



Quantifying Eucalyptus Transpiration Using the Dissipation Thermal Technique in Porto Seguro, Bahia

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ABSTRACT

Granier's sap flow method proved to be an important tool for estimating transpiration in woody plants. The present work aimed to estimate the transpiration of two clones (VCC0865 and CO1407) of a hybrid of the eucalyptus species *Eucalyptus grandis* × *Eucalyptus urophylla*, in order to understand the efficiency and patterns of water use in the forest ecosystem. The experiment was carried out on a eucalyptus farm in the municipality of Porto Seguro, located in the extreme south of Bahia. The spacing between trees was 3.60 m × 2.50 m. Sap flow measurements were performed daily, between February and December 2022, using 10 sensors installed in tree trunks, according to Granier's thermal dissipation method. Data were recorded in the datalogger model CR10X system. For the systematization and analysis of the data, the R programming language was used. The results obtained indicated that the beginning of the transpiration period of the clones occurred around 07:00. On rainy days, less transpiration was observed in both clones. There were no significant changes in sap flow between dry and rainy seasons. It was also found for clone VCC0865 a transpiration rate of 43% higher in the daily average compared to clone CO1407. The present work is an important tool to contribute with information about transpiration in eucalyptus cultivation in the extreme south of Bahia, since there are few studies on the subject and given the importance of the activity in the region.

Keywords: Eucalyptus, Seed flow, Granier

SUMMARY

The Granier Sap Flow Method has been shown to be an important tool for estimating transpiration in woody plants. The objective of this study was aimed to estimate the transpiration of two clones (VCC0865 and CO1407) of the hybrid *Eucalyptus grandis* × *Eucalyptus urophylla* to understand the efficiency and patterns of water use in the forestry ecosystem. The experiment was carried out on an eucalyptus farm in the city of Porto Seguro, in the Extreme Part of South of Bahia. The spacing between the trees was 3.60 m × 2.50 m. The flow measurements of sap were carried out daily, between the months of February to December 2022, using 10 sensors installed in the trunks of the trees, according to the method of thermal dissipation of Granier. The data was recorded in the CR10X model datalogger system. For a Systematization and analysis of the data used the R language. The results obtained indicated that the start of the period of sweating of the clones occurred near 07h. On rainy days, less transpiration was observed in both clones. No significant changes in the flow of sap between drought and rainy periods. It was also found that the clone VCC0865 had a transpiration rate of 43% higher on a daily average compared to clone CO1407. This current task is an important tool to contribute with information on transpiring in forestry of eucalyptus in the Far South of Bahia, because there are few studies on the subject and given the importance of the activity in this region.

Transpiration Estimates in a Eucalyptus Plantation by the Thermal Dissipation Method

Introduction

The genus *Eucalyptus* is one of the most planted all over the world. The distribution of this genus occurs in about 95 countries, with an area of 22.57 million hectares worldwide (Zang Yuxing & Wang Xuejun, 2021). It is estimated that there are in the world about 800 eucalyptus species, of these 102 species have already been introduced and cultivated in Brazil (Brasil's Flora, 2020). In Brazil, eucalyptus planting has reached approximately 9.93 million hectares in Brazil (IBÁ, 2022), being pioneer in the clonal propagation system for higher planting productivity (Flores et al., 2016).

The cultivation of eucalyptus feeds a variety production chain, being used mainly for the production of paper and cellulose, laminated wood, sawdust or in timber, coal and wood, as well as in oils essential and biocides (Amorim, 2016; Teixeira et al. 2022).

In addition to raw material for various segments of industry, the eucalyptus forests offer a variety of ecosystem services, contributing mainly for carbon withdrawal of the atmosphere, softening the effects of global warming and improving the air quality (Poorter et al., 2021; Beslity et al., 2021; Amorim et al. 2021). These forests also contribute to production of rain, transferring water from the soil to atmosphere and thus cooperating with the hydrological cycle of the region in which is inserted (Schlesinger e Jasechko, 2014).

In the Far South of Bahia, the paper and cellulose industries started the plantation of eucalyptus, reforested mainly on already deforested land and degraded with the exploitation of timber native to the Atlantic forest, and subsequently by the use of agriculture (Cerqueira Neto, 2013). In this region, in the 1980s, these industries have expanded their activities, encouraged by the favorable conditions of edafoclimatics, availability of large extensions of land and cheap labor, plus a development plan supported by the government (Medeiros et al., 2021). Four decades later, the region becomes one of the major producers of paper and cellulose of the country (SEI, 2020) highlighting the State Bahia as the 4th largest producer of *Eucalyptus* in Brazil (ABAF, 2021).

According to Costa e Oliveira (2019), the greatest challenge for this economic activity is to make production more sustainable, where ecosystems service offered by this culture and its commercial importance, balance the use of natural

resources necessary for the handling and production of the same. Therefore, there is an expressive quantity of studies developed related to forest nutrition in eucalyptus plantations (Stape, 2004; Laclau, 2003; Sette, 2014; Rabbit et al. 2021; Florentino, 2022), however, there are still few studies related to quantity and efficiency of water use in this cultivation (Wullschleger et al., 2011; Beslity et al., 2022). The efficiency of ecosystem in water use (WUE) is defined as the relationship between annual primary productivity (GPP) and annual evapotranspiration (ET) (Huanget al. 2015). However, differences significant in environmental parameters can induce different variations in the water efficiency and use (Yao et al. 2023).

To understand the use and the water efficiency in a forest, uses mainly the flow patterns of Seiva (MFS) which includes the methodologies energy balance, heat pulse and thermal dissipation, among others (Venâncio et al., 2019).

Although there are other methodologies for measurement and estimation of the sap flow, mostly, there is still a complexity in the accuracy of results, in addition to the high costs of experiments, limiting the number of studies in this area (Beslity et al., 2022). In this work, the MFS developed by Granier (1985), developed by Granier (1985) due to their cost-effectiveness and resources, backed by results satisfactory in previous surveys (Delgado-Rojas et al., 2006; Gentil, 2010; Beslity et al., 2022). Considering the climate change context global, it is essential to understand the relationship between sweating and factors which influence the species of trees and predict changes in water use through of modeling (Wang et al. 2022).

The purpose for this research was to estimate the transpiration rates in two hybrid clones *Eucalyptus Grandis* × *Eucalyptus Urophylla* (VCC 865 e VCC1407) through seam flow measurements to understand efficiency and the water usage patterns in ecosystem forestry. Furthermore, understand how climate factors can influence the rates of transpiration between the two clones, seeking to understand how the environment can modulate this process. And evaluate the efficiency in adjusting the proposed equation by Rojas-Delgado in the estimate of transpiration in *Eucalyptus*.

