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THREE-DIMENSIONAL DISTRIBUTION OF LIGHT INTENSITY IN THE DRY DIPTEROCARP FOREST AT SAKAERAT, NORTHEASTERN THAILAND

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บทคัดย่อ

การแจกแจงความถี่ของปริมาณแสงสว่างสัมพัทธ์ตามระดับความสูงต่าง ๆ กันในป่าเต็งรังสะแกราช ภาคตะวันออกเฉียงเหนือของประเทศไทยนั้น ปรากฏว่าอยู่ในรูปของ lognormal ซึ่งเป็นเครื่องชี้ให้เห็นว่าตัวแทนที่เหมาะสมของปริมาณแสงสว่างสัมพัทธ์ที่ระดับใดระดับหนึ่งนั้นควรจะอยู่ในรูปของตัวกลางเรขาคณิตมากกว่าตัวกลางเลขคณิต

การลดลงของค่าเฉลี่ยของปริมาณแสงสว่างสัมพัทธ์ตามแนวดิ่งที่ระดับ 0-2 เมตร (ไม้พื้นล่าง) 2-16 เมตร (เรือนยอดชั้นล่าง) และสูงกว่า 16 เมตร (เรือนยอดชั้นบน) จากระดับพื้นดินนั้น ปรากฏว่าอยู่ในของ exponential ซึ่งแสดงให้เห็นว่าการกระจายตามแนวดิ่งของ leaf area density ในแต่ละชั้นอยู่ในลักษณะที่เป็นเนื้อเดียวกันไม่มากก็น้อยตลอดทั้ง 3 ชั้น

ABSTRACT

The frequency distribution of relative light intensity at various height levels in an undisturbed dry dipterocarp forest at Sakaerat, northeastern Thailand was closely approximated by the lognormal distribution, proving that the geometric mean was more reasonable than the arithmetical mean as the representative value of light intensity received by a certain height level under the leaf canopy. The mean value tended to decrease exponentially with decreasing height in each of the three layers between o m and 2 m, (ground vegetation), 2 m and 16 m (lower strata) and over 16 m (upper strata) above the ground level. This suggested that the leaf area density was more or less homogeneously distributed in the vertical direction within each of the three layers. A diagrammatic representation of the three-dimensional distribution of relative light intensity in the forest canopy was presented.

INTRODUCTION

Light conditions under tropical forest have so far been insufficiently studied, although preliminary efforts were made to reveal the pattern of light distribution on the forest floor as affected by very deep and dense canopies (Richards 1952; Evans *et al.* 1960)

Considerable, attention has been paid to the physical process of light interception by

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leaf canopies since the classical work by Monsi and Saeki (1953). However, most researchers dealt with the vertical distribution of the arithmetical mean of light intensity observed at a certain depth in the canopy, without considering the nature of the uneven distribution of light on the forest floor as well as at any height levels within the canopy. Ogawa (1966, 1974) found that the frequency distribution of relative illuminance on a plane inside leaf canopies was closed to the lognormal distribution with its modal value strongly biased to the darker side, and that the representative light intensity on a given plane should more properly be given by the geometric mean than by the arithmetical mean of the observed values. Special efforts were made in the field work to overcome the barrier of tree height and to obtains many light intensity readings as possible so that the three-dimensional distribution of light intensity could be revealed with high accuracy.

STUDY SITE AND METHOD

The study area is located in a relatively undisturbed dry dipterocarp forest in the reserved area of the Sakaerat Experimental Research Station (SERS), Pakthongchai, Nakornratchasima, NE Thailand. Detailed descriptions of the meteorological conditions, floristic composition, and forest structure were described in Dhanmanonda (1988) and Sahunalu & Dhanmanonda (1995).

Three-dimensional distribution of relative visible light intensity in a 100 m x 100 m permanent sample plot was measured by two sets of Minolta Illuminance Corders. A temporary tower was built in the center of the plot and one illuminance corder (A) was fixed to the top of the tower, at 25 m above the ground and at 2 m above the forest canopy. The other illuminance corder (B) was fixed to the end of a pole which could be raised from the ground level to the height of the vegetation, and could be moved three-dimensionally in the forest stand, and the relative illuminance was obtained by simultaneous readings of the two illuminance corders.

