Short note [Nota corta]

DIURNAL EVOLUTION OF FIRE BEHAVIOR AND MICROCLIMATE IN AREAS OF *Eucalyptus urograndis* (CLONE H13) IN THE CERRADO AMAZONIA TRANSITION ZONE †

[EVOLUCIÓN DIURNAL DEL COMPORTAMIENTO DEL FOGO Y MICROCLIMA EN AREAS DE *Eucalyptus urograndis* (CLONE H13) IN LA TRANSICIÓN CERRADO-AMAZONIA]

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SUMMARY

Background. Forest fires generate several economic, social and environmental losses in native and planted forests. For the prevention and combat of forest fires it is important to know the behavior of fire in each environment potential for its development. This analysis depends on the direct measurement in the field of the parameters associated with the speed of propagation of the fire line and the length of the flames. The fire behavior is influenced by the interaction between meteorological and topographic conditions and plant residues (combustible material) inherent to the environment in which they occur**.** **Objective.** This paper evaluated of the fire behavior and microclimate in prescribed burnings performed at different times of the day, on the areas of 5.5-year-old *Eucalyptus urograndis* (clone H13), in the Cerrado Amazonia transition zone, Mato Grosso state, Brazil. **Methodology**. Prescribed burnings was carried out in eucalyptus/crop (EC), eucalyptus/eucalyptus (EE), and eucalyptus/forest (EF) interfaces from 8:00 to 16:00 (considering solar time), in subdivided plots with ten replications. We conducted characterizations of the combustible material - CM (density, moisture, and dry mass), meteorological variables (air temperature, relative air humidity, and wind speed/ direction), and fire behavior (flame length, fire spread rate, and fire intensity). **Results.** The EF interface showed the highest density, moisture, and herbaceous material. The changes in solar energy scattering represented by the zenith angle (Z) directly affected the meteorological variables, with a gradual increase in the interfaces EC, EE, and EF, respectively. **Implications.** The results obtained allow the definition of the best times to carry out burns prescribed in forest monocultures, optimizing the available resources (water, retardants, labor, among others) in the direct fight against forest fires. **Conclusion.** Diurnal evolution of Z affected the fire behavior; in addition, the greater solar radiation between 10:00 and 14:00 resulted in fire intensification in the environmental interfaces.

Keywords: Prescribed burning; Zenith angle; Forest fires.

RESUMEN

Antecedentes. Los incendios forestales generan varias pérdidas económicas, sociales y ambientales en los bosques nativos y plantados. Para la prevención y el combate de incendios forestales es importante conocer el comportamiento del fuego en cada ambiente potencial para su desarrollo. Estas análisis depende de la medición directa en el campo de los parámetros asociados con la velocidad de propagación de la línea de fuego y la longitud de las llamas. El comportamiento del fuego está influenciado por la interacción entre las condiciones meteorológicas y topográficas y los residuos de la planta (material combustible) inherentes al entorno en el que se producen. **Objetivo.** Este artículo evaluó el comportamiento del fuego y el microclima en quemaduras prescritas realizadas en diferentes momentos del día, en las áreas de Eurolyptus urograndis (clon H13) de 5.5 años de edad, en la transición Cerrado-Amazonia de Mato Grosso, por medio de quemas prescritas realizadas en diferentes horarios del día. **Metodología.** Las quemas prescritas ocurrieron en las interfaces eucalyptus/agricultura (EC), eucalyptus/eucalyptus (EE) y eucalyptus/bosque (EF), con variación horaria entre las 8h y las 16h (considerando la hora solar local), en parcelas subdivididas en el tiempo, con diez repeticiones. Se realizaron las caracterizaciones del material combustible (MC) (densidad, humedad y masa seca), de las variables meteorológicas (temperatura del aire, humedad relativa del aire, velocidad y dirección del viento) y de las variables del comportamiento del fuego (longitud de la llama, velocidad de propagación de la línea de fuego e intensidad del fuego). **Resultados.** La

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mayor densidad, humedad y ocurrencia de material herbáceo vivo se obtuvo en la interfaz EF. La variación de la dispersión de energía solar representada por el ángulo zenital (Z), la dispersión de la energía solar, afectó directamente a las variables meteorológicas evaluadas, con el aumento gradual en el sentido de las interfaces EC, EE y EF. **Implicaciones.** Los resultados obtenidos permiten la definición de los mejores tiempos para realizar quemaduras prescritas en monocultivos forestales, optimizando los recursos disponibles (agua, retardantes, mano de obra, entre otros) en lo combate indicrecto contra incendios forestales. **Conclusión.** El comportamiento del fuego fue afectado por la evolución diurna del Z, con intensificación del fuego en las interfaces ambientales entre los horarios de las 10h y 14h, en respuesta a la mayor radiación solar incidente.

