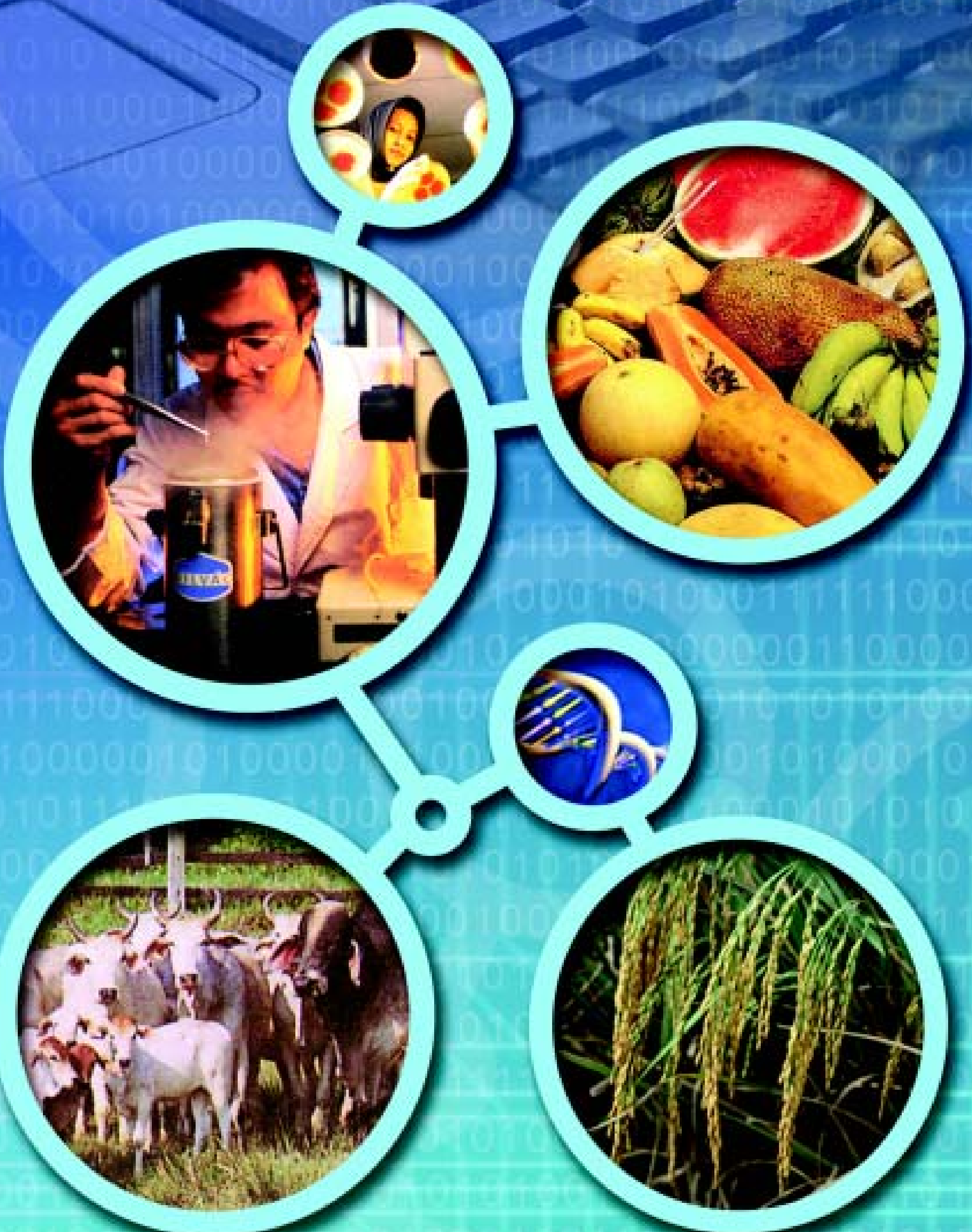
National Conference On
AgrICT2005

Theme: Revolutionising Agriculture Through ICT

PROCEEDINGS



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Edited by
Dr. Ibni Hajar Rukunudin
Dr. Umi Kalsom Abu Bakar
Dr. Mohd Norowi Hamid
Dr. Chan Chee Wan
Muhamad Isa Othman
Muhammad Zamharir Ahmad

