT

Sago palms planted on shallow and deep peat, adhering to good agricultural practice showed good growth performance at early stage of its development i.e. less than 4 years after planting (Fariza, 2008). However after 4 years, reaching trunking stage of development, the growth on deep peat begins to deteriorate as could be observed from high incidences of tapering mother palm and poor growth of succession palms. It had been observed that sago palm on peat exhibited distinct elemental deficiency symptoms in the leaves (Kueh, 1987). Usually the plant exhibited a visual symptom indicating a deficiency in a specific nutrient even with the application of fertilizer. The soil physical properties play an important role in determining the growth performance of sago in peat area and there is inter relationship between the soil characteristics and the growth pattern of sago palms (Melling, 2000).

1.3 OBJECTIVE OF THE STUDY

The goal of this study was to identify the effect of soil in terms of physical and chemical characteristic that contributed to the growth performance in terms of trunk formation of sago palm. The study also involved in determining the inter relationship between peat characteristic and root distribution of sago
palm. The study will be conducted in sago palm planting area with different peat depth in Sungai Talau Research Station (STRS) and Sebakong Sago Plantation (SSP) by CRAUN Research Sdn. Bhd. research plot.

2.0 LITERATURE REVIEW

2.1 SAGO PALM

Sago palm (*Metroxylon sagu* spp.) is a unique tropical crop which accumulates starch in its trunk. This starch has long been a staple food for humans in South-East Asia and as with most other palms, nearly all the other parts of the plant are used for subsistence. The dry yield of starch can be as high as 10-25 t/ha (Flach 1983). It is a pinnate-leaved palm occurring in the hot humid tropics of South-East Asia and Oceania. The scientific name is derived from *metra*, meaning pith or *parenchyma*, and *xylon*, meaning *xylem*. In some varieties, after the leaf dies, the sheath may adhere to the bole, the part of the trunk below the crown, while in other varieties, the sheath drops. Without leaf sheaths, boles have a diameter of 35-60 cm and reach a length of 6-16 m. The bole stores starch in its central parenchyma at 10-25% of its fresh weight of 1-2 t. Healthy palms under good conditions carry approximately 24 leaves or fronds. The higher the number of fronds the crown carries, the larger the diameter of the trunk. Each month, one new frond appears out of the growing point, and the oldest one dies. Including the leaf sheath, each fully grown frond is 5-8 m long and carries 100-190 leaflets. Some leaflets may reach a length of 150 cm and a width of up to 10 cm. The average maturity (flowering) of sago on mineral soil is 8-11 years and 10-14 years in peat soil (Flach, 1983).

Sago palm is soboliferous; it produces tillers or suckers. Once planted, a regular succession of suckers are produced from the lowest part of the trunk, forming a cluster in various stages of development. Occasionally, suckers may be formed higher up on the bole. The palm is also hapaxanthic (once flowering) each bole heralds the end of its life cycle by developing a huge branched
terminal inflorescence with a large number of fruits. The starch stored in the bole is meant for the production of flowers and fruits. After the formation of fruits, the trunk decays and one or more of the suckers from the cluster take over. Only under prolonged flooding does the palm form pneumatophores, roots functioning as respiratory organs on top of the soil. Many varieties of the palm are covered by spines on the rachis, on the leaf sheaths and some even on leaflets and on bracts in the inflorescence.

There are many uses of sago palm. The boles have always been used to obtain starch as a staple food for humans. Fronds of the palm can be used for thatching and the rachis of fronds often is used for walls. The bark may be used as a floor material and the leaf sheaths sometimes are used for mats, and fibre from young leaves may be used for mats. Ground pith sometimes is used as an animal feed, when dried, it is also used for pigs and for chickens. The rice-straw mushroom (*Volvaria volvacea*) can also be cultivated on refuse from sago extraction. In decaying trunks, grubs, especially *Rhynchophorus spp.* or locally called ‘ulat mulong’, may grow. These are considered a delicacy by all sago growers. Sometimes parts of trunks are even left in the field to be infested. The grubs are eaten fresh or roasted.

