INVESTIGATION OF IRRADIANCE MEASUREMENTS IN A SEASONAL RAINFOREST AREA

Jorge Luis Gavina Pereira
João Roberto dos Santos

National Institute for Space Research
P.O. Box 515 - Av. dos Astronautas, 1758 - CEP 12210-012 - São José dos Campos, SP - Brazil

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ABSTRACT

The purpose of this paper is to analyse the behavior of the irradiance in a forest area. The study was carried out at the Professor Augusto Ruschi Forest Reserve, city of São José dos Campos (23° 12'S and 45°52'W). The vegetation type at the study area is designated Seasonal Evergreen Rain Forest of the South Central Brazilian Plateau. A spectroradiometer SPECTRON SE-590 equipped a cosine receptor was used to measure spectral irradiance in the spectral range of 400 to 900nm at five randomly selected points within ten forest plots of 10m x 10m, for a total of fifty measurements. Irradiance measurements were also collected in a clearing to represent the incident radiation over the forest canopy. In the most forest plots, the irradiance curve was similar to the green leaf transmitance curve, with lower values in the visible range (400-700nm), increasing significantly at the beginning of the near infrared (700nm). However, three points have had a irradiance curve similar to irradiance curve at the clearing due sun flecks. This three points account for 68.5% of the radiation in the visible range in the forest area. The average of the ratio between the total irradiance in the forest and at the clearing was 2.4%. In addition to it has observed a change in the spectral composition of the incident radiation after its penetration in the forest canopy. Out forest the total irradiance has 682% ofradiation in the visible range and in forest the visible range represent 45.5% of the total irradiance.

t. INTRODUCTION

Knowledge of radiation levels in the interior of tropical rainforests is a necessary background the for understanding the growth of plants in them. According to Lee (1987), recent studies of radiation levels in the interior of forests have concentred on the radiation avaliable for photosynthesis (400-700nm). Conduced studies in forests of Costa Rica and Hawaii have shown that in the inferior levels, small areas of solar illumination (sun flecks) can contribute to more than 50% of the daily photosynthetic flux density.

Solar energy within the top of the atmosphere is found in the spectral range of the short waves, of 200 to 5000nm. Approximately 45% of this energy is concentred in the spectral range of 380 to 780nm, characterizing the visible radiation flux in the top of the atmosphere (Moraes, 1986). The solar radiation, when across the atmosphere, is selectively spread (diffused radiation) and absorbed. The atmospheric spreading is reverse proportionally to the wavelenght of the eletromagnetic radiation. Soon, a larger spread in the blue range is observed, diminishing progressivelly with an increase in the wavelengt: (infrared). The atmospheric absorbtion by the water vapor (H_2O), ozone (O_3), aerosol, and other gases principally affect radiation with wavelenght larger than 800nm (infrared).

The portion of the incoming eletromagnetic energy, that isn't reflected by leaves, can be aborbed or transmitted. Therefore, the existing interelationship between the reflection, the absorbtion and the transmission is necessary to considering them together when to analyzing the physical and physiologycal base of the spectral response of the canopies. According to Myers (1983), in the range of 500 to 2500nm, the spectral curves of transmitance of ali the mature and healthy leaves are similar to the spectral curves of reflection. However, the first curves are a bit smaller in rnass. The absortion complements the two curves. The leaves typically reflect and transmit little radiation in the visible range (400-700nm), and it do the opposite for the wavelenght larger than 750nm. The absorbtion of the radiation by leaves and others canopy elements is a function of these two properties (absorbtion = I - reflection - transmition). Therefore, a larger density or lenght of the canopy must alter the spectral composition ofthe incident solar radiation.

Literature suggest that these changes in the spectral quality of radiation can partially control the development of the plants in the inferior levels of the canopy Although the spectral distribution of radiation in the forest interior can have significat effects on growth patterns and plant development, little is know about the spectral quality of radiation in the interior of tropical rainforests (Lee, 1987). The objective of this study is to analyse the behaviour of the irradiance in the interior of a forest and at a clearing.