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SIMULATING OIL PALM GROWTH AND YIELD

Teh, C. B. S[1]., Henson, I[2]., Harun, H[2]., Goh, K. J[3]., and Husni, M. H. A[1].
Department of Land Management[1], University Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia.
Email: chris@agri.upm.edu.my; Tel: 03-89466976

[2] Malaysian Palm Oil Board, Bangi, Selangor, Malaysia.

[3]Applied Agric. Res. Sdn. Bhd., Sg. Buloh, Selangor, Malaysia.

Keywords: oil palm; model; flower; transpiration; evaporation; growth; yield

ABSTRACT

The objective of this study was to develop a semi-mechanistic model to simulate the oil palm growth and yield. The model consisted of four core components: a) 3-D ray tracing to simulate the plant-radiation regime, b) growth model, adapting from the growth model by van Kraalingen *et al.* (1989), c) water balance model, allowing for interaction between the heat and water fluxes from the soil and plant, and d) flowering cycle model. The growth and yield of oil palm was effected by water and flower cycle stresses. Simulation of oil palm growth and yield for a 30-year period from 1974 to 2003, using actual weather and field conditions, were done. Simulations followed trend usually observed in field conditions. Ongoing work is now to compare model simulations and field measurements.

INTRODUCTION

There has been very few mechanistic-based models on oil palm. Most notably is the model by van Kraalingen *et al.* (1989) whose model was developed based on the generic plant growth model SUCROS (van Keulen *et al.*, 1982). Other oil palm models are not holistic as they concentrate on certain processes or development of oil palm such as the plant-radiation regime in the oil palm environment, and the flowering cycle (Jones, 1997) and photosynthesis (Henson, 1998) of oil palm. Consequently, there is a need to further develop the oil palm model by van Kraalingen *et al.* (1989), modifying it to local conditions and to develop it, using the current knowledge of oil palm. Therefore, the main objective of this paper was to develop a semi-mechanistic model to simulate the oil palm growth and yield, taking into account water and flowering stresses.

MATERIALS AND METHODS

The model has four core components. The first component modelled the plant-radiation environment using a detailed 3-D ray tracing method. Firstly, the oil palm canopy was divided into a network of 3-D cuboids, where for each cuboid, three properties must be calculated: 1) leaf area, 2) leaf orientation, and 3) mean path length of solar beam. And secondly, to calculate these properties, algorithms from computer graphics, namely polygon clipping and ray-tracing, were adapted. This component also modelled the separate interception of direct and diffuse solar radiation by the oil palm canopy.

The second component modelled the oil palm growth. The growth component in the model by van Kraalingen *et al.* (1989) was adapted. The trunk height growth was based on an empirical relationship established from measured data from previous works. The growth of the oil palm canopy (width and height) was also based on measured data. One major deviation from van Kraalingen *et al.*'s model is this study's model accounts for the factor of water stress on oil palm growth and yield, where reduction in gross photosynthesis was directly in proportion to the degree of water stress.

The third core component was for modelling the water balance in the oil palm environment. Oil palm water use, transpiration and soil evaporation were modelled based on the Shuttleworth-Wallace (Shuttleworth and Wallace, 1985) equation which allows for the interaction of heat fluxes between the tree and soil. The water balance for two soil depths (0-20 mm and 20 mm until rooting depth) were also modelled to determine the critical water amount based on a generic C3 plant. Thus, the oil palm growth and yield would decrease in proportion to the critical water level.

The fourth component modelled the flowering pattern of oil palm. The model by Jones (1997) was adapted, which allows for the setting of threshold values for male, female, mixed and aborted flowers. This component is essential because it allows for the annual cycle of oil palm yield often seen in the fields.

Additionally, this study oil palm model was developed to account for various land slope (elevation) and direction, and planting arrangement, direction and density.