2.2 PEAT SOIL

Peat which is classified in the United State Department of Agriculture (USDA) soil group as Histosols are found in many parts of the world both in the temperate and tropical region. Tropical peat lands occur almost everywhere in the tropical countries. Out of more than 400 million hectares (Hugo, 1960) (or 11 percent of the world area) peat lands resources in the world, about 72 million hectares are in the tropics. At the national level, out of more than 2.7 million hectares of peatland resources, about 1 million ha occurs in Peninsular Malaysia, 1.6 million in Sarawak and about 0.8 million is in
Sabah. It is estimated that more than 0.3 to 0.5 million ha of the peat land resources in this country has been developed mainly for agriculture cum settlement areas (Mutalib et al., 1991).

Histosols (from the Greek histos meaning tissue) are organic soil composed mainly of plant, but also sometimes of animal remains in various stages of decomposition (Fanning, 1989). These components have accumulated under water or under very wet condition which prevented decomposition activities. Once artificially or naturally drained, the organic matter decomposes and eventually they may change to mineral soil (Fanning, 1989).

Histosols behave like a sponge for available water in potentially cultivable land in the world (Brady, 1990). Increase in population for food has forced agriculture to expand to areas occupied by such soils. Sufficient knowledge in addition to improve management skills may transform Histosols into a much more productive tract of land. Utilization of Histosols as a chemical buffer, and as a media for partitioning water depends on the extent to which we understand the behavior and properties of the soil. It commonly contain more than 12% organic matter by volume (at least 20% by weight) unlike mineral soils that have 1 to 6% organic matter (Brady, 1990) and subdivided based on the state of decomposition. Fibrists are un-decomposed material, saprists are decomposed, whereas hemists are intermediate in state of decomposition (Brady, 1990).

The organic matter normally gets younger as the surface of the soil is approached from below. Geomorphologically, many histosols areas started out before organic matter accumulation process of organic material over a period of time with concomitant varying of decomposition playing a role (Sposito, 2008).
A typical cultivated Histosols is dark brown to intensely black in colour eventhough it may developed from materials that were gray, brown or reddish brown (Brady, 1990). The bulk density of a dried peat surface soil is only 0.20-0.30 Mg/m³ compared to 1.25- 1.45 Mg/m³ for mineral surface soils (Brady, 1990). Well humified organic soils will retain two to four times its dry weight of moisture. Undecayed or only slightly decomposed moss or sedge peat has an even greater water holding capacity, being able to hold water up to 20 times its dry weight (Brady, 1990).

When the mineral content of the soil ranges from 35 to 65%, it is called “muck” (Tie, 1979). Peats and mucks are classed as Histosols under the USDA comprehensive system of soil classification (Soil Survey Staff, 1975) and their formation is a phenomenon of a low lying and waterlog prone areas where partly decomposed dead organic materials mount up under the condition of poor aeration on mineral surface. The decomposition process is anaerobic in nature and is very slow, leading to the building up of partly or highly decomposed organic debris over time. The accumulation of varying sizes of the partly decomposed organic debris forms the physical problem of peatlands.

Peatlands are classified according to the depth of the organic portions which are shallow (<150cm) and deep (> 150cm). The varying depths of the organic portions show degree of accumulation of the organic debris. The organic classification of organic soil in Sarawak is based on the thickness of the organic soil material, nature of substratum and ash content (Tie et al. 1991). They are classified into Igan series (overlying quartzatic sandy soil with less than 15% clay), Mukah series and Anderson series (overlying heavy clay or silty clay loam). The Sarawak organic soil and their equivalent under soil taxonomy are shown in table 4. The Igan and Mukah series are shallow peat (<150cm) and the Anderson series are deep (>150cm). The Anderson series are further differentiated into three depth phases as shown in Table 5 below. The Anderson series form about 90% of total peat
area in Sarawak. Peat found in Sarawak is mostly the lowland peat types and has previously been
described as topogeneous or ombrogenous peat. It is 'topo' because it appears in basin as a result of
topographical features and 'ombro' because the source of water for its formation is assumed to be
from rainfall (Salmah, 2002)