2. METHOOS

The present study was conduced in an area of the Professor Augusto Ruschi Forest Reserve (PARFR), formely a forest garden of the city of São José dos Campos, State of São Paulo, Brazil. The area of the reserve is approximatly 2,500 ha, in mountainous terrain, which varies in altitudes of 640 to 1040m. The PARFR is contained in domains of the Seasonal Evergreen Rain Forest of the South Central Brazilian Plateau. The climate of the area according to the classification of Koeppen, is of the type Aw. The total annual medium of precipitation is 1100mm with a dry season during the winter (april to september) that owns monthly totals of precipitation less than 50mm. The medium air temperature fluctuates between 17.5° C in june and 23.9° C in february, with an annual medium of 21.3° C. In the rougher areas, the soil pertaining to the unit Oxisol, occuring also, Inceptisol and Alfisol, associated with topographical variations. At the bottom the montain prevails the alluvial soil of medium to moderate texture (Silva, 1989).

Silva (1989) conducted a study of the composition and structure of arborial stratum at PARFR. The author established seven sample stations at different altitudes between 640m and 1000m of altitude. Each station totalled $1000m^2$ distributed in ten plots of 10m x 10m, with distance of 25m. At the station I, located at 640m in altitude, were observed 241 trees with minimal circunference of the trunk of 15cm to 1.30m from the ground, pertaining to 29 families. The estimated basal area per hectare was $47.67m^2$, and the volume of wood $81.73m^3$. The medium height was 11.10m with maximum height measurement of25m.

For obtaining the spectra of irradiance in the interior of the forest and at the clearing, the spectroradiometer SPECTRON SE-590 was utilized composed by a controlled unit and a detectoral unit. The detectoral unit is based on a net of difraction combined with a linear matrix of 256 siliceous detectors, which allow to aquire spectra in the range of 350 to 1150nm, with a spectral resolution of 8nm (Steffen, 1993). It was coupling to unit detector a cosine receptor, with the purpose of measuring the hemispheric spectral irradiance (E_h), given by the following equation:

$$E_h = d\varphi/dA \qquad (1)$$

where $d\varphi$ represents the incident ratiation flux and dA the area of incidence (Slater, 1980). The range spectral used in this study was of 400 to 900nm (visible and near infrared).

The spectra collect at field was conduced on november 12th, 1993, at 9:00am until 11:30am. Fifty-nine spectra were collected, 9 at the clearing, with the purpose of measuring the total solar irradiance (direct + diffuse) that would be arrive upon the canopy, and 50 in forest area, to measure the irradiance below the crown of the trees. The forest measurements were conduced in the ten plots of station I delimited by Silva (1989), five spectra for each plot. Three measurements were realized at the clearing in the inicial data collect (9:17am), three measurements after of the first five plots (10:29am) and three measurements after of the last five plots (11:26am).

The following software were used in the treatment of the spectra registred by the SPECTRON SE-590: ESPECTRO, GRAPHER and LOTUS. The ESPECTRO was used to transform the associated values of each spectrum, formed by spectral amplitudes relative to the registred flux by SPECTRON SE-590, in values of spectral irradiance (in $W.m^{-2}nm^{-1}$), and also to obtain the integrated irradiance in the spectral ranges of 400 to 900nm (total irradiance), of 400 to 700nm (visible) and of 700 to 900nm (near infrared). The GRAPHER was used in generation of spectral irradiance graphics inside and outside (clearing) of the forest, and in the graphic of the ratio between the measurements realized in the forest and at the clearing. The statistical analyses was conduced on LOTUS.

3. RESUL TS AND DISCUSSION

The genereted data were analized at level of spectra of irradiance; integrated irradiance in the ranges of 400 to 900nm (total irradiance), of 400 to 700 (visible) and of 700 to 900nm (near infrared); and also the ratio between the total irradiance in the forest and at the clearing. This ratio may be understand as a aproximation of the transmitance ofthe forest canopy.

The curves of the spectral irradiance taken at the clearing have values more elevated in the visible range (except in the range of 400 to 450nm). This values decreasing with the increasing of the wavelenght, behaviour characteristic of the spectra of the solar irradiance on the surface. The analysis of the measurements of the spectral irradiance conduced in the clearing, taken at 9:17am, 10:29am and 11:26am, permit the accompaniment of behaviour of the irradiance curve, where it could be observed that the increase of the irradiance did not cause a change in the form of the curve. In this period the total irradiance integrated at the clearing increasing in 23% (figure 1).

