UNIVERSITI PUTRA MALAYSIA

MODELLING OF SOLAR RADIATION INTERCEPTION AND BIOMASS PRODUCTION IN AN INTERCROPPING SYSTEM OF RUBBER WITH BANANA AND PINEAPPLE

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MODELLING OF SOLAR RADIATION INTERCEPTION AND BIOMASS PRODUCTION IN AN INTERCROPPING SYSTEM OF RUBBER WITH BANANA AND PINEAPPLE

By

MOHAMADU BOYIE JALLOH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of Requirement for the Degree of Doctor of Philosophy

October 2003

This Thesis is dedicated to:

My Late

Guardian, Constance Agatha Cummings-John (Mammy)
Grandfather, Musa Jalloh (Grandpa)
Who were always hungry and enthusiastic in their desire and support to see me attain the highest of levels in the Academia.
May God Grant them Eternal Rest.

My Dear Parents

Chernor Jalloh and Fatmata Jalloh
The enduring parental and other support, love, encouragement patience and understanding toward me, and my siblings are priceless.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

MODELLING OF SOLAR RADIATION INTERCEPTION AND BIOMASS PRODUCTION IN AN INTERCROPPING SYSTEM OF RUBBER WITH BANANA AND PINEAPPLE

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Chairman : Associate Professor Jamal bin Talib, Ph.D.

Faculty : Agriculture

Simulation modelling is a powerful approach for studying complex intercropping systems in entirety and a complementary tool to conventional field experiments.

This study aimed to: 1) construct a dynamic model to simulate the biological productivity of an immature rubber (R), banana (B) and pineapple (P) intercropping system based on the interception and utilisation of incident solar radiation (SR), 2) evaluate growth and yield of the intercrop components using the model, 3) compare production for various cropping scenarios and 4) investigate the likelihood and effects of water stress on crop growth using a simple water budget.

A FORTRAN computer model, **SURHIS** (**S**haring and **U**tilisation of **R**adiation intercepted in a **H**edgerow-**I**ntercropping **S**ystem), was developed for simulating daily SR interception and growth of R-B-P intercropping system. SR interception was modelled using a modified Monsi-Saeki equation by including a clump factor to account for the loss in intercepted SR resulting from the wide row spacing between the crops. Crop growth was modelled based on the net biomass resulting from the difference between crop photosynthesis and respiration.

Simulation results showed that increments in the leaf area index (LAI) had a greater effect on SR interception by component crops compared to height increments. Changes in height affected only fractional interception, whereas LAI increments affected both fractional and total interception.

The crop growth modules were sufficiently accurate in estimating LAI and dry matter yield (DMY) but less precise for crop height. The girth of rubber was estimated with good accuracy. The general trend in overestimation for later part of the simulation period can be attributed to model assumptions for potential production conditions.

The intercropping system showed a DMY productivity advantage of 81% over the component monocrops grown at optimum population densities (PD). Higher PD resulted in greater DMY but fruit weight per plant of B and P in the

monocrop systems reduced with increased PD. There was no deleterious effect from resource competition between R, B and P on the growth of rubber.

The model estimated 24 t ha^{-1} of carbon sequestration by the three crops over 265 days after planting, with R, B and P, contributing 10, 13 and 1 t ha^{-1}, respectively.

The water budget analysis for the field plot in Taiping, showed that soil moisture storage resulting from normal rainfall was sufficient to supply the water requirements of all crops. Cumulative water requirements of R, B and P, 280 days after planting were 364, 920 and 494 mm, respectively.

The model has immediate applications in prioritising research in R-B-P, intercropping systems. With appropriate modifications, the model can be readily adopted for productivity analysis of similar cropping systems involving other crops.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PERMODELAN PINTASAN RADIASI SOLAR DAN PENGHASILAN BIOMASS DALAM SISTEM TANAMAN SELANG ANTARA GETAH DENGAN PISANG DAN NENAS

Oleh

MOHAMADU BOYIE JALLOH

Oktober 2003

Pengerusi : Profesor Madya Jamal bin Talib, Ph.D.

Fakulti : Pertanian

Model simulasi merupakan satu pendekatan yang berkesan untuk mengkaji sistem tanaman selang yang kompleks secara menyeluruh dan menjadi alat pelengkap kepada kajian ladang yang konvensional.