Material and methods

Study Area

This study was developed in a private area on the banks of the BR-367, between Porto Seguro and Eunápolis, at the Extreme South of Bahia, in

coordinates geographical (16° 22' 14.286"S, 39° 14' 59.211"W) (Figura 1). The total planted area is approximately 58 hectares.

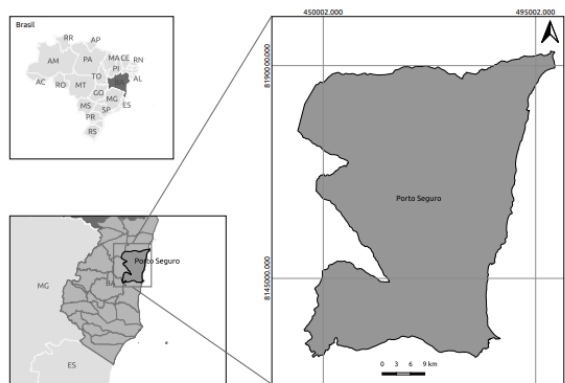


Figure 1. Map of the study area.

The climate of the region, according to Köppen's classification is of the type Af, defined as rainy, warm and humid, being characteristic of tropical zones, with vegetable cover of forests and low latitude zone (Alvares et al., 2013). The relief by presenting altitudes below 200 meters and slope below 5%, directly influences the regional climate, increasing the permanence of air masses and providing high rates of precipitation throughout the year (Silva et al., 2020).

The average annual temperatures in the municipality range from 22°C to 26°C.

The dry period runs from April to September and the rainy period from October to March. In the dry period, the accumulated precipitation ranges from 289 to 869 mm and in the rainy period the precipitation volume varies from 614 to 785 mm. Annual averages are above 1400 mm (Silva et al., 2020). According to Souza et al. (2011) the soil of Porto Seguro is classified as originating from pidginized sediments of the geological group Barreiras, predominating the oxidic soils, of characteristic Yellow Argisol-Sandy, of flat to wavy relief. Regarding to the chemical and granulometric characteristics of the soil, the analysis was carried out by the embroidery method according to Table 1 and Table 2 respectively. In this soil, the first cultivation of eucalyptus was carried out, being previously occupied with coconut planting (*Cocos nucifera*)

Table 1. Chemical attributes of the soil of the experimental area. Source: Authors (2022).

Parameter	Unit	Depth		
		0-20	20-40	40-60
P	mg dm ⁻³	6	3	1
K	mg dm ⁻³	30	17	13
S	mg dm ⁻³	6	7	8
Ca	cmol c dm ⁻³	0,7	1	1,3
Mg	cmol c dm ⁻³	0,2	0,3	0,3
Al	cmol c dm ⁻³	0,4	0,3	0
H+Al	cmol c dm ⁻³	5,2	3,8	3,3
pH em H ₂ O	-	5,1	5,3	5,7
Fe	mg dm ⁻³	191	383	389
Zn	mg dm ⁻³	2,5	0,7	0,5
Cu	mg dm ⁻³	1,5	0,6	0,3
Mn	mg dm ⁻³	5,5	2	2
B	mg dm ⁻³	0,22	0,16	0,12
Na	mg dm ⁻³	4	5	6
Ca/Mg	-	3,5	3,3	4,3
Ca/K	-	9,1	22,9	39
Mg/K	-	2,6	6,9	9
Sat. Ca in CTC (T)	%	11,3	19,4	26,4
Sat. Mg in CTC (T)	%	3,2	5,8	6,1
Sat. K in CTC (T)	%	1,2	0,8	0,7
Sat. Index Na	%	0,3	0,4	0,5
Sum of Bases (SB)	cmol c dm ⁻³	1	1,4	1,7
CTC effective (t)	cmol c dm ⁻³	1,4	1,7	1,7
CTC a pH 7,0 (T)	cmol c dm ⁻³	6,2	5,2	5
Sat. aluminum (m)	%	29	18	0
Saturation of base	%	16,1	26,4	33,5

Table 2. Physical Soil Properties. Source: Authors (2023).

Depth cm	Clay Silt		Sand		
			Coarse	Fine	Total
			%		
0-20	18	8,6	58	15,4	73,4
20-40	28	10,2	46,8	15	61,8
40-60	36	12,4	38,2	13,4	51,6

Experimental drawing

The study area experiment was carried out using eucalyptus clone VCC0865 and CO1407 clone, both of hybrid species *Eucalyptus Grandis* × *Eucalyptus Urophylla* with 48 months of age plant. The spacing between the trees was 3.60m x 2.50m.

Determination of sap flow

For determining the flow of sap, the data was collected daily from 28 January to 31 up to December 2022. In this type of study, 10 trees were selected, of which 05 clones of VCC0865 and 05

of clone CO1407 of the species *Eucalyptus Grandis* × *Eucalyptus Urophylla*.

The methodology implemented in this study followed the experiment developed by Zanchi et al. (2015), from so that the system composes a datalogger model (CR10X Campbell Scientific, USA). Datalogger is a data logger device that stores measurement values collected by sensors during a fixed time, for later use in the analyses. The use of this type of equipment favors the collection, as it does not require a computer in the field.

Copper-constantan thermocouples were also used. These thermal pair probes, when exposed to temperature variations, generate a potential difference (Figura 2). As probes were installed on the trunk of the eucalyptus, with a distance of 10 cm between the heated probe and the unheated probe. As they have 2 mm in diameter and 2 mm cm size. To minimize error measures and obtain greater precision in temperature measurements of the probes, thermal folders were placed in the tubes in contact with them. Avoiding influences of thermal natural gradients natural, the sensors were insulated with paper aluminum.

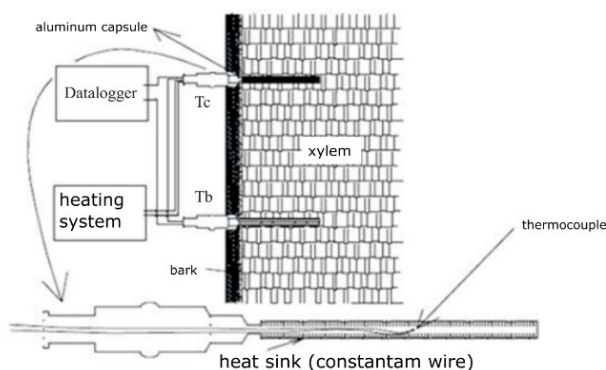


Figure 2. Scheme measurement of the thermal dissipation sensor. Source: Delgado-Rojas et al. (2006).