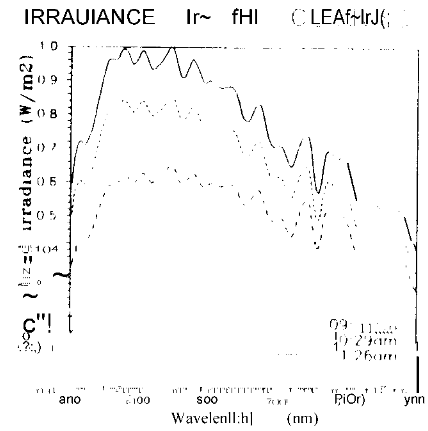

Figure 1 - Spectra of irradiance in the clearing.

In the interior of the forest almost ali of the irradiance curves are alike, with minor values in the visible range (a light peak in the green) and major values in the near infrared range. This form of the curves resembles the spectral transmitance curve of a typical leaf This show that part of the radiation present below the crown of the trees is a result of the transmition of the solar radiation that incoming over the canopy (figure 2).

The curves of irradiance that don't own a similar form of the spectral transmitance of a leaf are related to the incidence of the flux of solar radiation directly over the cosine receptor (sun flecks). These curves are very similar to the spectral irradiance in the clearing. The spectra of irradiance that are less resembling with the spectra of transmitance of a leaf are 13, 38, 50 and 55, plots 2, 7, 9 and 10, respectively. Particularly the spectrum 13 was collected in a point where there was practically no canopy cover, due to the decline of a tree, for this motive it was discarded of the analysis (figure 3).

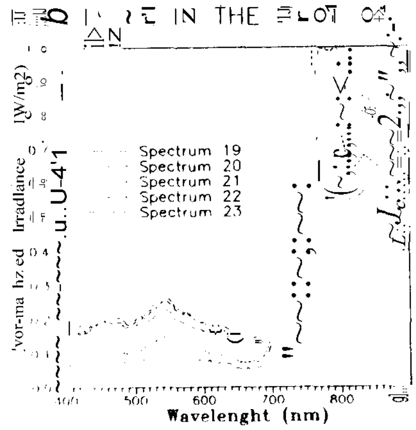

Figure 2 - Spectra of irradiance in [illegible].

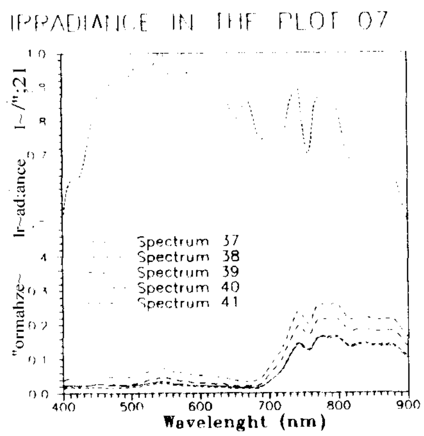

Figure 3 - [illegible] (plot 07).

One of the objectives of this work is to study the variation of the inside forest/outside total irradiance ratio. To come to know the value of total irradiance at the clearing, at the same time as the measurements in the forest, assuming that the solar irradiance had a linear growth, as observed by Moraes (1986). A linear equation of ajust between the values of measurements at the clearing, given for:

$$Y = 58.65X - 284,45 \quad (2)$$

where Y is the total irradinace and X [illegible] was established to obtain [illegible] values [illegible] irradiance at different times.

From this equation, the values of the total irradiance at the clearing were estimated at the same time as the measurements taken in the forest. These values were carried out the calculation of the ratio between them and the values of total irradiance in the forest, after this value is multiplied by 100. This operation is synthesized in the following equation:

$$IR = IF/IC \cdot 100 \quad (3)$$

where IR is [illegible] is the total irradiance in [illegible] is the total irradiance at the clearing.

Values between 0.26 (spectrum 35, plot 2) and 28.95 (spectrum 50, plot 9) were obtained by the ratio. The average (X) of the 49 values obtained was 2.4, and the standard desviation (s) equal to 4.5. With the purpose of verifing what are spectra that more collaborate for the variation of the values of the ratio, establishing the limits (X-s) and (X+s), -2.0 and 7.0, respectively. Only three ratios are not situated between these limits, the spectra 38, 50 and 55, the same spectra that have curves of spectral irradiance very similar to those found at the clearing (figure 4). These three spectra account for 46.7% of the total of radiation and 68.5% of the radiation in the visible range of the measurements taken in the interior of the forest.

