Spectral distribution of light in spontaneous and enriched fallow vegetation in NE Amazonia

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ABSTRACT

Light spectral composition was monitored during four periods, in the following stands of an improving fallow vegetation experiment in NE Amazonia, Brazil: 6 to 7-year-old fallow; 1.5 to 2.5-year-old fallow; and 1.5 to 2.5-year-old fallow stands enriched with fast growing N fixing leguminous trees (*Acacia mangium, Acacia angustissima, Clitoria racemosa, Inga edulis, Sclerolobium paniculatum* and a mixed population of of these trees). The analysis was centered on three parameters: photosynthetic active radiation, PAR (400nm to 700nm); phytochrome active radiation, PHYTAR (Red:Far Red ratio, ζ); and blue active radiation, BAR (400nm to 500nm). A sharp decrease on values of the studied parameters was observed in all enriched plots, from November 1996 to January 1997, associated to the fast canopy growth of the planted trees. The lowest values were found in June 1997, when the planted trees and the indigenous species were densely leafy. The values increased again in October 1997, following a decrease in canopy density, due to the lack of rainfall.

Key words: light transmission, photosynthetically active radiation, Red:Far Red ratio, blue active radiation; enriched fallow

RESUMO

A composição espectral da luz foi monitorada em quatro períodos, nas seguintes parcelas de experimento de enriquecimento se capoeira, NE da Amazônia, Brasil: capoeira de 6 a 7 anos; capoeira de 1,5 a 2,5 anos; e parcelas de capoeira de 1,5 a 2,5 anos enriquecidas com leguminosas arbóreas de rápido crescimento, fixadoras de N (*Acacia mangium, Acacia angustissima, Clitoria racemosa, Inga edulis, Sclerolobium paniculatum* e uma mistura dessas árvores). Foram analisados os parâmetros: radiação fotossinteticamente ativa, PAR (400nm a 700nm); radiação ativa ao fitocromo PHYTAR (razão vermelho:vermelho extremo, ζ); e radiação ativa no azul BAR (400nm a 500nm). Os valores desses parâmetros decresceram em todas as parcelas enriquecidas, de novembro de 1996 a janeiro de 1997, em resposta ao crescimento das árvores. Os menores valores ocorreram em junho de 1997, quando as densidade foliar estava elevada. Os valores tornaram a se elevar em outubro de 1997, refletindo a baixa densidade foliar, resultante da baixa oferta de chuva.

Palavras chaves: transmissão de luz através do dossel, radiação fotosinteticamente ativa, razão Vermelho:Vermelho Extremo, radiação ativa no azul; capoeira enriquecida

ZUSAMMENFASSUNG

Die spektrale Zusammensetzung von Licht wurde an vier Zeitpunkten in den folgenden Behandlungen des Brache-Anreicherungsversuches im Nordosten Amazoniens, Brasilien, untersucht: 6-7-jährige Brache, 1,5-2,5-jährige Brache und 1,5-2,5-jährige Bracheflächen, die mit schnellwachsenden, N-fixierenden baumartigen Leguminosen angereichert wurden *(Acacia mangium, Acacia angustissima, Clitoria racemosa, Inga edulis, Sclerolobium paniculatum* sowie ein Mischbestand dieser Spezies). Die Analysen konzentrierten sich auf drei Parameter: photosynthetisch aktive Strahlung, PAR (400 nm bis 700 nm), phytochrom-aktive Strahlung PHYTAR (Verhältnis Rot: langwelliges Rot, ζ) und blau aktive Strahlung BAR (400 nm bis 500 nm). Von November 1996 bis Januar 1997 wurde in allen angereicherten Bracheflächen eine deutliche Abnahme der erfaßten Parameter als Reaktion auf das schnelle Wachstum der gepflanzten Bäume beobachtet. Die niedrigsten Werte traten im Juni 1997 auf als die Vegetation stark belaubt war. Im Oktober 1997 stiegen die Werte aufgrund der Abnahme der Kronendichte wieder an, hervorgerufen durch das Ausbleiben der Regenfälle.
Schlagworte: Lichtdurchlässigkeit von Baumkronen, photosynthetisch aktive Strahlung, Verhältnis rot: langwelliges rot, blau aktive Strahlung; angereicherte Brache

INTRODUCTION

Light is a major biophysical factor to be taken into consideration while testing complex agroforestry arrangements, as is the case of enriched fallow, provide the role that both light quality and quantity play to a large range of processes and mechanisms, such as weed and seed bank dynamics, photosynthetic, and morphogenetic responses of involved species; and biodiversity maintenance. The purpose of this work was to provide light spectral information in support to the understanding of biological processes, such as floristic composition dynamics of vegetation (Wetzel et al., unpublished) in an enriching fallow vegetation experiment underway in Northeastern Amazonia, Brazil, also reported in this issue (Brienza Jr. et al., 1998).