The observations were in the wet (August 10-15, 1994) season, 300 pairs of readings at the ground level and 1 m above the forest floor were taken for the horizontal distribution. The vertical distribution of relative illuminance was observed along the tower at 14 height levels at 2 m-intervals from the ground surface up to 26 m. The total number of relative illuminance measurement was 300 the levels between 0 m and 6 m, 200 each for 8-16 m-levels, and 100 each for 18-26 m-levels. The measurements used the same technique as Yoda (1971; 1973) and Yoda *et al.* (1983).

RESULTS AND DISCUSSION

Daily changes of relative illuminance at fixed points

The frequency distribution of relative illuminance (RI) observed at ground level and 1 m above the ground in the sample plot in the wet (August 10-15, 1994) season is given as histograms in the upper graphs in Figure 1, in which the total range between the maximum and minimum of observed values was divided into 10 classes. Both histograms were biased to the left or darker side. Yoda (1974) and Yoda *et al.* (1983) reported that histograms in the dry season were biased to the left or darker side more than histograms in the wet season, because RI in the dry season was measure on a clear day, while, in the wet season it was measured on cloudy days.

The behavior of RI distribution agreed well with the results obtained by Ogawa (1967), Yoda (1974, 1978) Yoda *et al.* (1983), Visaratana (1983), and Vanna-prasert (1985), who fitted the lognormal curve successfully to such patterns. The logarithmic transformation of RI axis (lower graphs in Figure 1) resulted in a more or less symmetrical frequency distribution curve at both height levels. Thus, the geometric mean was more reasonable than the arithmetical mean as the representative values of relative light intensity for a specific height level under the leaf canopy.

The geometric mean value tended to increase with height, 5.7 % at ground level and 37.7 % at 1 m above the ground level. The lower of RI value at the ground level in the wet season corresponded to the new growth a *Arundinaria pusilla* Cheval & A. Camus. in the wet season.

The lognormal character of the frequency distribution curves of RI was further tested by the linear relationship between log RI and the cumulative frequency on the normal probability paper with satisfactory results (Figure 2). It is interesting to note that all the lines for height levels lower than 10 m were almost parallel to each other for some unknown reasons.

Vertical distribution of mean relative illuminance

In view of lognormality of the frequency distribution of RI on the plane at a given height, it is apparently more reasonable to use the geometric mean of observed values than the conventional arithmetical mean as the measure of the average light condition on the plane concerned. Both kinds of mean values at

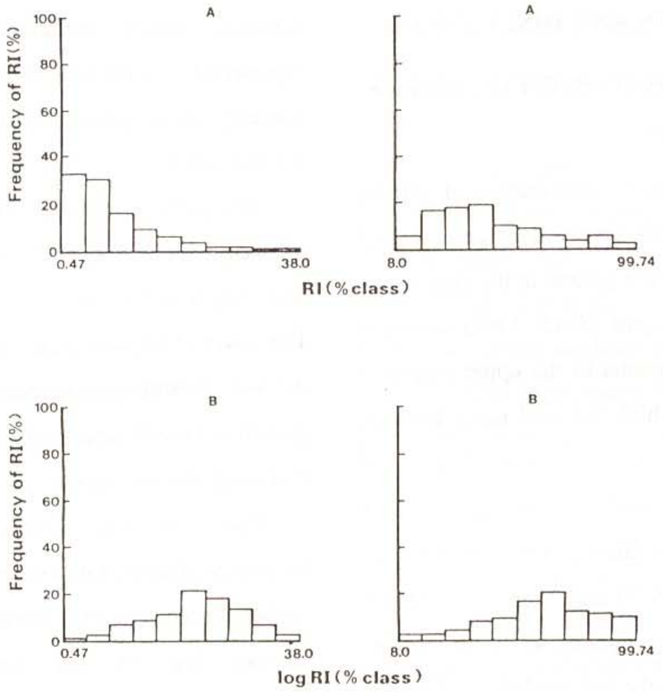

Figure 1. **Frequency distribution of relative illuminance at 0 m (left) and 1 m (right above the ground). Lower graphs represent the logarithmic transformation of RI axis.**