A 12v and 45A battery was used to provide energy, aiming the food system. Software was also used loggernet and R language with the software Studio R for data analysis.

Calculation of sap flow by Granier method.

The Calculation of the Sap Flow (FS) starts with the calculation of the density of flow, given as K_s , being:

$$(1) K_s = \frac{\Delta_{\max} - \Delta_{\text{inst}}}{\Delta_{\text{inst}}}$$

where $\Delta T_{\max}$ is the maximum difference of temperature between the two sensors, which usually occurs during dawn; and ΔT_{inst} is the difference of the temperature measured instantly. This way, you get the (FS) from the Equation 2 (GRANIER, 1987):

$$(2) FS = 0.119 \cdot K_s^{1.231} \cdot AS$$

AS refers to the effective area of xylem in m^2 . The area of the xylem of each tree, where the sap-wood is located, is the measurement taking into account the Diameter Breast Height (DBH) and total trunk area at chest height (m^2).

As the application of the method of thermal dissipation probe for the estimate of sew flow needs the knowledge of the conductive area of the stem, the value was determined following the adjustments made to the eucalyptus alburn, found by Delgado-Rojas et al. (2010).

In this project, it was used to the equation (3) proposed by Delgado-Rojas et al. (2010) to estimate the density of the sap flow, considering that calibration requires high-cost equipment and plant sacrifice, which is unfeasible in this study.

$$(3) FS = 478,017 \cdot 10^{-6} \cdot K_s$$

Field visits

The field visits were performed at intervals of 7 to 10 days for the collection of data recorded by datalogger. The batteries were also replaced, since the load only It lasted a maximum of 15 days.

The weather station of the National Institute of Meteorology - INMET in Porto Seguro is located in area belonging to ESPAB - CEPLAC, there are approximately 7 Km from the area of experiment.

This weather station belongs to the National Institute of Weather INMET. The data is available on a public website, being of great importance for the region and for this work, as they are made available the information recorded by the sensors with a high degree of trust.

Calculation of the estimated amount of water sweated by eucalyptus cultivation

For the estimate of the contribution of transpiration performed by planting of Eucalyptus for hydrolone cycle region of the Far South of Bahia, were considered the average of the values found by clone. It was also estimated tree density for plantations of eucalyptus, according to the practiced in the area of the experiment, totalling 1,111 trees per hectare. This given was also used for represent the spacing of the plantations of eucalyptus in the region.

For the city of Porto Seguro, the amount of hectare of plantation of Eucalyptus in the municipality of total of 40.417,00, for the year 2014 (Faria Filho, 2015). To the Far South of Bahia, Medeiros (2021) contacted quantity of 435.555,47 ha. Subsequently, the quantity of water was projected resulting from sweating it, made by the eucalyptus of the area of experiment in m³, as well as from Porto Insurance and Extreme South of Bahia, from according to the Equation 4, below:

$$(4) Da \times Q_{ha} = Q_a \rightarrow Q_a \times Q_t = Q_x \text{ m}^3$$

Where: Da= Tree Density, Q_{ha} = Area in hectares, Q_a = Quantity of trees, Q_t = average transpired value by clone and Q_x = total amount of water transpired by area.

Statistical analysis

For Statistical Analysis, it was used the linear regression model was used to R language, along with the software R Studio, with the libraries dplyr, tidyr, ggplot, car, mass, FSA, ggmisc, reade, GGally, corrgram, magrittr, rsq, plot, innards, easy stats and statistics plot. This is how the chart of dispersion with the trend line and the confidence interval.

In the regression analysis, it was sought the statistical dependency between the climate

variables and sew flow. For this purpose, algorithms of linear and polynomial regression in attempt to find an equation that responded statistically to this dependency. Furthermore, it was sought to correlation between variables through R square and F test of significant global which evaluates the coefficients.

Results

Weather data from the experiment

Precipitation

During the year 2022, in the period between April and December, a total of 1,790 mm, of precipitation exceeding the annual average of 1,400 mm. Over the experimental period (March to December), there was rainfall every month, being June and December the months with lowest and highest accumulated precipitation respectively. According to Mencia et al., (2021) rainy season in the region occurs in October to March. The months of November and December were the highest precipitation, exceeding 400 mm in these months (Figure 3).

In the municipality of Porto Seguro the drought period includes the months of April to September (Mencia et al., 2021). During that period, it was found that the month of June got the lowest precipitation, with 40 mm. Already the months of May and July showed a higher rainfall index, above 200 mm. According to the Group of Climate Studies (GrEC) of the Institute of Astronomy, Geophysics and Sciences Atmospheres - IAG of the University of São Paulo - USP (2022) the months of November and December, historically most precipitation, however, in 2022 the incidence of the La Niña phenomenon caused several anomalies in the climate of Brazil. It happened from the cold historical wave and snow in the south of the country at the beginning of November, with heavy rains and atypical in the northeastern region, reaching more than 50% higher than expected.

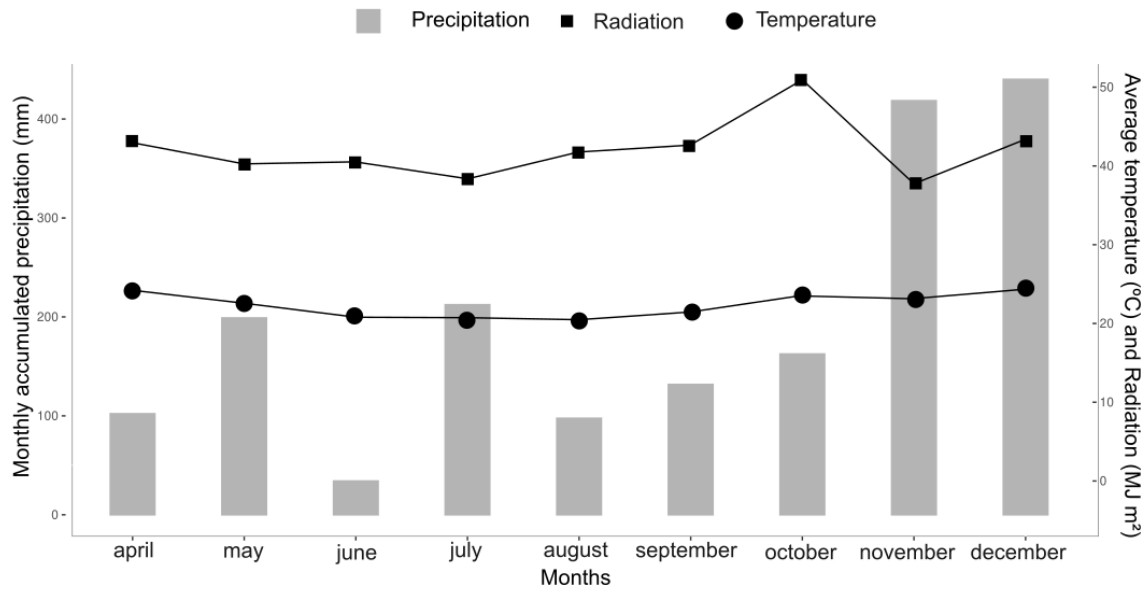


Figure 3. Precipitation, Radiation, Average temperature during the experiment period.