Trial runs of the model were done based on actual field and weather conditions of Serdang, Selangor area, using actual weather and soil conditions. Simulations were for 30 years from 1974 to 2003, where the soil type was Bungor series, planting density was 148 palms ha^{-1} with a N-S planting orientation and with no slope elevation.

RESULTS AND DISCUSSION

Figure 1 – 6 show the simulation results of the oil palm growth and yield model. In particular, simulation of oil palm yield fluctuate after ten years, as observed in field conditions (Figure 1). These fluctuations were caused by water and flowering stresses which would decrease growth. An increase production of female flowers would increase the number of bunches formed and increase yield; however, increasing female flowers would elevate stress and in turn cause male or aborted flowers to form in the next cycle. Thus, the oil palm yield would fluctuate from high (high number of female flowers) to low (high number of aborted or male flowers).

Figure 2 and 3 show the steady increase in above ground dry matter (which would steady at about 150 kg palm^{-1} year^{-1}) and LAI (which would reach a maximum of 6 m^{2} m^{-2}). Oil palm trunk height was simulated from an empirical equation developed from field measurements from various studies (Figure 4). Trunk height often appeared insensitive to environmental stresses.

As expected, oil palm transpiration would be low at the beginning as the tree is relatively small as compared to the bare soil (Figure 5). In contrast, soil evaporation was higher in the early growth stages. However, as the palm matured and covered increasingly more of the bare soil, the oil palm transpiration exceeded that of soil evaporation. Potential evapotranspiration averaged at about 5 mm day^{-1}. Soil water content in the oil palm rooting depth would fluctuate according to the rainfall and water balance of the environment, fluctuating between soil saturation and very dry soil.

This work is currently still ongoing. Further development is now to compare model simulations against actual field conditions as model validation.

ACKNOWLEDGMENTS

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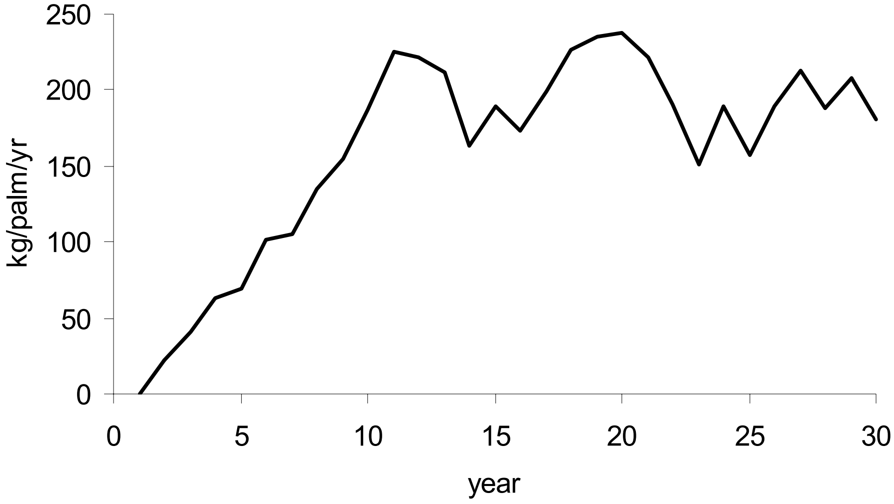

