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DIFFUSED LIGHT CONDITIONS IN CANOPY GAPS IN A DRY DIPTEROCARP FOREST AT SAKAERAT, NORTHEASTERN THAILAND

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บทคัดย่อ

การประมาณหาปริมาณของ diffuse light โดยการใช้โมเดลได้กระทำในป่าเต็งรัง สะแกราช ผลการศึกษาปรากฏว่าการเปลี่ยนแปลงสภาพของ diffuse light ตามแนวดิ่งในช่องว่างระหว่างเรือนยอด โดยใช้โมเดลนั้นสอดคล้องกับค่าที่วัดได้จริง เนื่องจากช่องว่างระหว่างเรือนยอดในป่าที่ทำการศึกษามีขนาดเล็กเกินไป ดังนั้น จึงไม่พบไม้เบิกนำปรากฎอยู่ในช่องว่างระหว่างเรือนยอดแต่ประการใด

ABSTRACT

A simple model for diffused light conditions in canopy gaps is presented. The vertical changes of illuminance in gaps calculated from the model agreed with the changes observed in dry dipterocarp forest. The illuminance in a given sized gap in the forest could be estimated from the model. Size distribution of gaps in the forest suggested that most gaps were too small, and pioneer tree species.were not found in the gap.

INTRODUCTION

Since Watt (1947) presented mature forests as mosaics of patches in various stages of regeneration, canopy gap formations have been recognized as important phenomenon in studies on forest regeneration. The nature of gap formations have been clarified for several forests (Hartshorn 1978; Runkle 1982; Naka 1982; Nakashizuka 1984 and Dhanmanonda 1988). However, micro-climate, particularly, light in the gaps, have been poorly reported.

Many authors have reported on light conditions in plant communities. Evans (1966) presented a model for woodland light conditions. Anderson (1966) made a theoretical analysis on light penetration and forest structure. Yoda (1974) clarified the three dimensional structure of light conditions in a tropical forest. In the study of light conditions in forests, gap size depth (height of the canopy) and other measurable quantities should be taken into consideration. Monsi and Oshima (1955) presented a

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theoretical model of light conditions in gaps, and calculated tree's matter production. They showed that pioneer species grow faster than late successional species in gaps.

In the present study, the earlier presented model is modified, and a simpler and more practical model is shown in comparison with the results obtained from field measurements.

STUDY SITE AND METHODS

The study area is located in a relatively undisturbed dry dipterocarp forest at the reserved area of the Sakaerat Experimental Research Station (SERS), Nakornratchasrima Province in the North-eastern part of Thailand. Detailed description of the meteorological conditions, floristic compositon, and forest structure were described in Dhanmanonda (1988) and Sahunalu and Dhanmanonda (1995).

The model in this study considered only diffused light illuminance relating to the canopy structure surrounding a gap. The model for direct sunlight must be different, and considered the solar track diagram and angular height of the sun together. Two illuminometers (Minolta Illuminance Corder) were used for the measurements.

Illuminance was measured on the day of overcasting cloud, when the fluctuation of illuminance is small, to estimate relative illuminance of diffused light in gaps (RI, ratio of illuminance in the forest to that in the open).

In August, 1994, a transect line (30 m long) was drawn across a gap (Gap-1) in the forest on a gentle slope. Illuminance was measured at every 1 m in height (0-7 m above the ground), every 2 m in horizontal distance along the line. Illuminance in an open site was measured simultaneously.

At the center of the four other gaps in the forest (Gaps-2, 3, 4 and 5), illuminance was measured at every 1 m in height (0-7 m above the ground). Illuminance in the open was measured at the same time. The mean values of relative illuminance (RI) of 5 observations for each point were used for the analysis. The canopy structure surrounding these gaps is recorded. The largest diameter of a gap and the largest one perpendicular to it were measured, and its area were calculated assuming its shape to be an ellipse.

RESULTS AND DISCUSSION

In this study, as in the studies by Monsi and Oshima (1955) and Nakashizuka (1985), the model for light conditions in a gap is formulated under two assumptions : (1) The shape of the gap is round. (2) The canopy is horizontally flat with scattered microgaps among leaves. Monsi and Oshima (1955) calculated using the following formula :

Eq. (1)

$$U = \frac{1}{2}\left[1 - \frac{(H/R)^2 + (D/R)^2 - 1}{\sqrt{\{(H/R)^2 + (D/R)^2 + 1\}^2 - 4(D/R)^2}}\right] + d'$$

where, U, T. H and D are the relative illuminance of diffused light of an observation point (the ratio of illuminance in the forest to that in the open site), radius of the gap, height of the canopy above the point, and horizontal distance of the point from the center of the gap, respectively. Coefficient d' is the component of diffused light penetrating through the canopy. If the observation point is under the center of the gap.

