

ANNUAL VARIATION IN CANOPY OPENNESS, AIR TEMPERATURE AND HUMIDITY IN THE UNDERSTORY OF THREE FORESTED SITES IN SOUTHERN BAHIA STATE, BRAZIL

VARIAÇÃO ANUAL NA ABERTURA DO DOSSEL, TEMPERATURA E UMIDADE DO AR NO SUB-BOSQUE DE TRÊS AMBIENTES FLORESTAIS NO SUL DA BAHIA, BRASIL

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ABSTRACT

Aiming at contributing to the knowledge of physical factors affecting community structure in Atlantic Forest remnants of southern Bahia state, Brazil, we analyzed the annual variation in the understory microclimate of a hillside forest fragment in the 'Reserva Particular do Patrimônio Natural Serra do Teimoso' (RST) and a rustic cacao agroforestry system (Cabruca), located nearby the RST. Canopy openness (*CO*), air temperature (*Ta*), air relative humidity (*RH*) and vapor pressure deficit (*VPD*) data were collected between April, 2005 and April, 2006 at the base (RST_B, 340 m) and the top (RST_T, 640 m) of the RST and at the Cabruca (CB, 250 m). Data of rainfall, *Ta*, *RH* and *VPD* were also collected in an open area (OA, 270 m). The highest rainfalls (> 100 mm) occurred in November, 2005 and April, 2006, whereas October, 2005 was the driest month (< 20 mm). *CO* ranged between 2.5 % in the CB (April, 2006) and 7.7 % in the RST (October, 2005). Low rainfall in October, 2005 affected *VPD*_{max} in all sites. Those effects were more pronounced in OA, followed by CB, RST_B and RST_T. During the period of measurements, the values of *Ta*, *RH* and *VPD* in CB were closer to the values measured in OA than to the values measured inside the forest.

Keywords: Atlantic Forest; microclimate; rainfall; vapor pressure deficit.

RESUMO

Visando contribuir para o conhecimento dos fatores físicos que afetam a estrutura da comunidade vegetal em remanescentes de mata atlântica do sul da Bahia foi analisada a variação anual do microclima do sub-bosque num fragmento de floresta de encosta na Reserva Particular do Patrimônio Natural Serra do Teimoso (RST) e num sistema agroflorestal rústico utilizado para o cultivo do cacau (Cabruca), localizado nas proximidades da RST. Dados da abertura do dossel (*CO*), da temperatura do ar (*Ta*), da umidade relativa do ar (*RH*) e do déficit de pressão de vapor (*VPD*) foram coletados entre abril de 2005 e abril de 2006 na base (RST_B, 340 m) e no topo (RST_T, 640 m) da RST e na Cabruca (CB, 250 m). Dados de precipitação pluvial, *Ta*, *RH* e *VPD* foram também coletados numa área aberta (OA, 270 m). As maiores precipitações (> 100 mm) ocorreram em Novembro de 2005 e Abril de 2006, enquanto outubro de 2005 foi o mês mais seco (< 20 mm). *CO* variou entre 2,5 % na CB (Abril, 2006) e 7,7 % na RST (Outubro, 2005). Os baixos valores de pluviosidade registrados em Outubro de 2005 afetaram *VPD*_{max} em todos os ambientes. Estes efeitos foram mais pronunciados em OA, seguido de CB, RST_B e RST_T. Os valores de *Ta*, *RH* e *VPD* em CB foram mais próximos aos valores observados em OA do que aos valores observados no interior da floresta.

Palavras-chave: déficit de pressão de vapor; Floresta Atlântica; microclima; precipitação pluvial.

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INTRODUCTION

The Brazilian Atlantic Forest is one of the most endangered forest biomes in the world (MYERS et al. 2000). Floristic inventories have shown that the southern Bahia holds a higher level of plant endemism in comparison with other regions of the Atlantic Forest (THOMAS et al., 1998) and one of the highest tree species diversity in the world (MARTINI et al. 2007; THOMAS et al., 2008). According to Mori and Silva (1978) and Thomas and Barbosa (2008), following a rainfall gradient from littoral to the interior, the vegetation of the southern Bahia region can be divided into four main vegetation types, i.e. wet forests, mesophytic forests, liana forest and 'caatinga'. The socioeconomic history of the region is linked to the cultivation of cacao trees (*Theobroma cacao* L.) in a rustic agroforestry system called 'Cabruca'. In 'Cabrucas', a selected part of the native trees is preserved, while the understory is substituted by cacao trees. Despite large areas of deforestation, southern Bahia still preserves highly complex forest-like coverage, due to remaining native trees in the cacao plantations (SAMBUICHI and HARIDASAN, 2007). Furthermore, more studies analyzing the ecological significance of 'Cabrucas' are needed to determine the dependence of this system on the native forest remainders and their functionality as ecological corridors linking the same (FARIA et al., 2007).