FIGURE 1. Simulation of the Oil Palm Yield

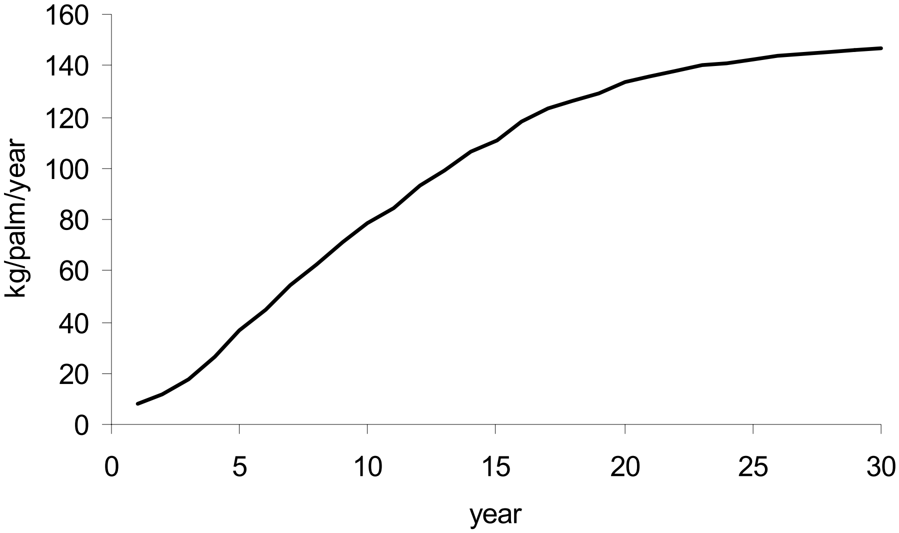

FIGURE 2. Simulation of the Above Ground Dry Matter of Oil Palm

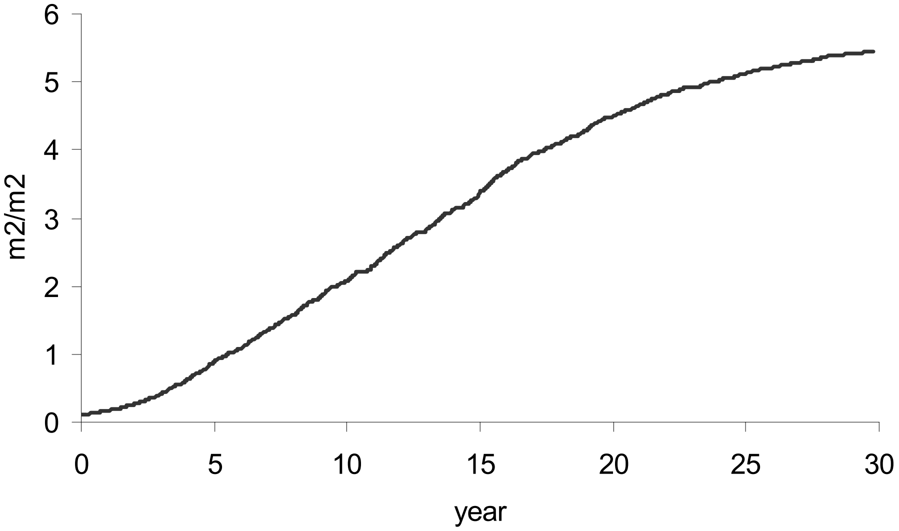

FIGURE 3. Simulation of the Leaf Area Index (LAI)