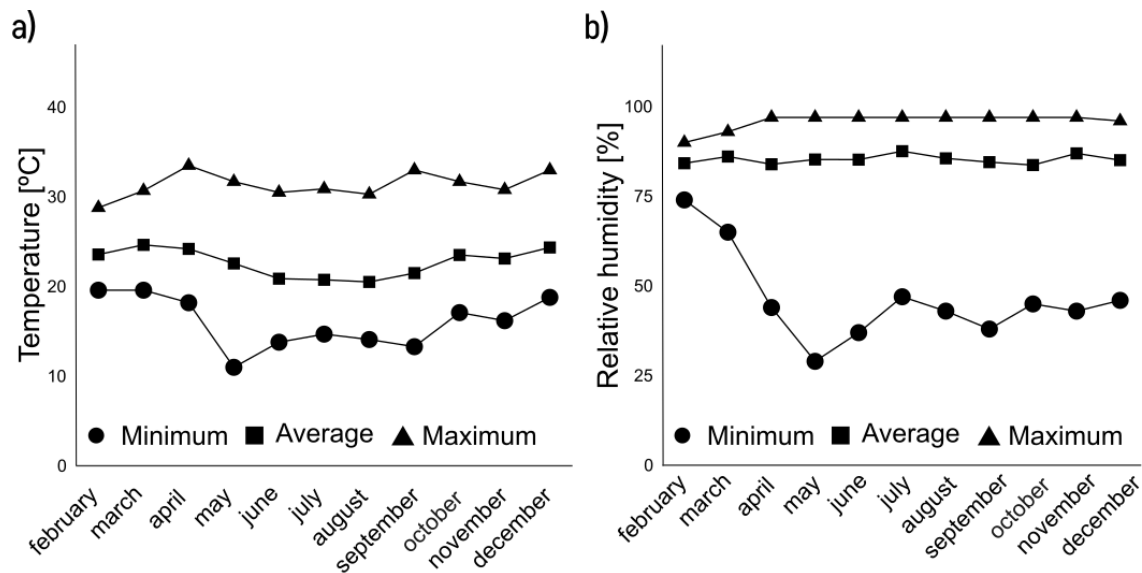


Figure 4. Average temperature, minimum and maximum, and average, minimal and maximum relative humidity in the municipality of Porto Seguro - BA in 2022.

Air Temperature and Relative Air Humidity

Air Temperature and Relative Humidity over the period of the experiment, the average monthly air temperature oscillated between 20 and 24°C (Figure 4a), considered below the average of the last years, between 22 and 26°C (Silva et al., 2020). A minimum thermal amplitude was 9.2° C registered in February, while the maximum thermal

amplitude was 20.7°C in May. The minimum temperatures were recorded in March with 11.1° C and the highest in April with 33.5° C (Figure 4a).

The Average Monthly Humidity Relative was 83 to 87% (Figure 4b). The lowest monthly value was recorded in April at 29 percent. Other months except December, February and March showed the highest index with 97% (Figure 4b).

Wind speed and direction

The winds (Figure 5) recorded in period varied from 0 to 6 m s⁻¹, being the highest incidence between 2 and 3 m s⁻¹, considered Light breeze and 3 to 4 m s⁻¹ Breeze Weak, besides winds of 6 m s⁻¹, classified as Moderate Breeze, second Beaufort scale.

The direction of the wind was predominantly from the ocean to the mainland, with the highest occurrence of northeast direction. The wind speed, although it affects sweating, since it removes water vapor on the surface of the leaves (Taiz, 2017), it didn't present significant influence. The wind gusts recorded in the period reached 11.5m s⁻¹.