Table. 1: Organic Soil and their equivalents under soil taxonomy (source Tie 1982)

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Soil Series</th>
<th>Soil Taxonomy (USDA) Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic soil</td>
<td>Anderson</td>
<td>Dysic, isohyperthermic, typic/Fluvaquentic, tropofibrists</td>
</tr>
<tr>
<td></td>
<td>Mukah</td>
<td>Clayey/loamy, mixed/siliceous, dysic, hyperthermic, terric tropofibrists</td>
</tr>
<tr>
<td></td>
<td>Igan</td>
<td>Sandy, siliceous, dysic, hyperthermic, terric tropofibrists</td>
</tr>
</tbody>
</table>

Table. 2: Soil phase for Anderson Series

<table>
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<th>Soil Phase</th>
<th>Depth of peat (cm)</th>
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<tr>
<td>Anderson 1</td>
<td>150-200</td>
</tr>
<tr>
<td>Anderson 2</td>
<td>200-250</td>
</tr>
<tr>
<td>Anderson 3</td>
<td>&gt;250</td>
</tr>
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</table>

Other outstanding characteristics of a typical woody or fibrous organic soil is its almost
invariably loose physical condition. Humified organic matter is largely colloidal and possesses high
adsorptive powers, but the cohesion and plasticity is rather low. The permeability in Histosols is
important since this reflects the continuity of pores within the soil and also the size
of the pores (Evans, et. al. 1950). In Histosols the water flow generally faster horizontally phase than
vertically. However, there is a lack of information on the influence of spatial variability on the flow
of water through this soil type.
The cation exchange capacities (CEC) of organic colloids are very high (Brady, 1990). A highly charge micelle is surrounded by swarm of cations and the negative charges of humus are associated with partially dissociated enolic, carboxyl and phenolic groups (Brady, 1990). Physical indicators may be obtained from sample observation. Exposure of subsoil, change in soil colour and deposition of foreign organic and inorganic material are examples of potential locally determined indicators. Field evidence can be a clear indication that the soil quality is threatened or changing (NRCS, 1996). Physical indicators are related to arrangement of solid particles and water flow rate. Examples include bulk density, degree of decomposition, soil composition and shrinkage percentage. Physical indicators primarily reflect limitations to root growth, infiltration or movement of water within the soil profile.

Chemical indicators include measurements of pH, elemental composition and cation exchange capacity (CEC), those that are needed for plant growth and efficient fertilizer application. In order to ensure the efficiency and sustainable utilization of Histosols, it is imperative that the quality be ascertained first in order that constant monitoring of properties and any remediation measures will be facilitated. There is a lack of knowledge on the fundamental behavior and properties of Histosols. It is imperative that a detail study be undertaken in a careful and systematic manner in order that sustainable utilization and conservation of such soils can be achieved.

2.3 SAGO PALM PLANTATION IN SARAWAK

Palms constitute one of the oldest family of plants on earth. Several cultural groups have developed self-sufficient economies based on various palms. Examples of such groups are the West Africans based on the oil palm (*Elaeis quineensis*) and the Moluccans based on the sago palm (*Metroxylon*
sagu Rottboll) (Tan, 1983). Before the emergence of rice, sago (*Metroxylon sagu* Rottboll) was the main source of sustenance for the inhabitants of the Malay Archipelago region. Malaysia is facing scarcity of land for agriculture development. Unfortunately, sago is now only a minor crop in Peninsular Malaysia, with its acreage less than 1 percent of the total land use under agriculture. The biggest sago areas in Malaysia are to be found outside the Peninsular, in the state of Sarawak. Malaysia is facing scarcity of land for agriculture development. In order to introduce new commodity, land availability of prime areas become a major issue. Even in Sarawak which has the biggest peat land of about 100,000 hectares are shallow peat, many plantations such as oil palm plantations are competing to develop on shallow peat (PELITA, 2013).