The 'Reserva Particular do Patrimônio Natural Serra do Teimoso' (RST) is a small hillside forest fragment located in the transition area between wet and mesophytic forests, ranging from 200 to 850 m above sea level. The edaphic and climatic components of the altitude gradient influence the RST floristic composition (AMORIM et al., 2005; THOMAS et al., 2009). At the base of the forest (below 500 m), seasonal semideciduous forest species prevail, including *Averrhoidium gardnerianum* Baill. (Sapindaceae), *Cavanillesia arborea* (Willd.) K. Shum. (Malvaceae), *Caesalpinia echinata* Lam. (Fabaceae) and *Chrysophyllum subspinosum* Monach. (Sapotaceae), among others (AMORIM et al., 2005; THOMAS et al. 2009). At the top (above 500 m), wet evergreen forest species are predominant, including *Bathysa cuspidata* (A. St.-Hil.) Hook. f. (Rubiaceae), *Euterpe edulis* Mart. (Arecaceae) and *Prunus sellowii* Hoehne (Rosaceae) (AMORIM et al., 2005; THOMAS et al., 2009).

Microclimate of forest understory presents a great importance for the regeneration and distribution

of understory species, for the maintenance of belowground processes and for the ecosystem dynamics overall, being highly dependent in a time and space to the forest structure and weather conditions (CHEN et al., 1999; LÜTTGE, 2008). Even though efforts have been made to improve the knowledge on community diversity in forest areas of southern Bahian forest areas (AMORIM et al., 2005, 2009; FARIA et al., 2007; MARTINI et al., 2007; SAMBUICHI and HARIDASAN, 2007; THOMAS et al., 2008, 2009), at this moment, no studies have analyzed the effects of the forest cover vegetation on understory microclimate.

Aiming to contribute for the knowledge of physical factors affecting community structure and the forest conservation in Southern Bahia, we analyzed the effects of regional climatic seasonality in the understory microclimate (air temperature, relative humidity and vapor pressure deficit) of a fragment of the southern Bahian Atlantic Forest and a rustic cacao agroforestry system.

MATERIAL AND METHODS

The study was conducted in the 'Fazenda Teimoso' (FT), municipally of Jussari (15°12'S, 39°29'W), Bahia state, Brazil. The FT covers 520 ha divided in native forest, cocoa cultivation in Cabrucas and livestock pastures. The climate is Am of the Köppen classification with an annual mean precipitation of 1,323 mm and a mean air relative humidity of 84 %. Annual mean air temperature varies between 23 and 24 °C (BAHIA 2001). The study was conducted in four sites located at the base (RST_B, 340 m) and the top (RST_T, 640 m) of the RST, in a 'Cabruca' (CB, 250 m) located near the RST and in an open area (OA, 270 m). The CB has approximately 50 years-old and an area of about 30 ha.

The canopy openness (*CO*) was analyzed based on 18 sample points through hemispherical photographs; six sample points were marked in each of the three forest covered sites (RST_B, RST_T and CB). In RST the sample points were positioned in the three highest (RST_T) and in the three lowest (RST_B) parcels of the transect previously marked by Thomas et al. (2009). The parcels with 20 x 10 m were divided in sub-parcels with 10 x 10 m and the photographs were taken at the central point of each sub-parcel. In CB the sample points were marked considering a minimum distance of 20 m from the edge and 20 m among them. A Nikon Coolpix

4300 digital camera equipped with a hemispherical lens fish-eye (180°) was used. This was mounted on a 1.5 m tripod, which was leveled using a bubble level. Hemispherical photographs were taken in the RST, during five periods (April, July and October, 2005 and January and April, 2006) and in the CB during three periods (October, 2005 and January and April, 2006). The photographs were analyzed using the GLA software (Gap Light Analyzer - FRAZER et al., 1999). The *CO* values were transformed arcsine transformed before analysis and the results were subjected to an analysis of variance followed by a Tukey test with 5 % probability.

Air temperature (*Ta*) and relative humidity (*RH*) Hobo H8 Pro Series (Onset, USA) sensors were installed at the four sites. The sensors were installed on 1.5 m wooden stakes. In RST the sensors were installed at the center of the lowest (RST_B) and the highest (RST_T) parcels of the transect previously marked by Thomas et al. (2009). The Hobo sensors were programmed to produce readings at 30-minute intervals, for comparisons between the sites. Data were collected between April, 2005 and April, 2006. Due to the difficulty to access the top of RST, the data in RST_T was collected in intervals of three months between the field campaigns. A problem in the RST_T 's sensor, probably due to the high *RH* values, caused the loss of data between the months of November 2005 and January 2006. The daily maximum, minimum and average values were obtained through the *Ta* and *RH* data. Day and night values were also separated. Readings taken between 06:00 and 17:30, were considered as day values and between 18:00 and 05:30 as night values. Monthly-average and ten-day minimum, day average, maximum and daily and nocturnal *Ta* values (Ta_{min} , Ta_{avr} , Ta_{max} , Ta_d and Ta_n , respectively) and the corresponding *RH* values (RH_{min} , RH_{avr} , RH_{max} , RH_d and RH_n , respectively) were calculated. Based on data of *Ta* and *RH* the vapor pressure deficit (*VPD*) was calculated, using the formula proposed by Landsberg (1986). Rainfall data were obtained using a pluviometer (Meteoro Instrumentos, Brazil) installed in the OA. Relationships between rainfall and *VPD* were analyzed using non-linear models.