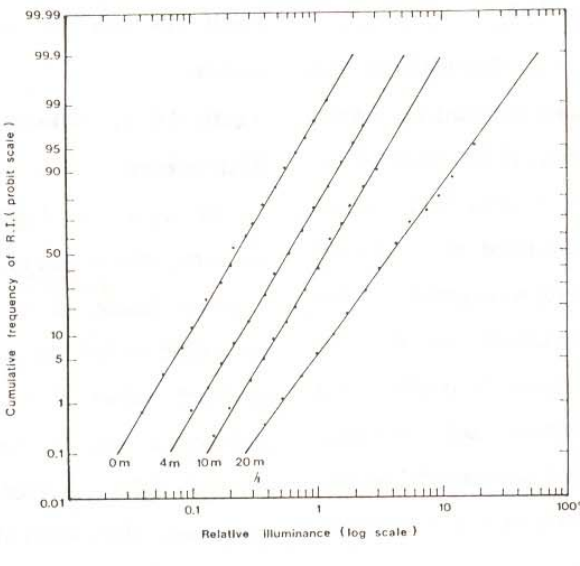

Figure 2. **Linear transformation of the frequency distribution of log (RI) on the normal probability paper.**

respective heights are given in Table 1.

The ratio of the geometric mean to the arithmetical mean was least between 18 m and 20 m and largest in the upper most part of the canopy above 22 m. In average, the geometric mean was equal to ca. 88 % of the arithmetic mean. The average difference of 12 % was not very large, and therefore both means might be similarly employed for practical use, although Ogawa (1974) suggested that the geometric mean might more closely follow the Beer-Lambert's law concerning the interception of light by canopy leaves.

Figure 3 shows the vertical distribution of the mean RI in the dry dipterocarp forest at SERS with a diagrammatic profile of the forest. The arithmetical mean was used for this study. The relationship between log (mean RI) and above ground height was approximated by three straight lines.

A linear relationship on Figure 3 means an exponential decrease of RI with aboveground height. Assuming the Beer-Lambert's law (Monsi and Saeki 1953) and a constant light extinction coefficient per unit amount of leaf area, it is further known that the leaf area density remains more or less even through out the layer of leaf canopy in which linear relationship is held.

On this basis, the leaf canopy of the dry dipterocarp forest might be divided into three layers corresponding to the three linear segments of the log (mean RI)-height curve. The first or uppermost layer consisted of the crowns of canopy trees 22 and 26 m in tree height which intercept ca. 30 % of incident light. The second layer corresponded to the space between the base of the canopy crowns, the upper surface of subcanopy at about 16 m above the ground. The relative illuminance was rather rapidly decreased with decreasing height in this layer because of denser distribution of leaves in the second layer. The third layer, lower than 2 m, corresponded apparently to the dense layer of *Arundinaria pusilla* Cheval & A. Camus. (Raungpanit 1981).

Three-dimensional distribution of relative illuminance

An isogram showing the three-dimensional distribution of RI in this forest is prepared and shown in Figure 4. The ordinate refers to the height above the ground, and the cumulative frequency (relative) of RI is taken on the abscissa. The curves represent the isopleths where the cumulative frequency reaches a certain RI value, 0.2 %, 0.5 %, 1 %, 2 %, etc., calculated from the Figure 2. Each isopleth

Table 1. Vertical distribution of mean relative illuminance

Height above ground (m)	Relative illuminanc (RI) Arithmetic mean (I_A%)	Geometric mean (I_G %)	I_G/I_A	Number of observation
0	5.04	4.50	0.894	300
2	10.91	9.73	0.892	300
4	12.57	11.51	0.916	300
6	19.78	18.59	0.940	300
8	27.68	24.96	0.902	200
10	29.12	25.16	0.864	200
12	31.14	27.53	0.884	200
14	54.23	46.85	0.864	200
16	70.16	59.42	0.847	200
18	76.48	58.81	0.769	100
20	80.12	60.89	0.760	100
22	91.00	85.63	0.941	100
24	94.21	87.80	0.923	100
26	96.28	87.99	0.914	100