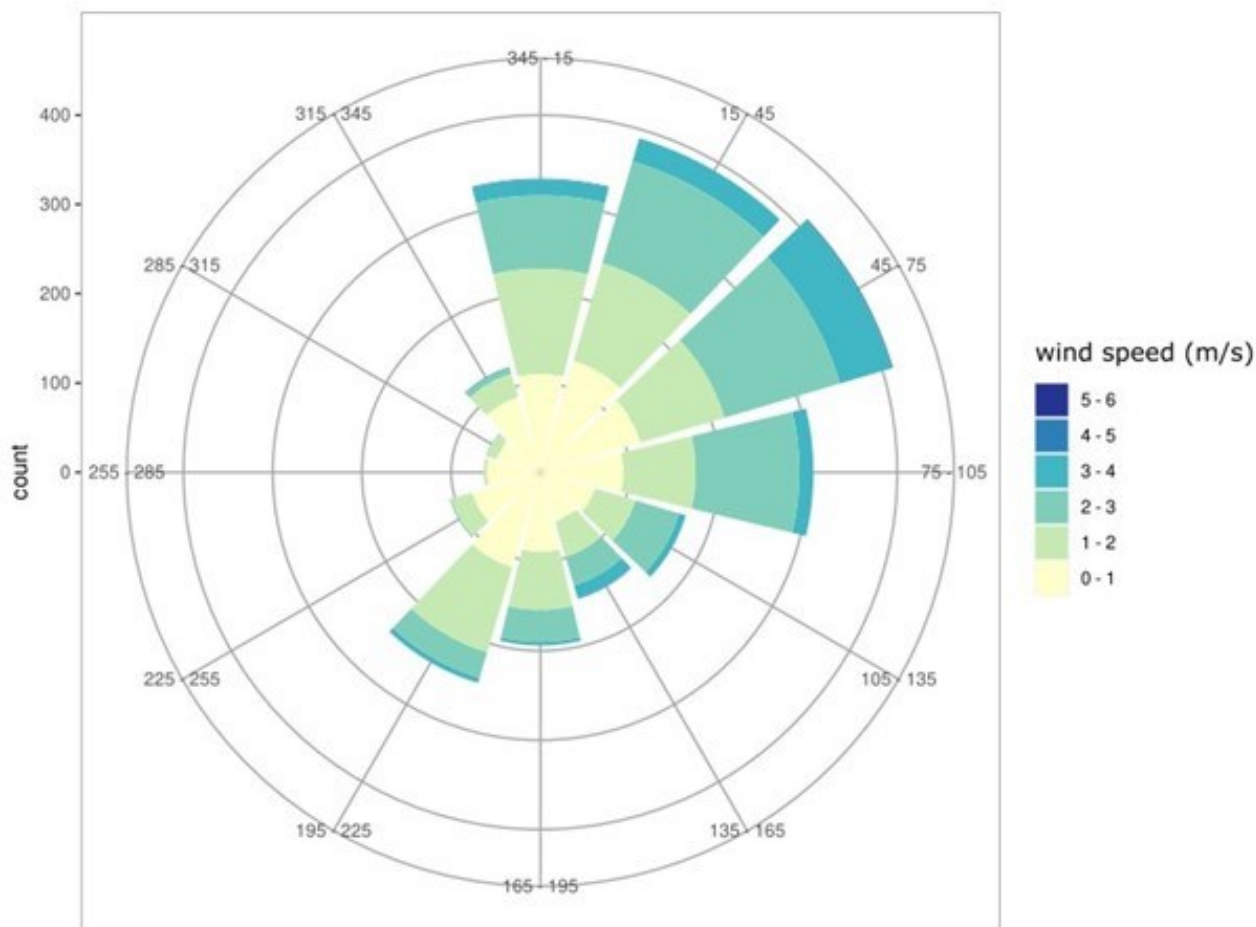


Figure 5. Wind direction and speed in the municipality of Porto Seguro in 2022.

Sap flow data

Eucalyptus sweating in periods of dry and rainy

The average daily sew flow, separated by dry and rainy periods, can be observed in Figure 6.

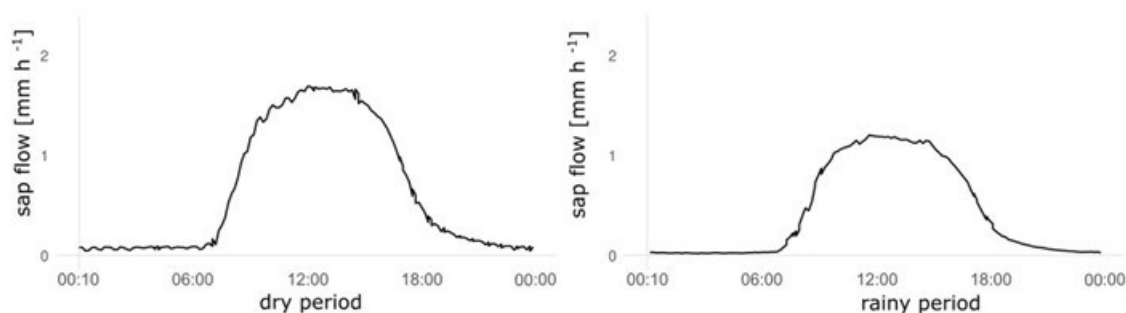


Figure 6. Average daily sap flow in the dry and rainy seasons.

During the period of drought, it was noted that there were higher rates of transpiration in relative to the rainy season, this occurs, because the region showed high rates of rainfall throughout the year, no there is a deficit of water resources during this period. This condition becomes favorable for the development of Eucalyptus culture (Mencia et al., 2021).

It was also noted that the Eucalyptus transpiration started around 7 p.m. in both periods. As the highest rates occurred between 11 and 2:00 p.m. Between 3:40 a.m. and 6 o'clock the flow decreased significantly. From 6 p.m. the same flow continued reducing it up to midnight. During the early morning, it showed minimal flow or null (Figure 6).

It was possible to observe that the transpiration responded to the demands of air evaporation, pressure deficit and of solar radiation, up until sunset, these climate variables started increasing. Sunny days, during the morning, there had been influence with a fast increase of transpiration, moving the present water in plant tissues, stored overnight (Oogathoo et al., 2020). About noon, these climate conditions reached a peak, with temperatures and solar radiation more intense, providing greater openness of the stomata, the moment when it occurs in the ideal photosynthetic conditions, in case there is water availability. Thus, a plant will acquire higher rates of CO₂ and consequently the loss occurs of water vapor, which leads to a greater movement of sap flow in the stem of the tree (Taiz et al., 2017).

After reaching the peak values, it was noted that transpiration decreased slowly, until close to 3 p.m. Afterwards, there was a sharp decrease until approximately 6 p.m. Subsequently, at 6 p.m., a relatively small quantity of sap flow continued to act in the xylema area. This probably happened, according to Fricke (2019), due to the replenishment of the reserves of water lost throughout the day. Some studies are also linked to these flows in small amounts to the reverse flow, which occurs mainly during dawn, although the method of thermal dissipation is not able to detect this type of flow (Delgado- Rojas et al., 2006).

Clone Eucalyptus Sweating VCC0865 and CO1407

The daily average of sap flow in clone of *Eucalyptus Grandis* × *Eucalyptus Urophylla* VCC0865 was significantly larger, compared to clone trees CO1407. In clone VCC0865, an average sweating of the trees was of 59.77 liters per day⁻¹.

An amplitude was expressive observed between the minimum and maximum, ranging from 14 to 89 liters per day⁻¹. The clone trees CO1407, the average transpiration was 41.76 liters per day⁻¹, ranging from 12 to 64 liters per day⁻¹. The present study has corroborated the values found in literature. Gentil (2010) as regards *Eucalyptus Grandis* × *E. Urophylla*, recorded 68 to 79 liters per day⁻¹ in unirrigated treatments with 48 months planting, in the municipality of Eunápolis - BA. Delgado (2006) in study conducted using the universal equation of Granier, in syringe (*Hevea brasiliensis*), considered a large tree, found values between 18 and 75 liters per day⁻¹ in 12 year-old plants. Maier et al. (2017) in comparison in using water efficiency in *Eucalyptus benthamii* and *Pinus taeda* in the South of United States, found 15 liters per day⁻¹ for eucalyptus and 24 liters per day⁻¹ for pinus. 24 liters per day⁻¹ for pinus.

In a study conducted by Casaroli et al. (2016) with Mogno Africano (*Khaya ivorensis*) in plants in the early stages of growth (210 days), a water consumption per plant of 2.5 liters per day⁻¹, being this influenced by local micrometeorological conditions. Madurapperuma et al. (2009), conducted in Sri Lanka experiment with palm trees (*Syagrus romanzoffiana*) of 20 years of age, adapting the Granier method for the estimation of seam flow and found a value of 96 liters per day⁻¹. These studies show that a developmental age tree is able to transfer significant quantity of soil water to the atmosphere.