Presently, sago is grown in Sarawak as a smallholder's crop. In view of the current sago logs production which is dominated by the smallholders and the total raw materials produced cannot give continuous support to the demand of the 9 modern factories in Mukah and Dalat areas. These factories consumed about 245,000 sago logs a year while the sago smallholdings can only supply about 202,500 logs per year due to low productivity (PELITA, 2013).

In order to increase the raw material production, Land Custody and Development Authority of Sarawak (or termed LCDA), a government statutory body, has started the development of three sago plantations – one located at the boundary between Oya and Igan known as the Dalat Sago Plantation which is 6,722 hectares and the others located in the Mukah District known as the Mukah Sago Plantation with an area of 7,486 hectares and Sebakong Sago Plantation with an area of 3,640 hectares (PELITA, 2013). Plantation agriculture is a long term investment. Currently, sago exports ranks as the fourth biggest agricultural revenue earner for Sarawak after oil palm, rubber and pepper. Sago brought in RM91.3 million in export earnings in 2011, overtaking the export of cocoa in value...
terms in that particular year. The exports of sago from Sarawak over the years are as shown in Table 3.

Table. 3: Export value of agricultural products 2002-2011 (Source: Department of Agriculture Sarawak (DOA) statistic 2011)

<table>
<thead>
<tr>
<th>Year</th>
<th>Oil Palm</th>
<th>Rubber</th>
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<th>Sago</th>
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<td>1026378</td>
<td>14103</td>
<td>138491</td>
<td>32165</td>
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<td>2004</td>
<td>1944137</td>
<td>104108</td>
<td>116151</td>
<td>37020</td>
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<td>147625</td>
<td>144812</td>
<td>62192</td>
<td>9841</td>
</tr>
<tr>
<td>2010</td>
<td>6253074</td>
<td>329722</td>
<td>193637</td>
<td>62832</td>
<td>13229</td>
</tr>
<tr>
<td>2011</td>
<td>9193640</td>
<td>489778</td>
<td>286436</td>
<td>91344</td>
<td>6832</td>
</tr>
</tbody>
</table>

Water shortage is detrimental to sago palm growth. The groundwater level should be at the most 40-50 cm below the soil surface (Flach, 1989). On the notoriously poor and usually undrained peat soils, sago palm grows 25% more slowly than on mineral soils (Jong and Flach, 1995). The development of a functional water management system – involving drainage but also maintenance of
a water table close to the surface to prevent excessive drying – is a prerequisite step for successful sago palm establishment on peat.

In plantations, the palm propagates itself through vegetative propagation by means of suckers, mostly growing from the lowest leaf axils. Suckers may start trunk formation close to the original trunk; they do so by means of a horizontal stem, the stolon. With full light in the surrounding area, e.g. in a paddy field, the stolon may become up to 6 m long. In wet and clayish soils, the stolon grows on top of the soil. In drier conditions, on lighter soils, it grows in the soil. In the long run, suckers are separated from the original trunk, thus forming new clusters. Occasionally, suckers may be formed higher up on the bole. Usually the harvested part is the trunk whereby the starch is obtained from the bole, which is cut into logs measuring 1 meter in length, which are rolled out of the planting area to the nearest waterway and then floated by river or transported by land to the factory. Harvesting is most suitable when the trunks are considered to be mature and close to flower initiation, when the inflorescence first begins to form in its growing point. It has an exceptionally high yield level. Under good conditions, the yield varies from at least 1.5 t to possibly 25 t of dry starch/ha. This is higher than that of any other starch crop (Flach, 1977).