RESULTS

The rainfall between April, 2005 and April, 2006 was 1,163 mm. In this period, the months of May, November and December, 2005 and January, March and April, 2006 showed values above

100 mm (Figure 1). April, 2006 was the month with the highest rainfall (170 mm). The months between June and October, 2005 had the lowest rainfall values and October was the driest month (13.9 mm).

The *CO* values varied between 2.5 % in CB (April, 2006) and 7.7 % in RST_B and RST_T (October, 2005) (Table 1). The highest values were observed in October, 2005. These were between 5.9 and 6.5 % in RST_B , between 5.2 and 7.7 % in RST_T and between 4.0 and 6.1 % in CB. The lowest mean values of *CO* were observed in April, 2006. In April, July and October, 2005, the mean *CO* values were very similar to RST, with non-significant differences ($p > 0.05$) between RST_T and RST_B .

The mean values of air temperature in CB, OA, RST_B and RST_T were respectively 22.2, 22.9, 22.1 and 19.8°C. The monthly-average values of Ta_{min} in RST_B (Figure 2A) were always higher than the other sites. The lowest Ta_{min} values were observed in July, 2005 at all sites; in which CB, RST_T and OA had very similar values (16.2 °C in CB, 16.4 °C in RST_T and 16.5 °C in OA). The largest temperature differences among sites were observed for Ta_{max} (Figure 2B). Those values were lesser in RST than in CB and OA. The lowest and highest Ta_{avr} values were registered in July, 2006 and February, 2006, respectively (Figure 2C). Those values were very similar in the CB, OA and RST_B , but always inferior in RST_T . The lowest Ta_d and Ta_n values were always registered for RST_T (Figure 2D and 2E).

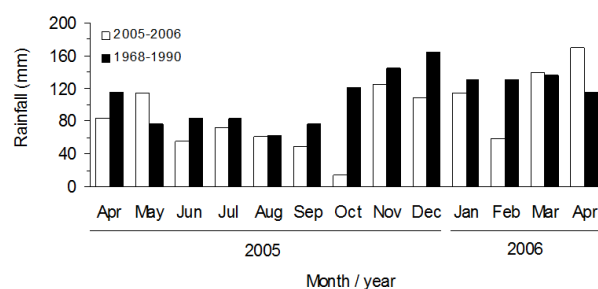


FIGURE 1: Monthly rainfall at 'Fazenda Teimoso', Jussari, Bahia state, Brazil, during the period of study (April 2005 to April 2006) and mean monthly values between 1968 and 1990 (Bahia, 2001).

FIGURA 1: Precipitação pluvial mensal na Fazenda Teimoso, Jussari, Bahia state, Brasil, durante o período do estudo (abril de 2005 a abril de 2006), e valores médios mensais entre 1968 e 1990 (Bahia, 2001).

TABLE 1: Canopy openness ($CO, \%$) at the three sites of the 'Fazenda Teimoso', Jussari, Bahia, Brazil, between April, 2005 and April, 2006. Mean values of $CO \pm$ standard errors. Values between parenthesis correspond to the minimum and maximum observed. ($n = 6$)

TABELA 1: Abertura do dossel ($CO, \%$) em três locais da Fazenda Teimoso, Jussari, Bahia, Brasil, entre abril de 2005 e abril de 2006. Valores médios de $CO \pm$ erros padrão. Os valores entre parênteses correspondem aos mínimos e máximos observados.

Site	April 2005	July 2005	October 2005	January 2006	April 2006
RST _B	4.7 ± 0.3 ^a (3.8-5.5)	4.5 ± 0.2 ^a (4.0-5.1)	6.1 ± 0.1 ^a (5.9-6.5)	3.8 ± 0.2 ^b (3.2-4.5)	3.4 ± 0.1 ^b (3.1-4.0)
RST _T	5.0 ± 0.4 ^a (4.1-6.8)	5.4 ± 0.3 ^a (4.5-6.2)	6.6 ± 0.4 ^a (5.2-7.7)	5.1 ± 0.3 ^a (3.7-6.0)	4.7 ± 0.3 ^a (3.4-5.1)
CB	-	-	4.8 ± 0.3 ^b (4.0-6.1)	4.7 ± 0.3 ^{ab} (3.9-5.2)	3.4 ± 0.3 ^b (2.5-4.3)

Means followed by the same letters do not differ by the Tukey's test at 5 % probability.