SITE, EQUIPMENT AND DATA

1 Field site

The study was carried out on small holder, in Cumaru, municipality of Igarapé-Açu, Northeastern Pará State, as described by Brienza Jr. (1998). The experimental area was slashed and burned in November/December 1994; maize and cassava were respectively planted in January and February 1995. In June 1995, just after the maize was harvested, the fast growing leguminous trees (FGLTs) were planted, as specified in Table 1. Cassava was weeded for the last time in November/December 1995 and harvested in February 1996.

Table 1: Details about the enriched fallow experimental plots.

Detail	Specification
Plot vegetation	enriched with: *Acacia angustissima* Kuntze (Aa), *Acacia mangium* Willd.(Am), *Inga edulis* Mart.(Ie), *Clitoria racemosa* G. Don (Cr), *Sclerolobium paniculatum* Vog. (Sp), and a mixture of all FGLTs; and control plots (spontaneous fallow vegetation, *capoeira*)
Spacing	1m x 1m, 1m x 2m and 2m x 2m
Plot size	10m x 8m
Replicates	four

2 Equipment used and monitoring procedure

Spectral irradiance (SI) was monitored at two heights within the canopy (ground level and 1m height) with a portable spectroradiometer (Li-1800, Li-Cor Inc., Lincoln, Nebraska, USA), as described by Pearcy (1989), scanning from 330 to 1100nm, at 2nm steps. Four field campaigns were performed during: November 1996; January 1997; June 1997 and October 1997. Each within canopy measurement was intercalated with a full exposition reading. All measurements were made from 10:00h to 14:00h.

3 Spectral composition of light

To describe the light environment within the vegetation the analysis was centered in the following radiation related variables, associated to either photosynthesis or to photomorphogenesis, which wave range specifications are presented in Table 2:

Photosynthetically Active Radiation (PAR); corresponds to the wavelength band in which photons are absorbed by chlorophyll, driving the photochemical process of photosynthesis (McCree 1981);

Phytochrome Active Radiation (PHYTAR); expresses the phytochrome regulation wavelength band and, considering that the absorption´s maxima of phytochrome have broad peaks around 660 and 730, and the photo equilibrium is largely determined by the Red:Far-Red ratio (ζ) of the incident radiation, this ratio is often used to describe light environments (Varlet-Grancher et al., 1993), as it is the case of the present study; and

Blue Active Radiation (BAR); corresponds to the wavelength band associated to the blue light receptor, which regulates morphogenesis of light-grown plants, without operating through phytochrome (Varlet-Grancher et al., 1993).

Table 2: Specification of wavelength bands corresponding to the photosynthesis and photomorphogenesis associated variables herein analyzed.

Variable	Wavelength band	Source
PAR	400nm to 700nm	McCree (1981)
PHYTAR	Red:Far Red (ζ)= photon irradiance 655nm to 665nm / photon irradiance 725nm to 735nm	Varlett-Grancher et al. (1993)
BAR	400nm to 500nm	Woodward (1983)

RESULTS AND DISCUSSION

1 Spectral distribution of radiation reaching the top of the canopy

Table 3 presents values of ζ, PAR, and BAR, reaching the top of the canopy during the monitoring field campaigns, showing that the values for all the three variables were lower during the first measuring period, probably associated to prevailing atmospheric conditions. The narrow range of variation in ζ values agrees with the conservative nature of this parameter in daylight, irrespective of the time of the year and, at a certain extent, of weather conditions, for a certain location (Smith, 1982). The observed average values of ζ of unfiltered sunlight (1.24 to 1.31) fall within the range (1.05 to 1.48), found in open habitats elsewhere (Smith, 1982, Chazdon et al., 1996).

Table 3: Summary of mean values with standard errors (±) of ζ, PAR (W m^{-2} 400nm to 700nm), and BAR (W m^{-2} 400nm to 500nm), reaching the top of the canopy during the monitoring field campaigns.

Variable	November 1996	January 1997	June 1997	October 1997
ζ	1.24 ± 0.15	1.31 ± 0.02	1.29 ± 0.03	1.27 ± 0.02
PAR	51.91 ± 0.96	162.22 ± 18.13	175.67 ± 10.89	185.33 ± 6.18
BAR	33.67 ± 1.54	52.41 ± 5.70	55.38 ± 3.64	58.66 ± 1.97

2 Light environment within fallow vegetation

2.1 Red:Far Red ratio (ζ)

A sharp difference may be noticed between the values of ζ found in the control (capoeira), as compared to those found in the enriched plots, at the two heights (Figure 1). The results suggest that due to the clump nature of their structure, without a strong stratification in height, capoeiras in early successional stages, as it is the present case, are able to strongly and uniformly filter red wavelengths, resulting in a narrow and low range of ζ values, even lower than those found in the understory of most tropical forests (Chazdon et al., 1996).

