A Simple Model to Simulate Sago Palm Growth

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Abstract

The interest in sago palm has been increasing over the past few decades. This attention can be attributed to the beneficial characteristics of this plant, as both a commercially viable and environmentally friendly crop. In attempts to increase sago palm utilization, the application of crop models that estimate sago palm growth has assumed increasing importance. Many analyses regarding the management planning of sago palm stands or plantations can be assisted by crop models. However, applying one of the generic crop models currently available in the literature often requires parameters that may not be available. Given the limitations inherent in direct observation of the entire life cycle of this crop, the authors propose a simple sago palm growth model that combines a deterministic model from previously developed generic crop models and a regression model derived from collected field data. The model considers two processes, i.e., crop development and crop growth. Development relates to the physiological age of the plant and to its morphological appearances, which is estimated by using the thermal unit concept. Growth refers to the increase in weight, volume, length, and area of certain parts or all of the plant. The dry matter was calculated based on intercepted solar radiation and then allocated to each of the plant’s organs according to a stage development function. Simulation results obtained when the model was applied in the study area demonstrated that the model gave a good estimate of sago palm yield.

Keywords: sago palm, growth model, crop simulation

Introduction

In Indonesia, sago palm has played the important role in socio-economic and cultural aspect since hundred years ago. Oates (1999) stated that by the early 14th century sago palm was the major agricultural product in the region between South Mindanaoa and Northern Borneo, South Sulawesi and the Maluku Islands. It was also reported that sago processing had been found in Sumatra in 1298 (Oates & Hicks, 2002). Currently, sago palm areas may be found approximately one million hectares distributed in Papua, Molucca (Seram Island and Halmahera Island), Kalimantan (West Kalimantan), Sulawesi and Sumatra (Riau). Most of these areas are natural sago stands, spread over low lands, coastal regions and river deltas of Papua, Seram, Halmahera, and Riau. In other areas, most of the currently found sago stands are cultivated stands which grow un-maintained and uncontrolled, and form sago forest. Sago palm is limited found in Java Island, such as Banten, and few areas in Northern shore of Middle Java.
Sago palm has become more attractive significantly in the last decade. It is regarding to the various advantages of the crop, such as economically acceptable, relatively sustainable, environmentally friendly, uniquely versatile, vigorous, and promotes socially stable agro-forestry systems. Attempts to utilize the crop are also increasing, either in harvesting sago palm from its natural stands or establishing new plantations.

As the interest in sago palm continues to grow, the application of crop models to this crop will assume increasing importance. Many analyses relating to the farm management including strategic, tactical and operational management of sago palm stands or plantations can be assisted by crop models. Using a model may reduce failure risk of field activities, that would save time and cost.

Applying the available generic crop models without any modifications seem to be difficult in case of sago palm. Many crop specific parameters are not applicable to sago palm. Therefore this study was aimed to obtain some parameters specific for sago palm to be used in growth simulation model, such as sago leaf characteristics and partitioning of above ground dry matter into each crop organs. By using these results, a simple model to estimate sago palm growth was developed. The model is assuming that sago palm grows under optimum environmental conditions without water and nutrient limitations and pest or disease attacks.

Model Structure
The model comprises two sub models dealing with phenology and crop growth. The phenology submodel determines the rate of crop development based on thermal response similar to Handoko (1992). It is used to determine partitioning of crop assimilate between component organs, such as root, leaf, trunk, flowers and or fruits. The crop assimilation is calculated in crop growth sub model from intercepted solar radiation.

Crop Phenology
The developmental stages of sago palm have been observed by several researchers. Flach (1997) proposed a simple model of sago palm development consisting of four stages: the rosette, bole formation, inflorescence, and fruit-ripening stages. In contrast, Jong (1995) identified 12 stages of sago palm development: the rosette, trunk formation, early trunk growth (2 stages), mid trunk growth, late trunk growth, full trunk growth, bolting, flowering, young fruiting, mature fruiting, and dying stages.

In order to simplify the sago palm life cycle, the model presented here adopts the development stage terminology of Flach (1997). Since the common practice of propagating sago is by mean of suckers, the phenological model started the cycle from planting, and continued through trunk formation, flowering, and fruit-ripening stages. The stages are aligned on a scale ranging from 0 to 1, where 0 corresponds to the stage of sucker planting and 1 corresponds to the timing of palm death (Fig. 1).

![Fig. 1. Phenological model of sago palm](image)

Crop Growth
The growth model simulates the daily gains and loses of leaf, trunk, root, flower, and fruit biomass. The scheme of dry matter production is adopted from Monteith (Monteith, 1977).
Dry matter conversion results from the interception of solar radiation by the crop canopy. The efficiency of solar radiation, which is usually referred to as light-use efficiency, determines the portion of the radiation converted into dry matter.