The largest differences among sites for the vapor pressure deficit were observed for VPD_{max} (Figure 2G). The highest monthly-average values of VPD_{max} were registered in October, 2005 (1.8 kPa in OA, 1.7 kPa in CB, 1.3 kPa in RST_B and 0.6 kPa in RST_T). As expected, the values of VPD_{min} were lower than 0.1 kPa for all sites and very similar to the values registered at night (VPD_n) (Figure 2F and 2J). The highest monthly-average values of VPD_{avr} and VPD_d were observed in October, 2005 for all sites (Figures 3H and I). The lowest values of vapor pressure deficit were always observed for RST_T, with exception to the month of April, 2006; in which the lowest values of VPD_{avr} and VPD_d were observed in OA (Figure 2H and 2I). In all sites the ten-day values of VPD_{max} showed a tendency to decrease with increasing rainfall (Figure 3).

Scatterplots comparing ten-day values of Ta_{max} , Ta_{min} , T_d and T_n measured in OA and in the other sites show direct relationships among temperatures measured in the open area and inside CB and RST (Figure 4). Nevertheless, there was a tendency of data collected in OA to be closest to the data collected in CB than the data collected in RST. All Ta_{max} (Figure 4A) and Ta_d (Figure 4C) values were higher in OA than in the other sites, but Ta_{min} (Figure 4B) and Ta_n (Figure 4D) were higher in RST_B than in the other sites. For the all temperature variables, the lowest values were measured in RST_T. The data presented in Figure 4 is consistent with monthly-average data presented in Figure 2, but show more accurately the differences among variable temperatures at different sites.

The lowest and the highest instantaneous values of Ta were observed on July 7, 2005 and March 5, 2006, respectively (Figure 5A and 5C). The lowest Ta value was 11.8 °C on July 7, 2005 at 6:30 AM in CB (Figure 5A). Between 10:00 AM and 17:00 PM, the highest Ta values were observed in OA and the lowest ones in RST_T. On the same

day, the highest value of RH was registered in RST_T around midday (Figure 5B). On the other hand, the highest Ta value (34.4°C at 13:30) was registered in OA on 05 March, 2006 (Figure 5C). On that same day, the lowest and highest RH values (44.1 %) were registered in the OA and in the RST_T (41.1 % and 65.7 %, respectively) (Figure 5D). The maximum instantaneous values of VPD were observed in OA and CB, respectively (Figures 4C and 5F). Those values were around 1.5 kPa in July 7, 2005 and 2.8 kPa in March, 5 2006. In RST_T, VPD was below 0.5 kPa in July 7, 2005 and 1.5 kPa in March, 5 2006.

DISCUSSION

The sum of rainfall from April, 2005 to March, 2006 (1,163 mm) was inferior to the values previously described for the Jussari region (1,323 mm). Most of the monthly data obtained, excluding the months of May, 2005, March and April 2006, were below those previously described for the region (BAHIA, 2001). Thus, the period of data collection was marked by two unexpected dry months (October, 2005 and February, 2006), being particularly interesting to analyze the effects of the changes in rainfall pattern along the year and its influence on the understory microclimate.

The values of CO in the forest area (RST) are in accordance with those observed by Trichon et al. (1998) in a humid tropical forest in Sumatra, Indonesia. The results of this study also resemble those obtained by Silva Júnior et al. (2004) in a semi-deciduous forest in southeast Brazil; which varied between 1 and 7 %. In contrast, Martins and Rodrigues (2002) obtained values of CO superior to those observed in this study, during the analysis of a gap regeneration phase in a semi-deciduous forest in southeastern Brazil. Considering that high CO values are indicative of large forest gaps (TRICHON et al., 1998), the RST plots in our study present low