Eq. (2)

$$d' = 2\,d\,\theta/\pi$$

where, d and θ are the proportion of micro-gap to the canopy and the solid angle of the gap, respectively. The calculations of d' are complicated at all points except directly under the center of the gap. Therefore, the following formula was adopted to simplify the model.

Eq. (3)

$$U = \frac{1-\alpha}{2}\left[1 - \frac{(H/R)^2 + (D/R)^2 - 1}{\sqrt{\{(H/R)^2 + (D/R)^2 + 1\}^2 - 4(D/R)^2}}\right] + \alpha$$

where, coefficient α is the component of diffuse light penetrating through the canopy. It depends on the proportion of micro-gaps among the leaves and canopy structure adjacent to the gap. When the observation point is under the center of the gap (D = 0),

Eq. (4)

$$U = \frac{1-\alpha}{(H/R)^2 + 1}$$

when it is expressed relating to the gap size (S, in area),

Eq. (5)

$$U = \frac{1-\alpha}{\pi H^2/S + 1}$$

A population of *Arundinaria pusilla* Cheval & A. Camus in Gap-1 had an average height of abount 1 m (dotted line in Figure1), RI values in the gap decreased abruptly in the leaf layer of the grass population. Vertical decrease in RI under the canopy was small except near the ground, where seedlings and grasses reduced RI. Vertical change of RI from the periphery to the center of Gap-1 was presented in Figure 2.

The vertical decrease of RI above the grass layer at the center of Gap-1 (at 14 m in horizontal distance in Figure 1) could be approximated by *Equation (4)*. The gap was assumed to be round, and R was calculated to be 14 m from the size of the gap (Table 1). The canopy was not actually flat, although the "imaginary canopy flat (ICF)" was assumed to be Z m above the ground. When the observation point is at X m in

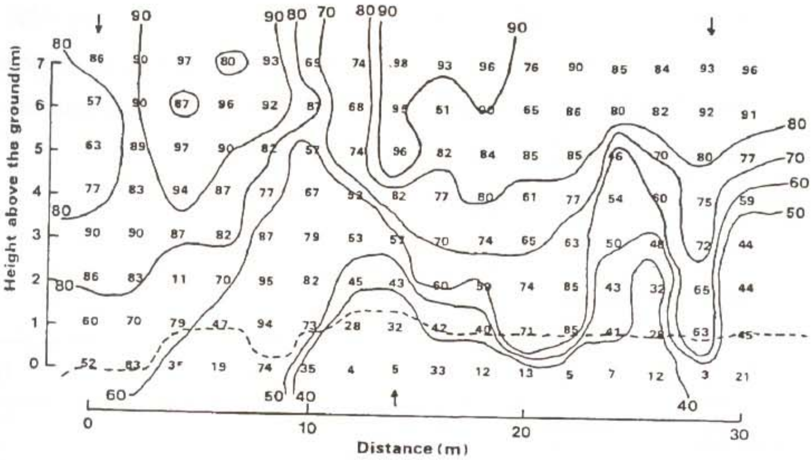

Figure 1. **Profile of light condition across the Gap-1. Solid lines are the ISO-RLI (relative light intensity, %) curves. Broken line shows the height of *Arundinaria pusilla* Cheval & A. Camus regenerating in the gap. Arrow indicate the edge of the gap.**

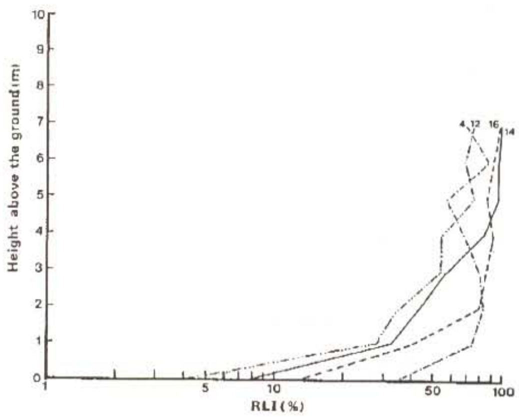

Figure 2. **Vertical change of RLI from the periphery to the center of the gap. Figures are the distances from the starting point of the belt, as shown in Figure 1.**

height,

$$H = Z - X$$

From *Eqs. (4)* and *(6)*, Z and α were calculated to be 8.08 m and 0.128, respectively, by the non-linear least squares method. Calculated profile assuming these values was shown in Figure 3). Fundamental structure of calculated distribution was similar to the observed distribution. Observed distribution under canopy had some differences because the canopy was not flat and the height of canopy edge varied locally. Inside the gap, however, the distribution was well approximated except grass layer (Figure 4).