Among the FGLTs treatments, *A. mangium* seems to be the one to most strongly reduce ζ values at the two studied heights, followed by *S. paniculatum*.

For almost all the enriched fallow plots, the lower ζ values were obtained during June 1997, when the FGLTs canopy was already considerably high and the indigenous species canopy was considerably closed, resulting in ζ values even lower than those found in the control capoeira, for both ground level and 1m height level, and all tree planting spaces studied. The values nevertheless presented a considerable raise in ζ in most of the treatments (Figure 1), due to an increase in canopy openness, probably resulting from a considerable leaf fall caused by low rainfall associated to the strong El Niño event observed in 1997.

2.2 Photosynthetically Active Radiation (PAR)

For this parameter it is noticeable the difference in the values measured in the two heights, since in most of the treatments and almost with the exception of June 1997, the % PAR found at 1m height was over twice the value measured at ground level (Figure 2).

As it happened with ζ, the PAR values were relatively lower in the plots enriched *with A. mangium* and *S. paniculatum*, and relatively higher in the plots enriched with *C. racemosa*. These results seem to be linked to those presented by Wetzel et al. (unpublished), who studying the dynamics of floristic composition in these same experimental plots, found that *A. mangium* mainly at the 1m x 1m spacing, strongly suppress the natural secondary vegetation, while *C. racemosa* is the one to apparently less compete for site resources with the natural secondary vegetation species.

Due to the more stratified nature of the enriched plots, with a considerable possibility of microsite variation associated to the own enriching tree architecture attributes, affecting sunfleck activity and providing differences in light regime associated to penumbral effects, in most of the treatments, the PAR% reaching the studied heights was higher the found in the control plot (Figure 2).

2.3 Blue Active Radiation (BAR)

A similar pattern of behavior was found for BAR, as compared to PAR, except that a somewhat higher proportion of BAR reached the ground in the plots enriched with *C. racemosa*, than it was found with respect to PAR, and slightly lower values of BAR were measured at 1m height in plots enriched with *S. paniculatum* and in the control plots (Figure 3).

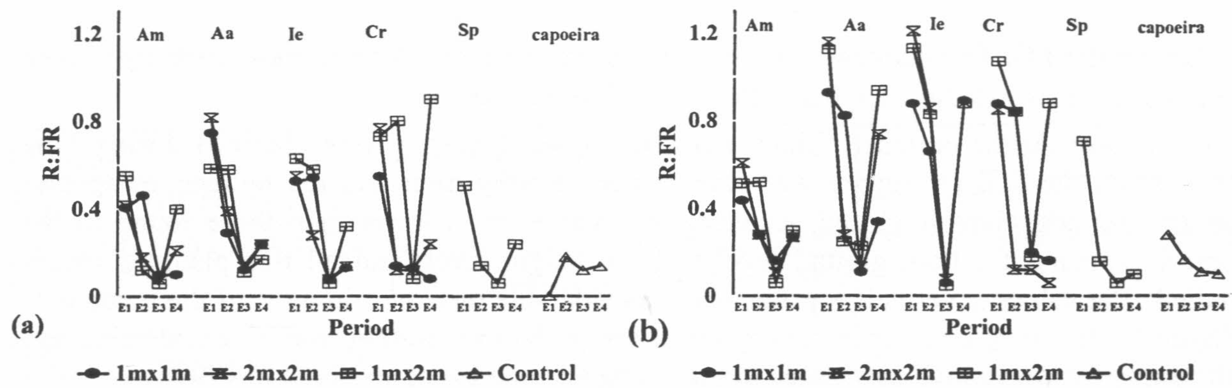

Figure 1: R:FR (ζ) values measured in four periods, in spontaneous fallow (*capoeira*, control), and in enriched fallow stands of: *A. mangium*, *A. angustissima*, *I. edulis*, *C. racemosa* and *S. paniculatum*, under three spacings. (a) at ground level; (b) at 1m height.