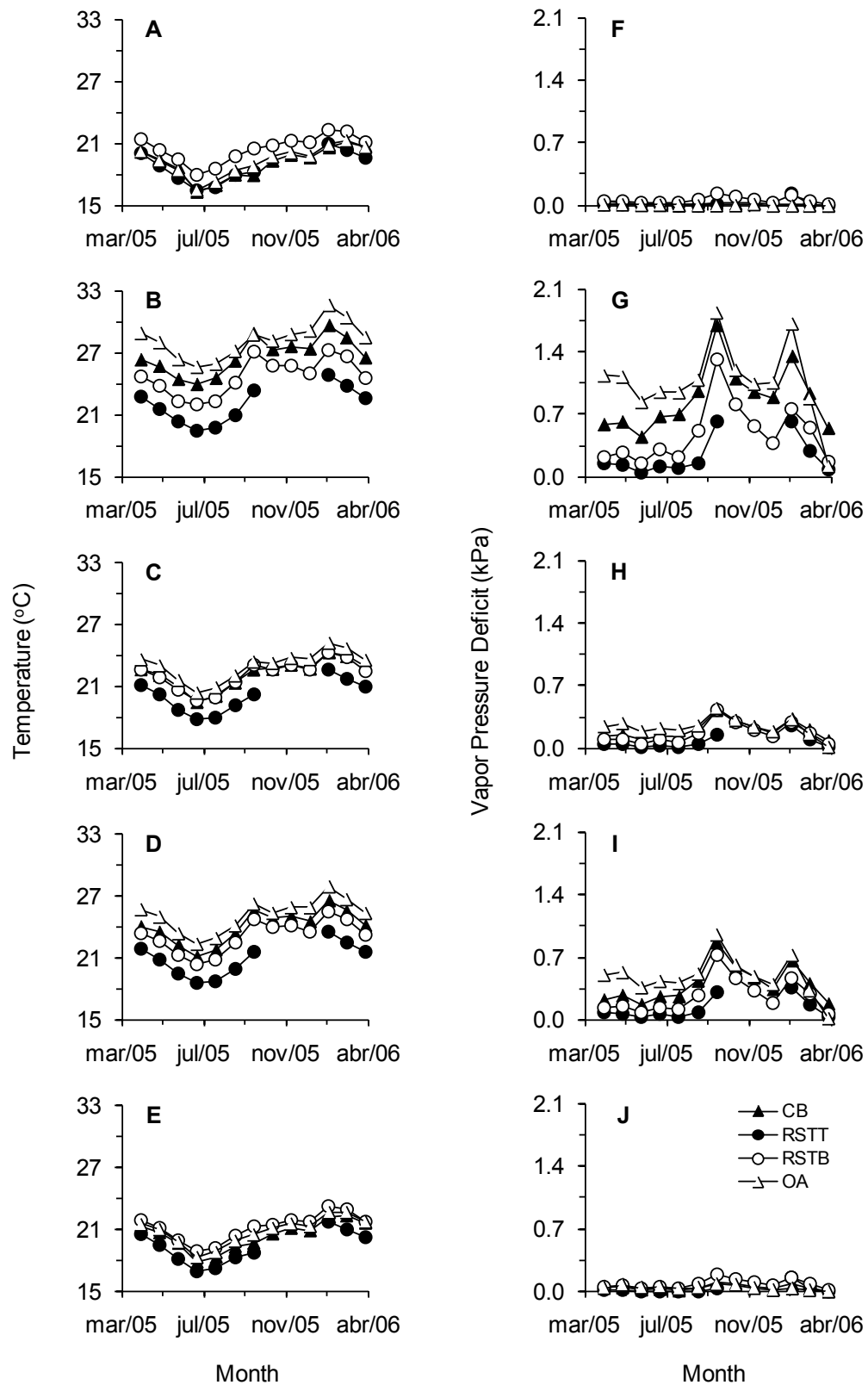


FIGURE 2: Values of Ta_{min} (A), Ta_{max} (B), Ta_{avr} (C), Ta_d (D), Ta_n (E), VPD_{min} (F), VPD_{max} (G), VPD_{avr} (H), VPD_d (I) and VPD_n (J) at four sites in the 'Fazenda Teimoso', Jussari, Bahia, Brazil, between April, 2005 and April, 2006.

FIGURA 2: Valores de Ta_{min} (A), Ta_{max} (B), Ta_{avr} (C), Ta_d (D), Ta_n (E), VPD_{min} (F), VPD_{max} (G), VPD_{avr} (H), VPD_d (I) e VPD_n (J) em quatro locais na Fazenda Teimoso, Jussari, Bahia, Brasil, entre abril de 2005 e abril de 2006.

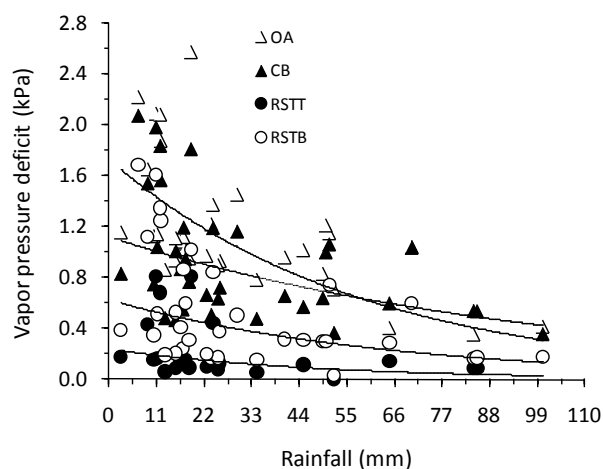


FIGURE 3: Relationships between rainfall and VPD_{max} in three forested sites at 'Fazenda Teimoso', Jussari, Bahia state, Brazil.

FIGURA 3: Relações entre a precipitação pluvial e VPD_{max} em em quatro locais na Fazenda Teimoso, Jussari, Bahia, Brasil.