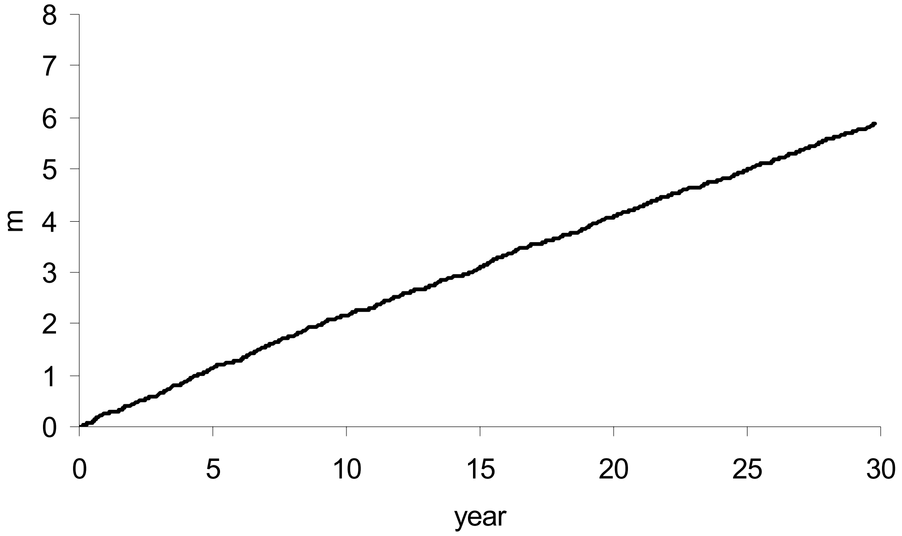

FIGURE 4. Simulation of the Oil Palm Trunk Height

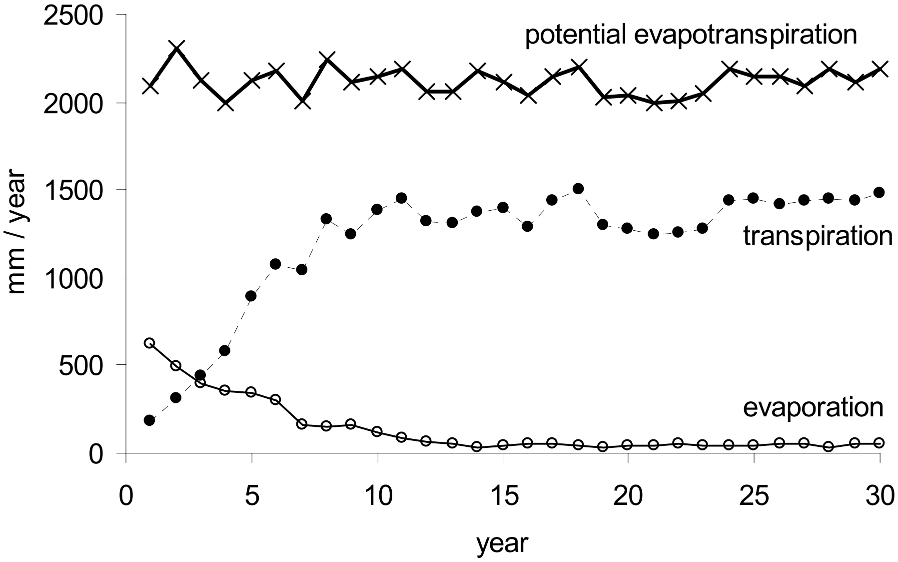

FIGURE 5. Simulation of the Annual Soil Evaporation, Oil Palm Transpiration and Potential Evapotranspiration

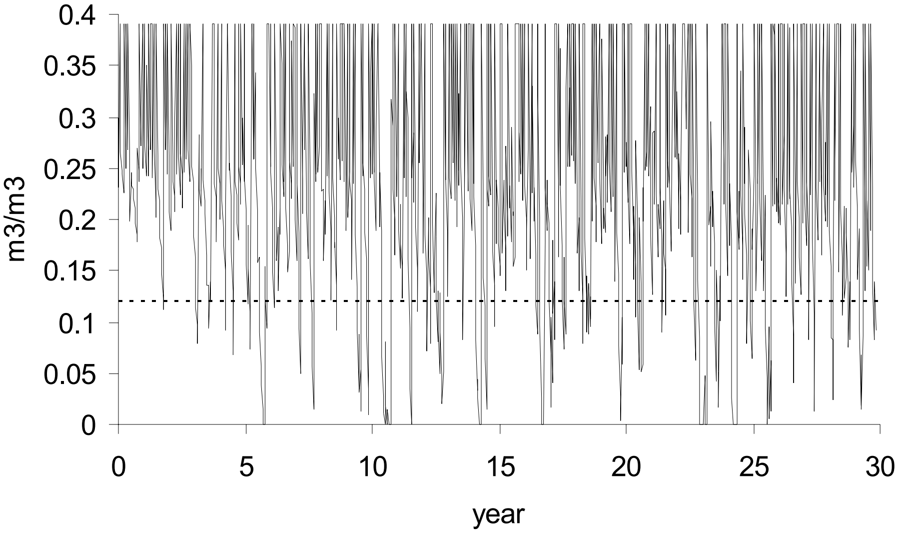

FIGURE 6. Simulation of the Soil Water Amount Within the Rooting Zone. Note: dotted line is the soil permenant wilting point.