Average Monthly Seiva Flow Clones VCC0865 and CO1407

To understand the transpiration behavior in both clones studied, found in Figure 7, a daily average flow of sap per clone.

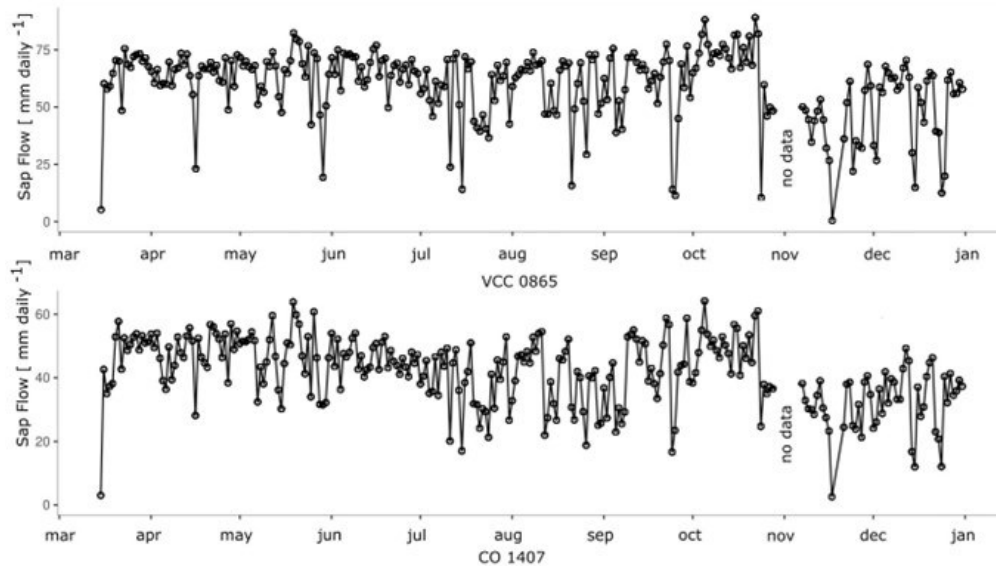


Figure 7. Average daily seam flow of the clones CO1407 and VCC0865.

The Average monthly sap flow in the clones VCC0865 and CO1407 can be observed in Table 3. It was found that in November, it was noted that the lower averages, while in the month of May there were the highest flow rates of sewage. For Clone VCC0865, it was observed a minimum

value of 884.32 liters per month in November and a maximum of 2,015.47 liters in June. For Clone CO1407 there was also a minimum value of 634.35 litres in November and maximum of 1,452.92 liters in the month April (Table 3).

Table 3. Average monthly seam flow in liters between March and December 2022.

Month	VCC0865	CO1407
March	1,074.81	772.25
April	1,904.74	1,452.92
May	1,979.08	1,445.96
June	2,015.47	1,389.82
July	1,694.04	1,164.9
August	1,849.77	1,213.72
September	1,784.59	1,246.91
October	1,943.76	1,329.39
November	884.32	634.35
December	1,607.48	1,044.85
Annual total	16,738.07	11,6995.07

Figure 8 shows the monthly sap flow behavior and the sweat differences between the studied clones, whose clone VCC0865 sweated 43.12% more than the clone CO1407. This difference may indicate also a better adaptation of the species and the possibility of to understand in depth the cultivation of eucalyptus in the region,

because these results open an opportunity in comprehension of the EUC (Use Effectiveness of Carbon) and US (Water Efficiency), in relation to each species. From this, studies with a focus on choices are proposed of species bringing a minor environmental impact and better management for the basins of the region (Hatfield and Dold, 2019).

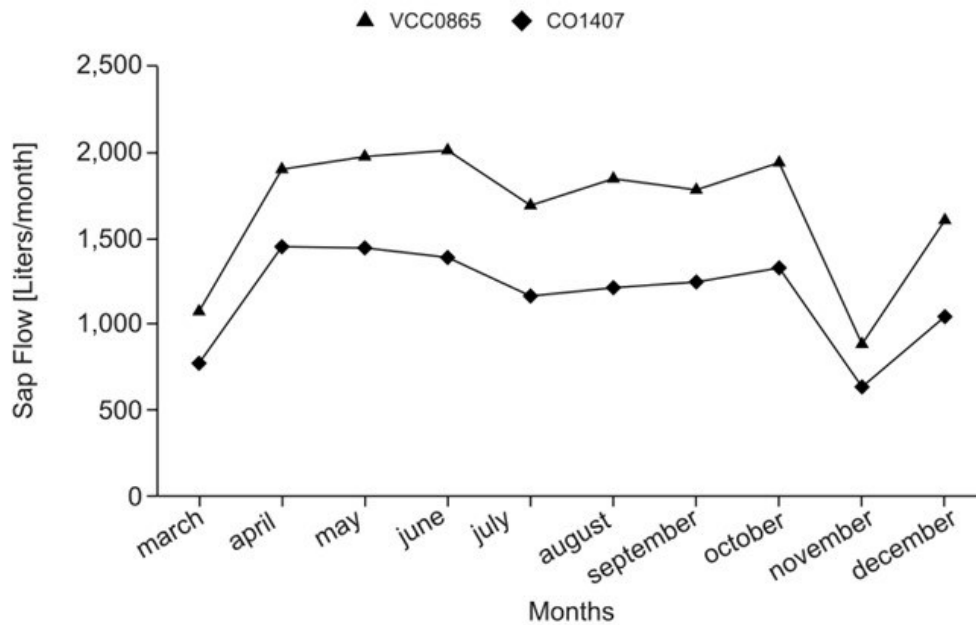


Figure 8. Average monthly sap flow from March to December 2022.

Sap flow values found, may be related with the high availability of water resources supplies in the area of the property, in addition to an atypical year of heavy rain (see Figure 3), in which the precipitation was intense this year of La Niña. There are also many rivers in property environment, such as the river Buranhém, which originated in Minas Gerais and merges with the sea in Porto Seguro, passing approximately 2 km south. This river has an average flow of $22.4 \text{ m}^3 \text{ s}^{-1}$, with significant amplitude reaching the average peak of $192.8 \text{ m}^3 \text{ s}^{-1}$ in floods and a minimum average of $6.6 \text{ m}^3 \text{ s}^{-1}$ in dry periods (Silva et al., 2020). This amplitude can be explained by

recharge originating mainly from the surface drainage and precipitation (Silva et. al., 2020). Other available water resource is the current Camurugi, less than 2 km in the direction of north of the property.

Transpiration of CO1407 in relation to the climate variables

Figure 9 shows the correlations between the sap flow and the precipitation, relative humidity, temperature and radiation variables clone CO1407.

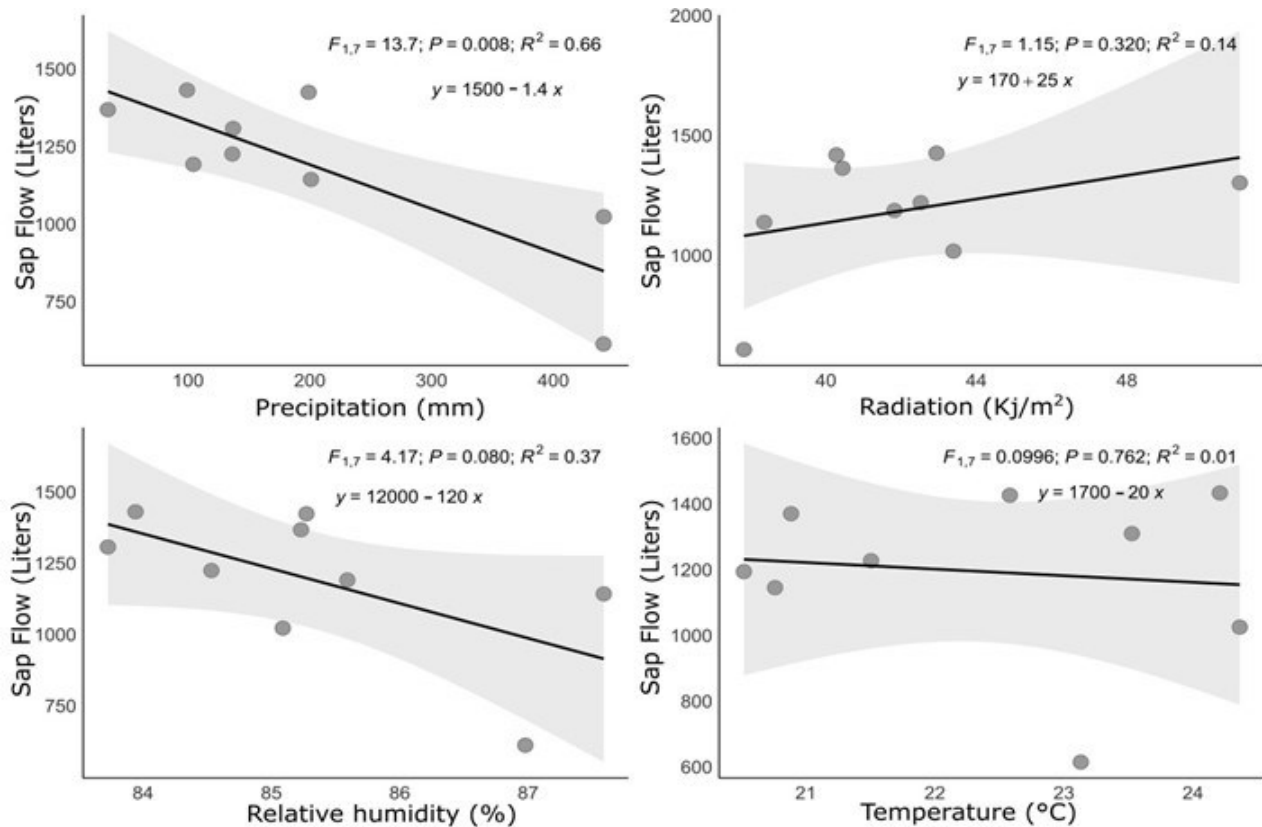


Figure 9. Relation between the sap flow and precipitation, radiation, relative humidity, temperature, for clone CO1407. Source: Authors (2023).

In this chart it was noted that the variable precipitation presented a more significant correlation with flow seam, $R^2 = 0.66$, indicating a relationship moderate. In relation to the relative humidity obtained $R^2 = 0.37$, considered weak, but explaining the phenomenon, and the higher the relative humidity in the Atmosphere less sweating. In what it refers to temperature or $R^2 = 0.14$ has shown a weak correlation, this form through the monthly average was not found an equation statistically explanatory. Of the same form, the radiation variable, obtained $R^2 = 0.01$, which was not explaining in the monthly averages. It was noted that for the analysis and statistical relations between the seam flow and climate variables local, the two-sides statistical test indicated that only the flow of seam and a precipitation shared the same variance in compared groups, revealing a $p < 0.01$.

VCC0865 sweat relative to climate variables

Figure 10 shows the correlations between the seam flow and the variables precipitation, relative humidity, temperature and radiation, referring to clone VCC0865.

Note that the clone (VCC0865), showed values very close to found for the clone CO1407. A variable that showed the highest correlation with the seam flow was precipitation, with $R^2 = 0.65$, being considered moderate. For variable humidity relative obtained $R^2 = 0.34$, considered a weak relationship. For temperature R^2 was found = 0.19, which is considered weak. Likewise, the radiation variable obtained a $R^2 = 0.05$, which was not the explanatory in the monthly averages.