CO values in comparison to data obtained by other authors (TRICHON et al., 1998; MARTINS and RODRIGUES, 2002; NASCIMENTO et al., 2007). The canopy openness values below 8 % (Table 1) are indicative that RST_T and RST_B present a relatively closed canopy.

The low values of CO observed in the Cabruca (CB) can be explained by the fact that the hemispherical photographs were taken just below the canopy layer of the cocoa trees (i.e. 1.5 m above ground). In general, light intensity under the shade of cacao trees is very low because of the canopy architecture and the size of the leaves. For example, Miyaji et al. (1997) reported that the relative light intensity in the lower canopy layer of shaded cacao trees (60-90 cm above ground) varied from 4 to 10 % of the full sunlight. Similar results were also found by Lima (2007), which reported that the relative light intensity below the canopy of cacao trees was around 5 % of the full sunlight. The lowest values of CO found in the RST_B in January 2006 and April 2006 are related to the semideciduous characteristic of the most frequent tree species in this part of the forest (THOMAS et al., 2009) and to the low rainfall values in the months of October 2005 and February 2006, respectively.

The highest values of Ta_{avr} and Ta_{max} observed in OA in comparison with values measured in the forested sites are in agreement with information found in the literature (HERNANDES et al., 2002;

PEZZOPANE et al., 2002; PEZZOPANE et al., 2005). Among all temperature variables, the largest differences were verified for Ta_{max} ; in which the greatest difference was observed between RST_T and OA. Within the forest sites (RST), the highest Ta values were found in the lowest portion (RST_B). During the period of data collection, the Ta_{min} was greatest in the RST_B . Hernandez et al. (2002), for example, also observed an inferior minimum temperature in a forest fragment in relation to the vineyard and weather station (external environments) during the coldest period of the year. According to the authors, this may be due to the semi-deciduous characteristic of the study site. On the other hand, the greatest Ta_d and Ta_n values were in the OA and in the RST_B .

Among all forest sites the lowest values of VPD were generally observed in the RST_T , demonstrating the expressive effect of the altitude gradient and forest environments on air humidity (LÜTTGE, 2008). In contrast, incongruent data was collected in April, 2006, in which the lowest VPD_d and VPD_{min} values were registered in the OA (Figure 2). This apparent incongruence can be explained by the fact that April, 2006 was characterized by the highest rainfall in the whole period of data collection (Figure 1). Our results demonstrate that VPD is dependent on the seasonal rainfall fluctuations. For instance, October, 2005 was characterized by the lowest amount of precipitation and the highest VPD values and April, 2006 had the highest rainfall precipitation and the lowest VPD values. The high VPD values in February, 2006 were probably related to the highest Ta values as well the low precipitation.

The data collected during this study was sufficient to demonstrate that the understory microenvironment in CB is more similar to that observed in OA than in the forest sites (RST). Alternatively, we also should consider that the altitude gradient could be affecting those differences, because the quota for the sensors located in OA, CB, RST_B and RST_T were respectively 270, 250, 340 and 670 m. In a study aiming to analyze the effects of dry and wet seasons on the microclimate of a cacao plantation in Ilhéus, Bahia state, Brazil, Miranda et al. (1994) also found that temperature and humidity were quite similar to an open area. In spite of the great heterogeneity of 'Cabruças' of southern Bahia, our results were in agreement with those reported by Miranda et al. (1994), showing that the values of Ta and VPD in CB during the measurement period were closest to the values

measured in OA than inside the forest.

The growth of plants, the accumulation and partition of photo-assimilates and the production of secondary compounds are factors that affect seedling establishment and forest regeneration (KITAJIMA, 1994). Accordingly, the understory light environment strongly affects forest regeneration because the light is the primary source of energy to photosynthesis (HOGAN and MACHADO, 2002). On the other hand, environmental factors as temperature and humidity are also important. Temperature affects the carbon balance (i.e. root and shoot respiration) and overall plant metabolism. Air humidity directly affects water flux in plants, cell turgor, stomatal conductance and, consequently, photosynthesis (SCHULZE et al., 2002). In our study CO_2 values were below 8 % through the year and were very similar among RST environments.

Despite differences in canopy structure, probably affecting the quality of radiation which reaches the understory, the light availability in the understory seems not to be the main factor that affects the regeneration of different species along the altitude gradient.