Kajian ini bertujuan untuk: 1) membena model dinamik yang boleh mensimulasikan potensi pengeluaran biologi sistem tanaman selang getah belum matang (R), pisang (B) dan nenas (P) berasaskan kepada pintasan dan penggunaan radiasi solar (SR) insiden, 2) menilai tumbesaran dan hasil komponen tanaman selang dengan menggunakan model, 3) membandingkan hasil pengeluaran akibat senario penanaman yang berbagai dan 4) menyiasat kemungkinan kejadian tegasan air dan kesannya terhadap tumbesaran tanaman-tanaman dengan menggunakan bajet air yang mudah.

Satu model komputer FORTRAN, **SURHIS** (***S****haring and* ***U****tilisation of* ***R****adiation intercepted in a* ***H****edgerow-****I****ntercropping* ***S****ystem* atau Perkongsian dan Penggunaan Pintasan Radiasi dalam Sistem Tanaman Selang Berpagar) dibena untuk mensimulasikan pintasan SR dan tumbesaran tanaman harian bagi sistem tanaman selang R-B-P. Pintasan SR dimodelkan dengan menggunakan persamaan Monsi-Saeki dengan memasukan factor *clump* untuk mengambil kira kehilangan pintasan SR akibat dari jarak baris antara tanaman yang lebar. Tumbesaran tanaman dimodelkan berdasarkan kepada *net biomass* yang dihasilkan akibat dari perbezaan antara fotosintesis dan respirasi tanaman.

Keputusan simulasi menunjukkan bahawa penambahan dalam indeks luas daun (LAI) membawa kesan yang lebih besar keatas pintasan SR berbanding dengan kesan akibat penambahan ketinggian tanaman-tanaman komponen. Perubahan ketinggian tanaman memberi kesan kepada hanya pintasan *fractional*, sementara penambahan LAI memberi kesan kepada kedua-dua pintasan *fractional* dan jumlah.

Modul tumbesaran tanaman adalah mencukupi dan segi ketepatannya bagi menganggarkan LAI dan hasil bahan kering (DMY) tetapi kurang tepat untuk ketinggian tanaman. Anggaran ukuran lilitan batang getah diperolehi dengan ketepatan yang baik. Kecenderungan terlebih anggaran (*overestimation*) pada bahagian masa simulasi yang terkemudian mungkin disebabkan oleh andaian yang dibuat untuk pengeluaran hasil potensi.

Sistem tanaman selang ini menunjukkan pengeluaran DMY 81% lebih baik dari sistem tanaman tunggal (monocrop) apabila ditanam pada kepadatan populasi (PD) tanaman optimum. Lebih tinggi PD, mengakibatkan lebih tinggi DMY, tetapi berat buah per tanaman B dan P berkurangan dengan penambahan PD. Tiada terdapat kesan buruk dari persaingan SR antara R, B dan P terhadap tumbesaran getah.

Model menganggarkan 24 t ha^{-1} karbon yang telah digunakan oleh ketiga-tiga tanaman 265 hari selepas ditanam di mana R, B dan P menyumbang 10, 13 dan 1 t ha^{-1} masing-masingnya.

Analisis bajet air bagi plot tanah di Taiping menunjukkan bahawa simpanan kelembapan tanah yang diperolehi dari hujan adalah mencukupi untuk memenuhi keperluan air tanaman-tanaman tersebut. Keperluan air kumulatif untuk tanaman R, B dan P, 280 hari selepas ditanam adalah 364, 920 dan 494 mm masing-masingnya.

Model ini boleh digunakan untuk menentukan keutamaan bagi penyelidikan sistem tanaman selang R-B-P. Dengan modifikasi tertentu, model ini juga sesuai digunakan untuk membuat analisis pengeluaran sistem penanaman selang yang melibatkan tanaman yang lain.

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I certify that an Examination Committee has met on October 8th 2003 to conduct the final examination of Mohamadu Boyie Jalloh on his Doctor of Philosophy thesis entitled "Modelling of Solar Radiation Interception and Biomass Production in an Intercropping System of Rubber with Banana and Pineapple" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the supervisory committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MOHAMADU BOYIE JALLOH

Date: 6th Jan 2004

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES