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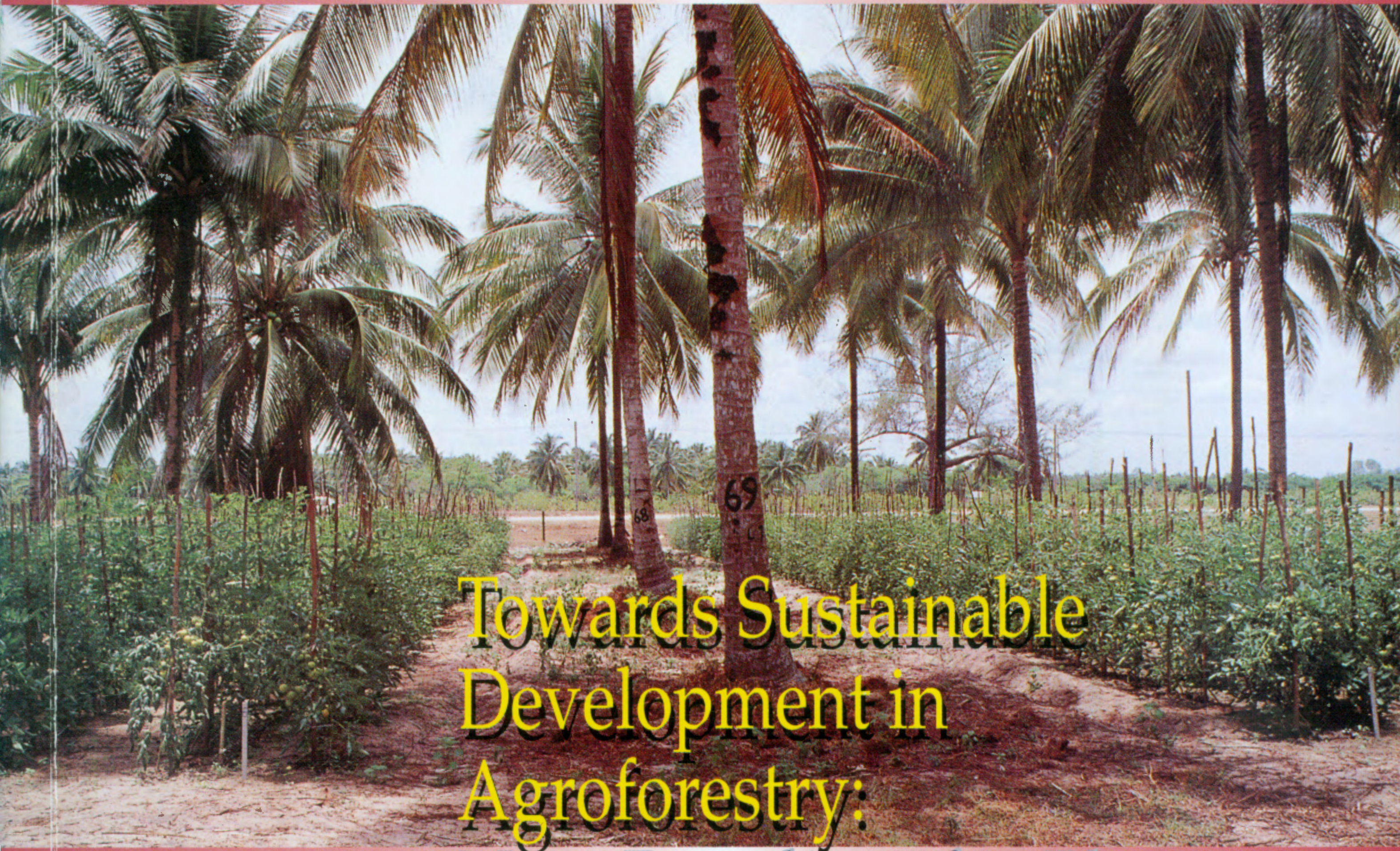

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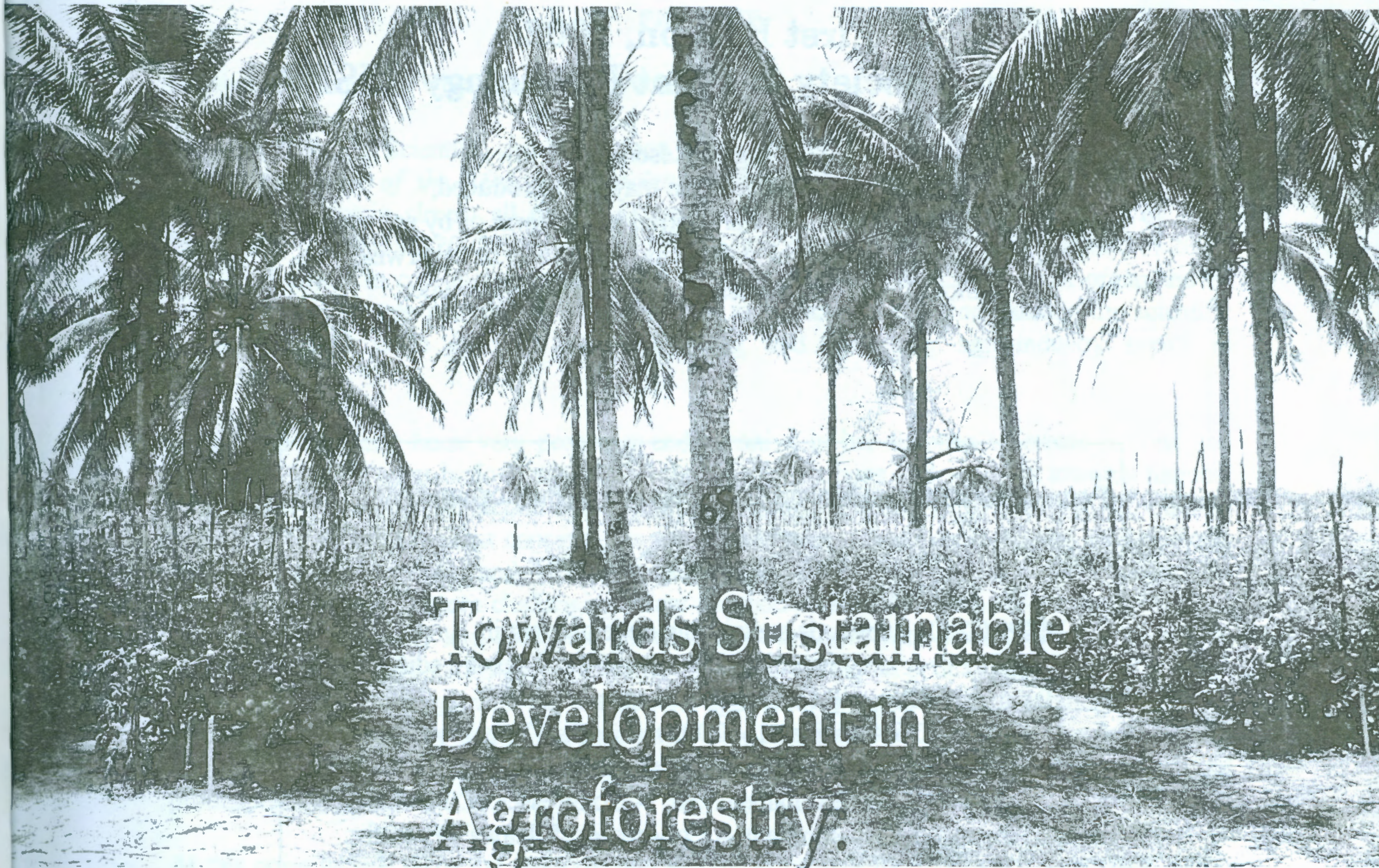

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RADINT: A MODEL FOR LIGHT PARTITIONING IN IMMATURE RUBBER, BANANA AND PINEAPPLE HEDGEROW-INTERCROPPING SYSTEM

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ABSTRACT

Light measurement in mixed, heterogeneous and/or tall canopies is fraught with difficulties and in most cases impracticable. Mathematical models are being widely used now for estimating light interception in a variety of cropping systems. A mathematical model developed to estimate light partitioning in an immature-rubber, banana and pineapple hedgerow-intercropping system is presented. It is based on a modified Monsi-Saeki equation to account for the wide-row gaps that exist in the cropping system, which causes a violation of the assumptions in the aforementioned equation. The simulation results showed that LAI, plant height, canopy width, row-spacing and light extinction coefficient influence light interception and partitioning in the cropping system but to varying extents. LAI affects total light interception as well as partitioning whereas height increment affects only light partitioning.

INTRODUCTION

Photosynthetically Active Radiation (PAR) from intercepted radiation (light) incident on a crop is the only limiting resource for the crop's growth in a potential production situation. Competition for this limited and non-storable resource is therefore inevitable in any cropping system wherein the plants are grown in close proximity, be it a mono or multiple (mixed/intercropping) cropping system. This competition for light is exacerbated as planting density is increased. Competitiveness of plants is also influenced by the morphological characteristics of the plants (Berkowitz, 1988).

PAR is the primary source of energy that drives crop growth processes and therefore its measurement is important and crucial for determining the efficiency of biomass production by crop plants. Measurement of radiation interception by crop plants has been given a lot of attention by crop physiologists. However, it has been realized that with the measuring instruments available to date, it is impracticable in many mixed-canopy cropping scenarios and for tall crops. Measurements can be an expensive exercise and fraught with difficulties in cases where it is possible especially if it involves integration over long growing seasons and the accounting of crop growth dynamics (Trenbath, 1986; Sinoquet & Cruz, 1995). Mathematical models have gained wide acceptance as a good alternative for estimation of radiation interception and partitioning particularly in multi-species cropping systems (Sinoquet *et al*., 2000).

RADINT (**RAD**iation **INT**erception) makes use of the mathematical modelling approach for estimating light partitioning in the cropping system of immature-rubber, banana and pineapple (I-R, B, P). It is an important statistical sub-model of a dynamic and mechanistic crop growth and development simulation model for the I-R, B, P hedgerow-intercropping system named, **SURHIS** (Sharing and Utilization of Radiation intercepted in double Hedgerows Intercropping System). This paper briefly describes **RADINT** and shows simulation results of the influence of some plant morphological characters and row-spacing on light partitioning in the I-R, B, P cropping system studied.

BRIEF MODEL DESCRIPTION

A modified Beer's law first applied by Monsi and Saeki (1953) for light penetration in crop plants is used in **RADINT**, taking into account the spatial heterogeneity of the cropping system. The modification accounts for violations to the assumptions in the use of Beer's law when applied to a wide-row spacing cropping system. These assumptions are a closed canopy with small-sized leaves that are randomly distributed. The following equations (eq) show the original Monsi and Saeki (1953) expression of Beer's law as applied to irradiance (*I*) penetration in plant canopies (eq. 1) and the modified version (eq 2), which includes a clump factor (Ω) for light interception (*A*) for a wide-row crop spacing arrangement (Kustas and Norman, 1999). This is followed by two expressions (eq. 3 & 4) for the light partitioning in the cropping system under consideration.

$$I_h = I_0 \exp(-k_h L_h) \qquad [1]$$

$$A_T = I_0\left[1-\exp\left(-\sum_{i=1}^{n} k_i \Omega L_i\right)\right] \qquad [2]$$

$$A_T = A_R + A_B + A_P \qquad [3]$$

$$A_i = \left(\frac{k_i L_i h_i}{\sum_{j=1}^{n} k_j L_j h_j}\right) \bullet A_T \qquad [4]$$

Where *k*, *L* and *h* represent light extinction coefficient, leaf area index (LAI) and plant height respectively. The subscripts $_h$, $_0$, $_T$, $_R$, $_B$ and $_P$ represent canopy depth, zero depth (i.e above canopy), total, rubber, banana and pineapple respectively.

MATERIALS AND METHODS

The algorithm for **RADINT** was coded in **FORTRAN (FORmula TRANslator)** and executed with FSE (Fortran Simulation Environment), a simulation system for dynamic processes (van Kraalingen, 1995). The computer program was run for different scenarios of *L*, *k*, *h*, row-spacing and canopy-width for the component crops to examine their effects on light partitioning in the I-R, B, P cropping system.

RESULTS AND DISCUSSION

From the simulation results as shown in Figure 1a-f, increments in LAI and height of the component crops showed significant influences on the partitioning of light between the crops. A doubling of the LAI of R resulted in about 30% reduction in light intercepted by P and B with an increase in about 54% in R interception. Doubling the LAI of B on the other hand resulted in a much higher increase in B interception (96.6%) but this had little effect on the interception by R and P as they showed only about 2% drop in interception. The higher interception by B can be explained by the larger doubling of B LAI (0.74) compared to that of R, which was 0.46. As for P, doubling of LAI more than doubled the light interception but the amount is still less than for either R or B. This low interception is understandable as pineapple has a lower *k* than the other crops because of the erectophile nature of the leaves. The results also show that the doubling of LAI of the component crops reduced the % of light not intercepted (% wastage) by between 1.5 and 12.6%.

Doubling of the height of the component crops showed similar trends on the effect of light interception but generally showed a greater effect compared to LAI increments in reducing light interception of the shorter species. However, improvements in light interception by doubling the heights of R and B was about 50% less in each case compared to doubling of the LAI. The results consistently showed that increments in height did not increase total light interception. The results showed about 62% light wasted at all times.

A cursory examination of the effects of canopy-width, row-spacing and k showed that they all had positive effects on the total light interception but the model was more sensitive to changes in k. Cenpukdee and Fukai (1992) indicated that if intercrops are of similar height, it is the canopy-width of each that mainly determines the amount of light intercepted.

CONCLUSION

LAI increments increase total light interception whereas increment in height only affects partitioning but not total light interception. As a heuristic tool, this model can help to gain insights into the mechanisms involved in light competition in wide-row intercropping systems. This and similar models which have been proven to estimate light interception with a reasonable degree of precision save crop physiologists from the difficulties in field measurements. This light module is an essential part of a crop growth and development simulation model for the I-R, B and P hedgerow-intercropping system.

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