Vapor pressure deficit is a very important environmental factor because is directly related to stomatal conductance and leaf gas exchange (LANDSBERG, 1986; FRANKS and FARQUHAR, 1999). Even though some recent results have shown that VPD does not have a significant long-term effect on growth of tropical evergreen rainforest trees (CUNNINGHAM, 2006) it is clear that there is an association between the distribution of species along the altitude gradient in RST and relative humidity. In addition, there are numerous references showing that the sensitivity to VPD is

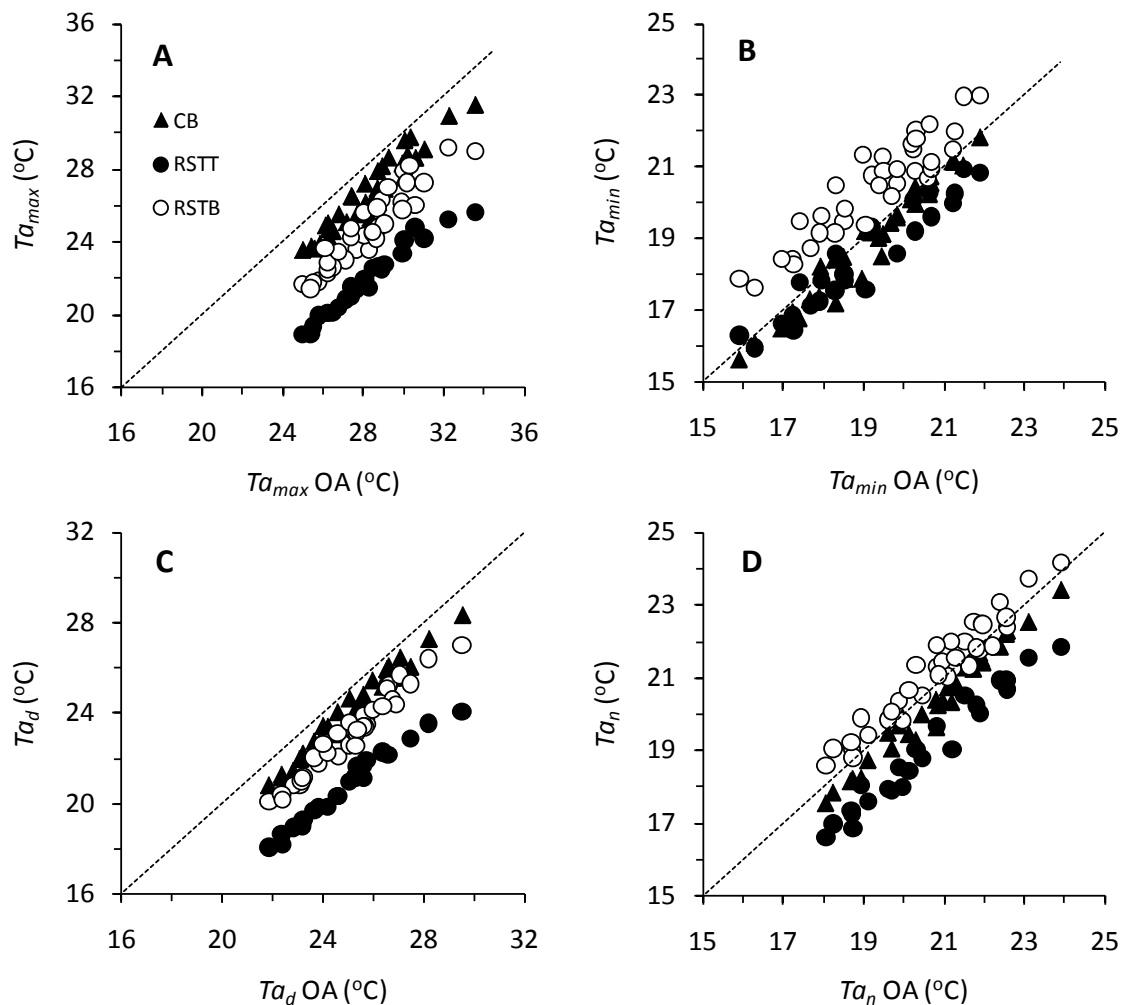


FIGURE 4: Scatterplot of air temperature in the open area (OA) and three forest sites in 'Fazenda Teimoso', Jussari, Bahia state, Brazil. The broken lines indicate 1:1.

FIGURA 4: Gráfico de dispersão da temperatura do ar numa área aberta (OA) e em três ambientes florestais na Fazenda Teimoso, Jussari, Bahia, Brasil. Linhas tracejadas indicam 1:1.