Table 1. Outline of studied gaps

	Gap-1	Gap-2	Gap-3	Gap-4	Gap-5
Gap size (m^2)	616	227	154	95	64
Height of surrounding canopy trees (m)	14.0	9.75	10.5	10.5	13.5
Height of canopy edge (m)	8.8	8.6	9.0	8.4	12.0
Maximum height of saplings in the gap (m)	4.1	2.9	3.8	4.7	5.2

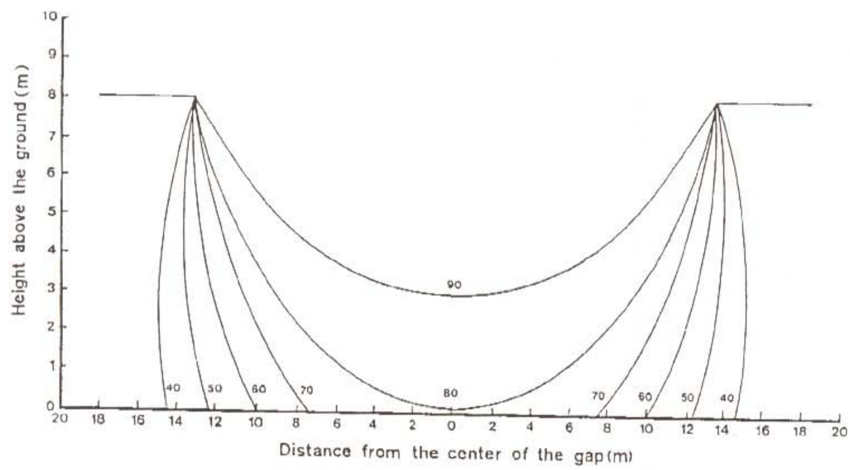

Figure 3. Calculated profile of diffused light condition in Gap-12, assuming α and Z in *Eq (3)* to be 0.128 and 8.08 m, respectively. Figures are the RI for the ISO-RI curves.

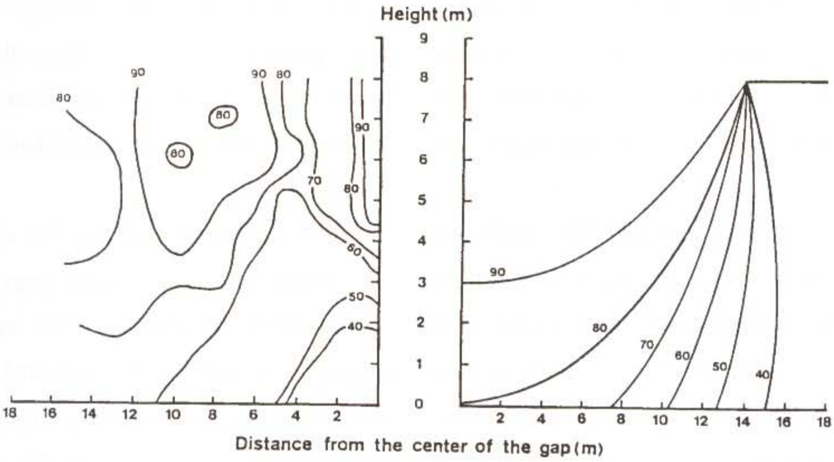

Figure 4. Calculated and observed profiles of light condition in Gap-1. The left half is the actual profile of the gap, and the right half is the calculated one by *Eq (3)*, in which a presumed canopy flat is at 8.08 m above the ground in the same sized gap.

The vertical changes of RI observed at the center of Gap 1 ~ 5 showed good agreement with the one calculated by the model (Figure 5). Illuminance in leaf layer of grass population decreased rapidly. Calculated values for α and Z by non-linear least squares method ranged between 0.07-0.62 and 6.86-10.99 m, respectively.