2.4 PRODUCTION TRENDS OF SAGO PALM IN SARAWAK

Sarawak, which is now the world’s biggest exporter of sago, exporting annually about 25,000 to 40,000 tons of sago product to peninsular Malaysia, Japan, Taiwan, Singapore and other countries. Since 1984, there has been an upturn in the export of sago starch, earning the state USD 11.4 million in revenues (PELITA, 2013).

Sarawak has a total of 1.60 million hectares of peat land of which about 54,905ha or 3.4% (Figure. 1) are covered with sago mostly located at riverbank areas of Batang Rimbas, Batang Saribas,
Batang Krian, Batang Igan, Batang Mukah, Batang Oya and Batang Balingian managed under the traditional smallholding system and plantation system. Currently, the sago industry is dependent totally on the smallholders’ performance. The production capacity of the sago palm varies from 2 to 5 tons/ha of dry starch/ha in the wild areas to 10-25 tons/ha in the case of smallholding area. (Abd-Aziz, 2002). Over the past three decades, there has been a significant growth in terms of absolute export value contribution of the sago commodity, increasing from 20.5 million in 1991 to RM 26 million in 2001 then to RM 91.3 million in 2011 and projected to RM 125.4 million in 2020. This growth trend is depicted in Figure. 2 and 3.

Fig.1: Total Sago planted area in Sarawak (Sources: Department of Agricultural Sarawak (DOA) Statistic 2011)

Fig. 2: Sarawak Sago Export Performance in Metric tonne (sources: PELITA, 2013)
Fig. 3: Sarawak Sago Export Performance in Ringgit (sources: PELITA, 2013)
3.0 METHODOLOGY

3.1 STUDY AREA

The sago palm plantations selected are owned by PELITA and the research station is owned by CRAUN Sdn. Bhd. Sebakong Sago Plantation (SSP), is located in Mukah (N02°44'44.5" E112°09'21.0"), while the Sungai Talau Research Station (STRS) is located in Dalat (N02°48'59.0" E111°54'22.4") (Figure 4). The sampling units were selected based on the growth performance of sago palm which is according to the standard monitoring standard (Table 4) by CRAUN (CRAUN, 2010). The growth performance indicators were based on number of fronds and the stages of the palm. Three sampling units in poor sago growth areas and two sampling units in good sago growth areas were identified (Table 5).

Fig. 4: Area of Sebakong plantation and Sungai-Talau Research Station
Table 4: Sago palm physical indicator standard

<table>
<thead>
<tr>
<th>Palm Age</th>
<th>Growth Stage</th>
<th>Frond Count</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 5 years old</td>
<td>Rosette</td>
<td>16-24</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-15</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;10</td>
<td>Poor</td>
</tr>
<tr>
<td>More than 5 years old</td>
<td>Trunking</td>
<td>15-20</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-14</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;10</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Table 5: Areas of sampling units

<table>
<thead>
<tr>
<th>Location</th>
<th>Sampling Unit</th>
<th>Peat Depth</th>
<th>Water Table (cm)</th>
<th>Growth performance</th>
<th>Stages</th>
<th>Age Stand</th>
<th>Fronds count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sebakong Sago Plantation (SSP)</td>
<td>1</td>
<td>Deep (&gt;5m)</td>
<td>0-30</td>
<td>Poor</td>
<td>Trunking stage</td>
<td>10 yr</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Deep (&gt;5m)</td>
<td>30-60</td>
<td>Poor</td>
<td>Trunking stage</td>
<td>10 yr</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Deep (&gt;5m)</td>
<td>30-60</td>
<td>Poor</td>
<td>Trunking stage</td>
<td>10 yr</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Sungai Talau Research station (STRS)</td>
<td>1</td>
<td>Shallow (&lt;1m)</td>
<td>0-30</td>
<td>Good</td>
<td>Trunking stage</td>
<td>7 yr</td>
<td>&gt;15</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Shallow (&lt;1m)</td>
<td>0-30</td>
<td>Good</td>
<td>Rosette</td>
<td>3 yr</td>
<td>&gt;16</td>
</tr>
</tbody>
</table>