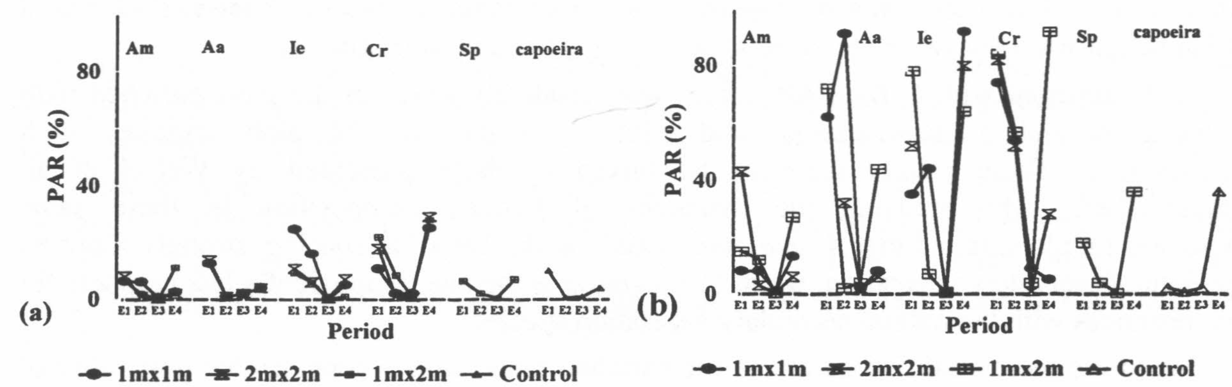

Figure 2: PAR (%) values measured in four periods, in spontaneous fallow *(capoeira*, control), and in enriched fallow stands of: *A. mangium*, *A. angustissima*, *I. edulis*, *C. racemosa* and *S. Paniculatum*, under three spacings: (a) at ground level; (b) at 1m height.

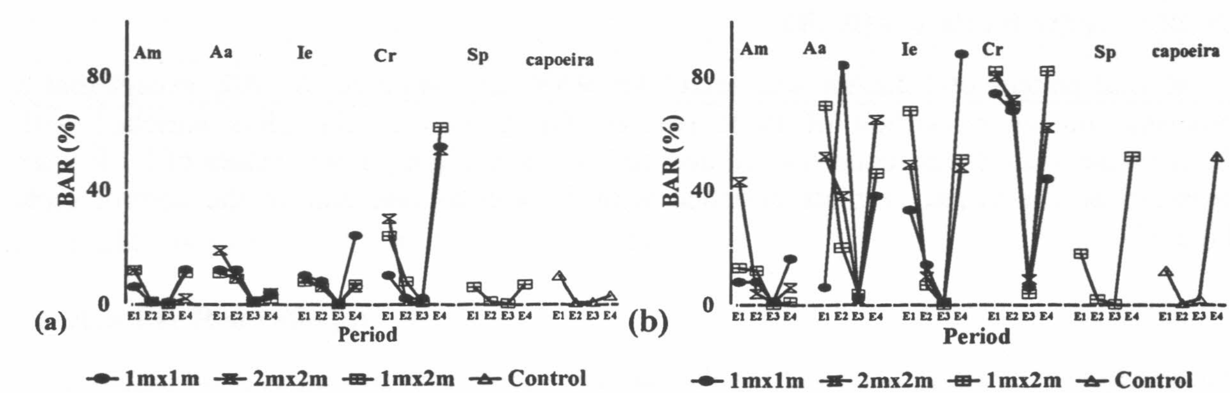

Figure 3: BAR (%) values measured in four periods in spontaneous fallow (*capoeira*, control), and in enriched fallow stands of: *A. mangium*, *A. angustissima*, *I. edulis*, *C. racemosa* and *S. paniculatum*, under three spacings. (a) at ground level; (b) at 1m height.

2.4 General comments

The relatively lower values of SI found in the energy reaching the top of the canopy during the first field campaign, as compared to the other studied periods (Table 3), denote partially cloudy conditions, and may have contributed to some extent to differences found as compared to the other periods, since the relative constitution of the incoming solar radiation as well as its partitioning traversing canopies may be differently affected under distinct cloudiness conditions (Smith, 1982, Káralis, 1989, Olesen, 1992, Baldy and Stigter, 1993).

The different sunlight regime found at the common two heights in natural and in the different enriched fallow vegetation experimental plots express the difference in vegetation dynamics, structure and spectral transmission of leaf components, characterizing these stands, and are relevant attributes to be taken into consideration while developing and testing complex sequential agroforestry systems such as enriching fallow.

Further work should include the accurate assessment of variables that would enable the analysis of the relationship between the light or radiation climate and vegetation structure associated to the monitoring light quality affecting photosynthesis and morphogenesis of vegetation components. Aspects associated to the: partitioning of solar radiation into direct and diffuse components; magnitude of penumbral effects of the sun in secondary vegetation canopies; and sunfleck distribution patterns must be considered, as spatial and temporal attributes. Very few studies focusing that are available for tropical secondary vegetation (Baldocchi and Collineau, 1994, Chazdon, 1996).

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