Monsi and Oshima (1955) estimated the productivity of trees grown in gaps of temperate forest in Japan. They showed that matter production of sun tree exceed shade tree when RI values higher than 0.3 in gaps. In beech forest of Japan in which α and Z were estimated to be 0.075 and 18.5 m by *Eq. (5)*. Nakashizuka (1984) showed that U at the ground level is greater than 0.3 in gap larger than about 350 m^2. In his study, out of 36 gaps in 2.4 ha area, only 3 gaps were larger than 350 m^2 and the largest was 470 m^2. If the estimation of Monsi and Oshima (1955) is right, the occurrence of sun plants must be limited in beech forest.

Whitmore (1982) stated that pioneer trees occur commonly in gap larger than 1,000 m^2 in tropical rain forest. In this study all gaps were smaller than 1,000 m^2, hence there was no occurrence of any pioneer trees in the study plot. In beech forest, Nakashizuka (1984) observed a significant positive correlation of floristic composition between the seedling and sapling communities under closed canopies and those in gaps. He also showed that the canopy of pioneer trees were only few in the forest. Therefore, the gaps formed in this forest seems to be too small for pioneer species to occur.

In this study, diffused light conditions under 9 m were discussed. The light conditions in the higher parts of the gaps cannot be estimated by the present method because the canopy surface is not actually flat. However, the present method is sufficient to estimate the diffuse light conditions near the soil surface in gaps, if there is no undergrowth. There were, however, several problems concerning the measurement of light in the field in the present study, such as spectral sensitivity, direct sunlight and so on. These problems could probably be solved if the model was applied to the results obtained from hemi-spherical photograph method (Nakashizuka, 1985).

RI values between 6 and 7 m high, at the center of various sized gaps were approximated by *Eq. (5)*. The average values for α and Z were estimated to be 0.83 and 8.08 m, respectively. The results seemed to be reasonable in this forest. Since the values of α and Z were peculiar to each gap (as shown in Figure 5), the deviation from the approximated line in Figure 6 was therefore rather large.

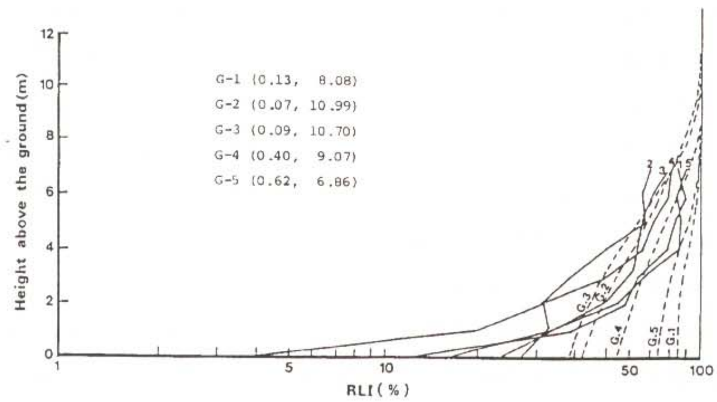

Figure 5. Vertical changes of RI at the center of G-1, 2, 3, 4, and 5. Smooth lines show the estimates using eq (4). Figures in parentheses are the estimated values for α (former) and Z (latter) in *Eq (4)*.

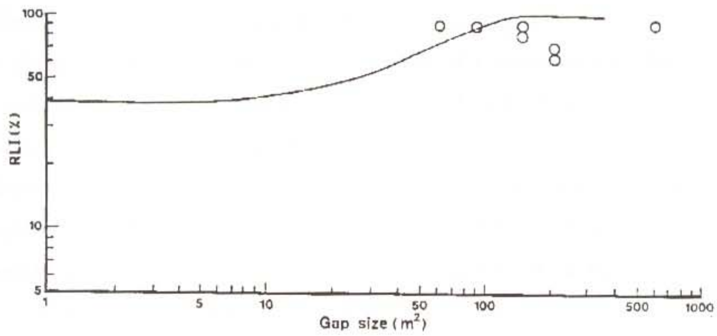

Figure 6. Relationship between the gap size and the observed RI between 6 and 7 m at the center of the gaps. The smooth line is the approximation by *Eq (5)*. Estimated values for α and Z are 0.83 and 10.5 m, respectively.

The relationship between the gap size and the relative light intensity at the ground level in the center of gaps by *Eq. (5)* are presented in Figure 5. The value for ICF was presumed to be 5, 10, 15, 20 and 24 m and α was estimated to be 0.38. The results corresponded with *Eq. (5)*.

CONCLUSION

The vertical changes of illuminance in gaps calculated from a model agreed with the changes observed in the forest. The illuminance in a given sized gap could be estimated from the model. Most gaps were too small for the frequent occurrence of pioneer species.

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