[illegible] analysed the ratio between the [illegible] within and outside of a rainforest in Costa Rica (10°26'N), in the spectral range of 300 to 1100, obtaining the value 1.7. The most probable cause for the difference in penetration of radiation between this experiment and that of Lee is associated to a difference of irradiance (São José dos Campos - 23°12'S; Costa Rica - 10°26'N) and precipitation (São José dos Campos - 1100mm; Costa Rica - 4000mm). A denser forest at the Costa Rica than São José dos Campos, that [illegible] radiation, is a [illegible]

By analysing the spectra of irradiance in the forest and at the clearing, and also the values of integrated irradiance (total, visible and near infrared), it can be observed, besides the reduction of 97.6% of radiation in the interior of the forest, a change in quality of solar energy that cross the canopy. The incident solar flux posesses approximatly 68.2% of radiation in the visible range (400 - 700nm, photosynthetic active radiation) and 31.8% in the near infrared range (700 - 900nm), while in the interior of the forest the photosynthetic active radiation represent nearly 45.5% and the near infrared 54.5% of the total radiation. The reduction of the total radiation, besides of the relative reduction of the radiation avaliable for photosynthesis, that is associated to the absorption hy forest, according to Lee (1987), is one of the factors that controls the growth of plants in the inferior levei ofthe canopy.

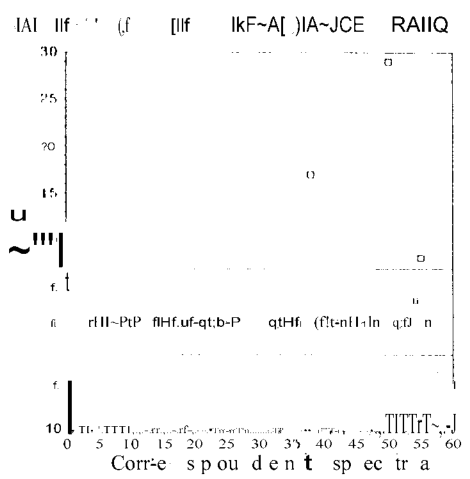

Figure 4 - Values of the ratio between the total irradiance in the forest and the total irradiance at the clearing.

4. CONCLUSION

The ratio between the total irradiance in the forest and at the clearing was 2,4 for the study area, showing three values outside the interval (X-s), (X+s), corresponding to spectra 38, 50 and 55. The elevated total irradiance of these three spectra account for 46.7% of the total radiation and 68.5% of the visible radiation measured in the interior of the forest..

The comparison between the values of the irradiance, outside and inside the forest, have shown, besides the reduction of the radiation in the interior of the forest, a change in the spectral quality of the solar radiation that cross the canopy. Outside the forest the visible range accounts for 68.2% of the total irradiance while within the forest, the radiation in the visible range represents 45.5% ofthe total irradiance.

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REFERENCES

Lee, D.W, 1987. The spectral distribution of radiation in two neotropical rainforests. Biotropica, 19(2), pp. 161-166.

Moraes, E.C., 1986. Comparação entre métodos de estimativa de radiação solar: satélite e convencional.. (Dissertação de Mestrado em Meteorologia) - Instituto Nacional de Pesquisas Espaciais, São José dos Campos (INPE-4025-TLD/242).

Myers, V.I., 1983. Remote sensing applications in agriculture. In: Colwell, R.N., ed. Manual of Remote Sensing. 2 ed. Falls Church, Virginia, ASP, v. 2, capo 33, pp. 2111-2228.

Silva, A.F., 1989. Composição florística e estrutura fitossociológica do estrato arbóreo da Reserva Florestal Professor Augusto Ruschi, São José dos Campos, SP. (Tese de Doutorado em Biologia Vegetal) - UNICAMP, Campinas.

Slater, P.N., 1980. Remote sensing: optics and optical systems. Reading, Massachussetts, Addison-Wesley.

Steffen, C.A., 1993. Técnicas radiométricas com o SPECTRON SE-590. In: Simpósio Brasileiro de Sensoriamento Remoto, 7., Curitiba, 1993. Tutorial 2. São José dos Campos, INPE, pp 1-7.