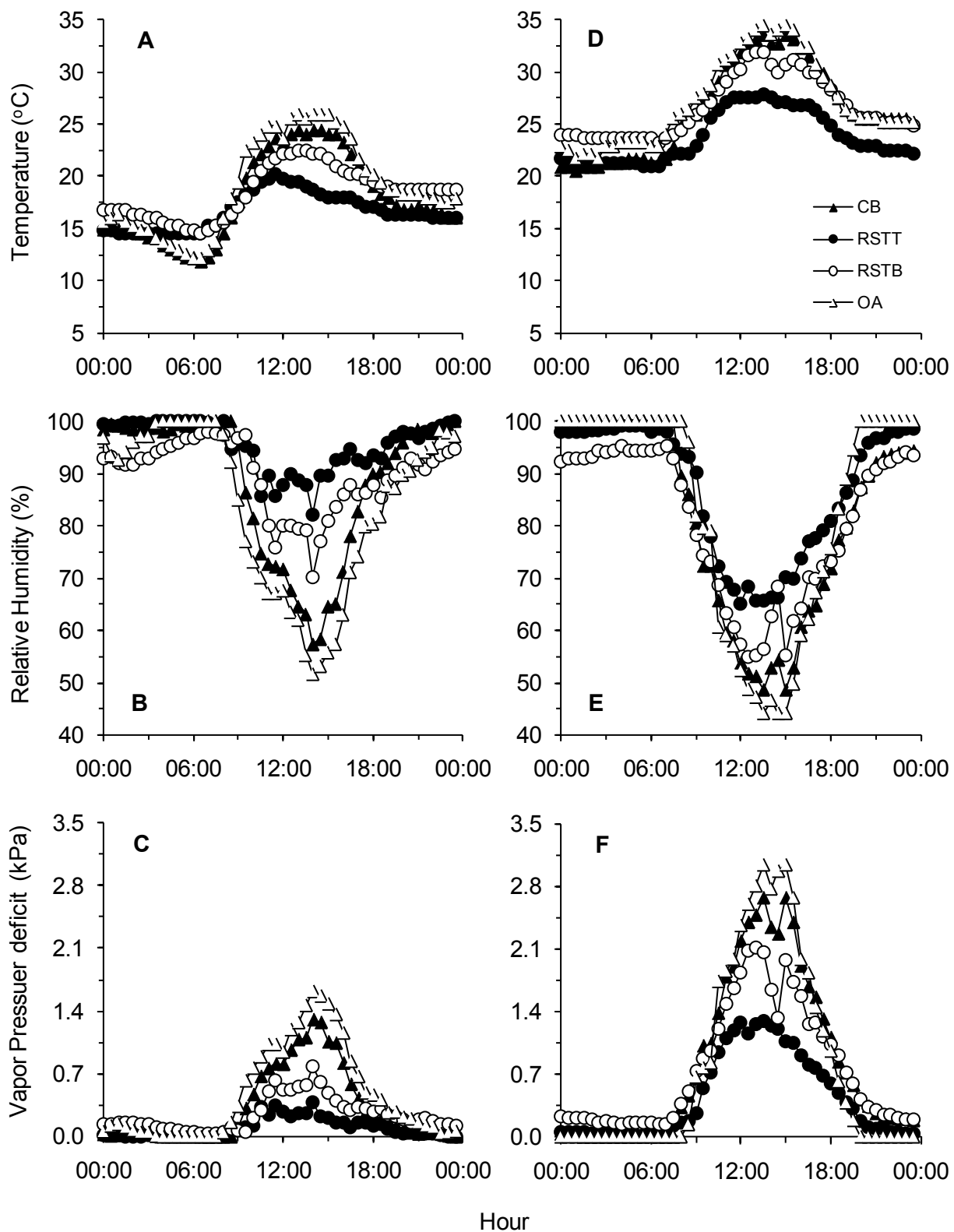


FIGURE 5: Air temperature, air relative humidity and vapor pressure deficit on two contrasting days, 10 July, 2005 (A, B and C) and 05 March, 2006 (D, E and F), at four sites in 'Fazenda Teimoso', Jussari, Bahia state, Brazil.

FIGURA 5: Temperatura, umidade relativa e déficit de pressão de vapor do ar em dois dias contrastantes, 10 de julho de 2005 (A, B e C) e 5 de março de 2006 (D, E e F), em quatro locais na Fazenda Teimoso, Jussari, Bahia, Brasil.

widely variable among plant species (FRANKS and FARQUHAR, 1999; CUNNINGHAM, 2004). In this way, studies aiming to investigate the effects of *VPD* on the growth of species that only occur in RST_T or RST_B may provide interesting information on the effects of air humidity in the canopy structure and tropical forest dynamics.

In summary, the largest differences among the sites were observed in the monthly-average values of the maximum air temperature (Ta_{max}). These values were always lower inside the mature forest (RST) in comparison to the CB and the OA. Changes in the monthly rainfall throughout the year affected *CO* and *VPD*. Seasonal changes in the climatic variables and the constant low values of *VPD* through the year in RST_T are in accordance with the floristic composition along the altitude gradient of the RST. During the period of measurements the values of Ta and *VPD* in CB were closest to the values measured in OA than to the values measured inside the forest.

CONCLUSIONS

The largest differences among the sites were observed in the monthly-average values of the maximum air temperature (Ta_{max}). These values were always lower inside the mature forest (RST) in comparison to the CB and the OA. Changes in the monthly rainfall throughout the year affected *CO* and *VPD*. Seasonal changes in the climatic variables and the constant low values of *VPD* through the year in RST_T are in accordance with the floristic composition along the altitude gradient of the RST. During the period of measurements the values of Ta and *VPD* in CB were closest to the values measured in OA than to the values measured inside the forest.

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