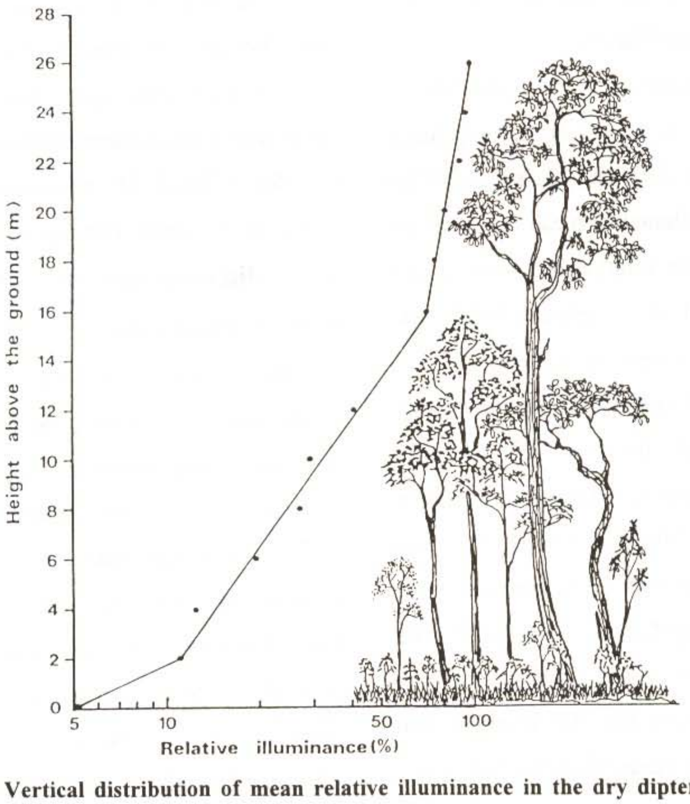

Figure 3. Vertical distribution of mean relative illuminance in the dry dipterocarp forest at SERS.

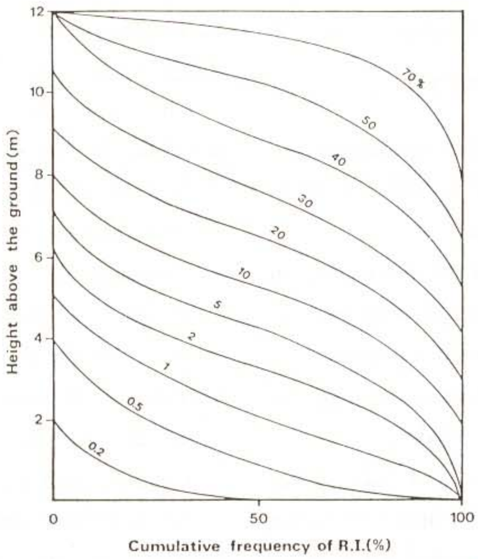

Figure 4. Three-dimensional distribution of relative illuminance in the dry dipterocarp forest at SERS.

cuts the 0 % axis diagonally, but is asymptotic to the 100 % line.

For example, the RI values less than 0.2 % occur at the relative frequency of ca. 50 % on the forest floor, those between 0.2 % and 0.5 % at ca. 40 %, 0/5 % illuminance at ca. 9 % and bright spots over 1 % at only 1 % frequency.

Evans (1966) gave a diagram showing the percentages of ground surface area covered by sun-flecks of various brightness. Since the above-mentioned frequencies are equivalent to the relative areas that receive the respective RI values, the isogram of Figure 4 is essentially the Evans' diagram expanded to a three-dimensional space of the whole forest canopy (Yoda 1974).

CONCLUSION

The frequency distribution of relative light intensity of various height levels was closely approximated by the lognormal distribution, proving that the geometric mean was more reasonable than the arithmetical mean as the representative value of relative light intensity received by a certain height level under the leaf canopy. Based on the vertical distribution of the mean relative illuminance, the whole canopy was divided into the following three strata; between 0 m and 2 m (ground vegetation), 2 m and 16 m (lower strata) and over 16 m (upper strata) above the ground level. The mean relative illuminance at 0 m, 2 m and 16 m was 5.72 %, 37.92 % and 95 %, respectively.

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