**Simulation Methods**

**Simulation Area**

The simulation area for the present study was Bengkalis (Tebingtinggi sub-district), which is located in Riau Province, Indonesia. It is one of sub-districts that are considered as potential areas for sago palm development in Bengkalis Regency. Most of sago starch produced in this area is sent as a raw material for food industries in Cirebon (Java Island). In addition to small holding sago palm gardens, which account for the majority of production in this sub-district, a sago plantation, commercially managed by private company, has been established since 1996.

**Model Parameterization**

**Phenology.** Duration of each phenological stage was calculated as heat sum (the difference between air temperature and crop critical temperature) and applied to the data of development sequences of sago palm observed by Jong (1995) and Flach (1997). It was found that duration of sago palm phenological stage are 23000 degree.days.Celcius (ddC), 25000 ddC, 5000 ddC, and 9000 ddC respectively for rosette, trunk formation, flowering, and fruit-ripening stage.

**Sago leaf characteristics.** Study on sago leaf was aimed to obtain a basis for calculation leaf area index, which is stated in term of specific leaf area (SLA). The analysis results from several palms sampled from local gardens show that SLA varied between leaf to leaf within a plant without consistent trend. However, the average SLA of the same leaf number show a slight decreasing trend from younger leaves to the older leaves. The average value of SLA within a plant show young palms have SLA relatively higher compared to the older palms.

**Above ground dry matter (AGD) partitioning.** The analysis of sampled palms from two different gardens shows that during rosette stage, most of AGD was allocated to leaf formation. In the next stage (trunk formation) allocation of AGD to leaf formation was decreasing, while to trunk formation is increasing significantly. In the flowering and fruit-ripening stage, most of AGD was allocated to flower/fruit formation. In the other hand, allocation to leaf and trunk formation changed slightly following the previous pattern, for simplicity they are assumed to be equal to zero.

**Simulation Results**

**Phenology.** The phenological model applied to six palms sampled from local garden in Bengkalis, Indonesia. The results show that s values estimated from the model can describe well the actual stage of the palm (Table 1). The results were especially good during early stages. The s values for stages between harvest and palm death seems to be slightly deviated from the actual stages. The sago palm which was estimated to be 15 years old was found still alive with several fronds in senescence process. However, the actual condition show that these palm should be in stage around s = 0.9 until s = 0.95. These deviations were difficult to avoid, since the basis of s calculation in crop age which was solely depend on farmers’ memory.
Table 1. Simulation results of phenological model

<table>
<thead>
<tr>
<th>Estimated Age (years)</th>
<th>Stage</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rossette</td>
<td>0.0460</td>
</tr>
<tr>
<td>4</td>
<td>Rossette</td>
<td>0.1842</td>
</tr>
<tr>
<td>5</td>
<td>Early trunk formation</td>
<td>0.2301</td>
</tr>
<tr>
<td>7</td>
<td>Mid trunk formation</td>
<td>0.3221</td>
</tr>
<tr>
<td>11</td>
<td>About harvest time</td>
<td>0.6030</td>
</tr>
<tr>
<td>15</td>
<td>Fruits have dried</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

**Crop growth.** Based on simulation results, the sago palm in Bengkalis, where the average air temperature is 26.5 °C, may yield 100 kg of dried starch per palm (Fig. 2.). Crop can be harvested optimally at 12.43 years (s = 0.56), although the common practice is to harvest at 12 years (Jong, 2001). Harvesting sago palms before and after this optimum time will reduce the potential starch yield.

![Dry matter content per palm](image)

**Fig. 2.** Estimated starch content per palm in Bengkalis

**Discussion**

The need of assistance tool to manage sago palm stand into a sustainable land or field is a background of this study to develop a growth model. The conceptual model proposed here is not completely new, since the model uses many conventional equations available in crop modeling literature. The original part offered by this study is the derivation of many parameters specific for sago palm from field experiments.

In general, performance of the growth model which simply need weather data as the input is good. Some small errors have still occurred due to its inherent simplifications, especially in simulating the last stage of sago palm life cycle. Fortunately, the common practice of sago palm cultivation is harvesting the mature palm before flowering (some late harvests can be carried out before fruiting) make the errors have small impact in well managed sago plantation or stands.

The author realized the limitation of the growth model proposed in this study, but it is believed as a good step for future studies toward a more adequate and applicable model in management of sago palm plantation. Increasing number of samples will increase the
reliability of derived equations, and furthermore increasing variable considered in the model (such as water, nitrogen, and crop competition variables) may increase the complexity of the model and finally will increase its similarity with the real field conditions.

References