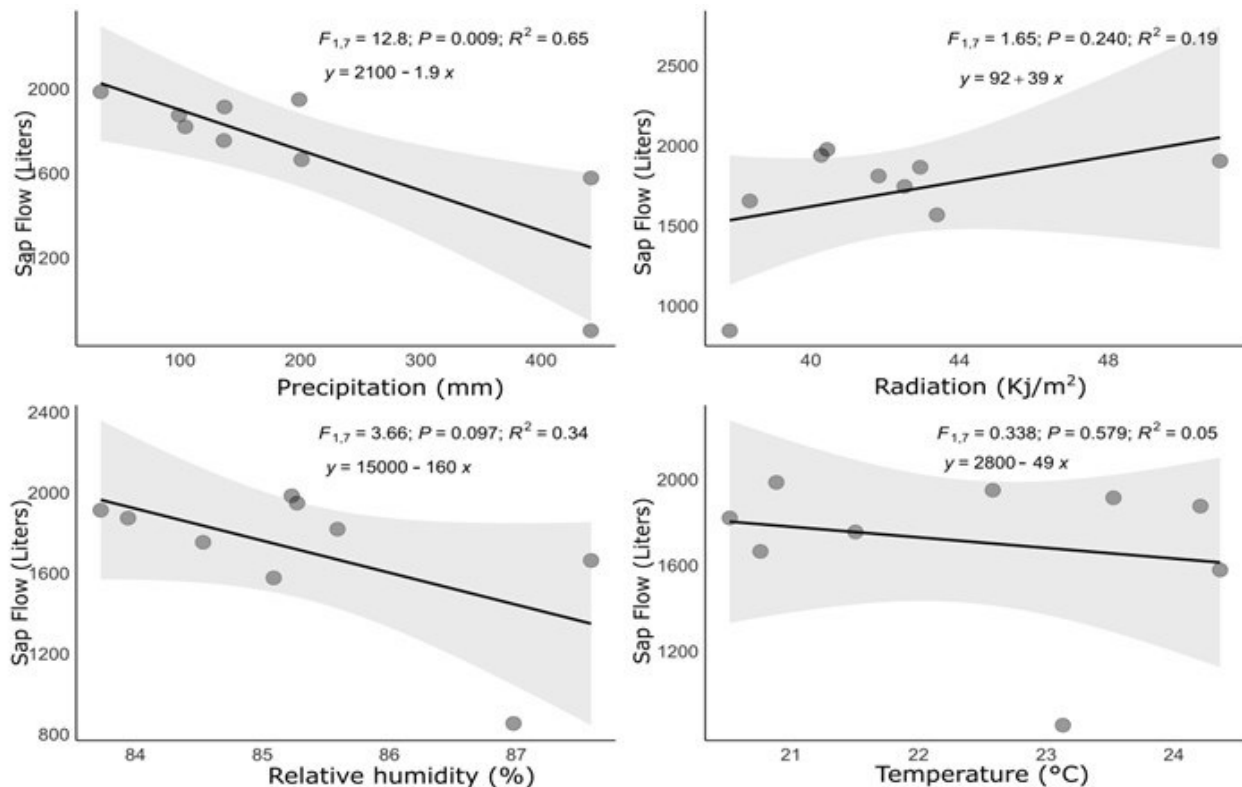


Figure 10. Relation between the sap flow and precipitation, radiation, relative humidity, temperature, for clone VCC0865.

According to Taiz (2017) the factors climates that affect sweating are temperature, solar radiation, the increase in relative humidity between others. These climatic factors, in arainfall event, influence on closure of the stomas, involving the decreased transpiration by the plant. In this study this statement was corroborated, although on monthly averages be more complex to find these patterns, different from a daily measurement where it is most obvious. It was also noted that for the analyses and relationships statistics between the seam flow and the local climate variables, the test statistical two-sided linear adjustment to comparison groups presented only the sap flow and precipitation with the same variance, presenting a $p < 0.01$.

Thus, although the clone VCC0865 has shown larger values in sew flow in liters, the variations versus physical variables showed a very behavior similar between the two clones, which it can be explained by being the same species (Eucalyptus Grandis x E. Urophylla), in addition to

having the same planting age and an Average DAP similar.

Contributions of the species eucalyptus grandis × e. urophylla for the cycle hydrological in the municipality of safe harbour and region

Based on the results of this study, it was estimated the contribution of this culture for the hydrological cycle in the area of experiment, in addition to the municipality of Porto Seguro and the Far South of Bahia.

It was found that in 1 ha of Eucalyptus species of this study, composed of 1,111 trees, there was a transfer of $55.55 \text{ m}^3 \text{ day}^{-1}$ of water to the atmosphere by the process of sweating (Table 4). Considering the 58 ha of study area, with 64,438 trees, a production of $3,221.90 \text{ m}^3 \text{ daily}^{-1}$. From these values it had been projected the amount of water that could be produced in the municipality of Porto Seguro, being $2,245,164.35 \text{ m}^3 \text{ daily}^{-1}$ of water, as well as in the Far South of Bahia $24,195,106.36 \text{ m}^3 \text{ daily}^{-1}$ (Table 4).

Table 4. Projection of the amount of water in m³ transferred to the atmosphere in relation to the area.

	Hectare	Number of trees	m ³ daily ⁻¹	m ³ yearly ⁻¹
Hectare	1	1,111	55.55	20,275.75
Area of Experiment	58	64,438	3,221.90	1,175,993.50
Porto Seguro	40,417	44,903,287	2,245,164.35	819,484,987.75
Extreme South	435,555.47	483,902,127	24,195,106.36	8,831,213,820.85

In this case, the estimate highlighted achievement of the contribution in the quantity of water generated by sweating of the species *Eucalyptus Grandis* × *Eucalyptus Urophylla* for the cycle hydrological, both at the local and regional, carrying out a service important ecosystem in regulation climate. This is because, the sweating of the trees contributes to the formation of clouds. This moisture is transported through the wind currents to the interior of the continent. Whereas, the direction of the wind in the municipality of Porto Seguro is predominant from the ocean to the mainland, coming mainly from northeast direction, favoring the rainfall formation in other countryside regions.

It is highlighted that according to Medeiros et al. (2021), the cultivation of eucalyptus in region of the Far South of Bahia has grown 471% in the last 30 years and continues in a growth trend. In the municipality of Porto Seguro, in 2014, this crop occupied 7% of the territory, being set the limit of 15% for cities coastal and 20% to the interior (Faria Filho et al., 2015). Such a tendency for a growth can double the amount of eucalyptus cultivation in the coming years in the municipality of Porto Seguro, consequently, the amount of water transferred to the atmosphere can increase proportionally.

Conclusion

The VCC0865 clone presented a transpiration rate 43% higher on average daily in relation to the clone CO1407. A sweating showed little variation between periods of drought and rain, however, there was a sharp reduction in November and December, the high precipitation rates involved in the saturation of water vapor in the atmosphere, and low sweating, due to the use of

available energy to be used for evaporation of leaf water.

The adjustment to the Granier equation proposed by Rojas-Delgado used in this study, it has been shown to be effective for the estimate of sweating in species of eucalyptus.

The oscillations of physical variables studied, presented little significant relationship with the sweating of the eucalyptus, except with precipitation.

The estimate of water production by the transpiration process of the species of this study, demonstrated a significant contribution to the cycle hydrological in Porto Seguro and in the Extreme South of Bahia.

The study showed that there is a big difference between the two clones cultivated, suggesting studies on the best clones to be grown in the region. So, the use and efficiency of water in relation to the increase and biomass production, promoted discussions on a more suitable production for the use and occupation in the areas cultivated, assisting in the improvement of techniques in basin management.

The present study is an important instrument to contribute with information about sweating in eucalyptus forestry in the Far South of Bahia, as there are few studies on the subject and given the importance of activity in the region.

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