Palabras clave: Quema prescrita; Ángulo zenital; Incendios forestales.

INTRODUCTION

Forest fires result in negative impacts on humans and the environment (Cruz et al., 2017), such as loss of biodiversity, desertification, destruction of forests (Alves et al., 2017), environmental pollution by increasing CO_2 in the atmosphere (Wiedinmyer and Hurteal, 2010; Liu et al., 2010), and monoculture yield loss of agricultural or forestry due to susceptibility to fire (Silva et al., 2011; White et al., 2013; Lima et al., 2020).

Prescribed burning is a mitigating measure to prevent forest fires. Prescribed burning consists of managing the fire through monitoring the vegetal residues, aiming to eliminate the superficial ground layer of combustible material, and consequently, minimizing the spread of fire during critical periods (Burrows and Mccaw, 2013; Eckerberg and Buizer, 2017). Prescribed burning is considered an important tool to renew pastures, reduce pests and diseases, and clean agricultural areas (Redin et al., 2011), and for the implementation of firebreaks for environmental protection (Cruz et al., 2017).

Knowing the factors that directly affect the fire is essential for the efficiency of prescribed burning; the characteristics of combustible materials and microclimate generate different dynamics of fire behavior in different environmental conditions (Ryan et al., 2013; Alves et al., 2017). The fire behavior can be characterized by flame length, fire spread rate, and fire intensity (Scott and Burgan, 2005). Knowledge about these variables is necessary to employ techniques of prevention and control against forest fire, as well as the effectiveness of prescribed burning (Alves et al., 2017; Lima et al., 2020).

Combustible material flammability is essentially determined by moisture content, layer thickness, and physicochemical factors inherent to the vegetal species (Gould et al., 2011). Additionally, microclimate enhances fire spread throughout an area, directly influencing combustible material conditions (Hoffmann et al., 2012; Barker and Price, 2018). Another essential characteristic for the effectiveness of a prescribed burning is the environmental layout; for instance, the amount of solar radiation incident (energy) over an area is influenced by irregularities in terrains such as slopes or valleys (Seger et al., 2013; Rim et al., 2018).

The diurnal evolution of fire behavior descriptive variables indicates expected trends in long-term events. In general, the behavior of meteorological elements is dependent on the incidence of energy, which in turn causes instantaneous variations depending on the time of year, latitude (Liu et al., 2018; Séférian et al., 2018), and time of the day (Barry and Chorley, 2013). The zenith angle (Z) consists of the degree of scattering of solar energy in relation to a local zenith (Santos et al., 2015) and its behavior indicates that the smallest spreads occur when the zenith angle approaches zero (between 10:00 and 14:00 hours) (Souza and Escobedo, 2013); this moment is when the behavior of the local meteorological elements intensifies and consequently alters the behavior of the fire (Torres et al., 2010).

Knowledge about the fire behavior in different environments - conditioned by the microclimate - and time of day is fundamental for the planning forest protection teams focused on the combat and prevention of forest fires, mainly in the reduction of monoculture losses in fire events. Therefore, the objective of this study was to analyze the diurnal evolution of fire behavior and microclimate effect in different zenith angles (times) using prescribed burning in different environmental interfaces in an area of *Eucalyptus urograndis* (clone H13) in the Cerrado Amazonia transition.

MATERIAL AND METHODS

The experiment was conducted at Fazenda Santo Antônio, BRF – Brasil Food S.A Company, located in Sorriso (12° 51' 43,47" South and 55° 52' 34" West), in the state of Mato Grosso, Brazil, in August of 2016 (Figure 1). The experimental area was located in the geographic mesoregion of the Cerrado Amazonia transition. The climate of the region, according to the Köppen's climate classification, is characterized as Aw (tropical wet and dry) with two well-defined seasons: rainy (October to April) and dry (May to September) with an average monthly temperature varying from 24 °C to 27 °C and an average annual rainfall of 1900 mm (Souza et al., 2013). The flat land with an average altitude of 365 meters.

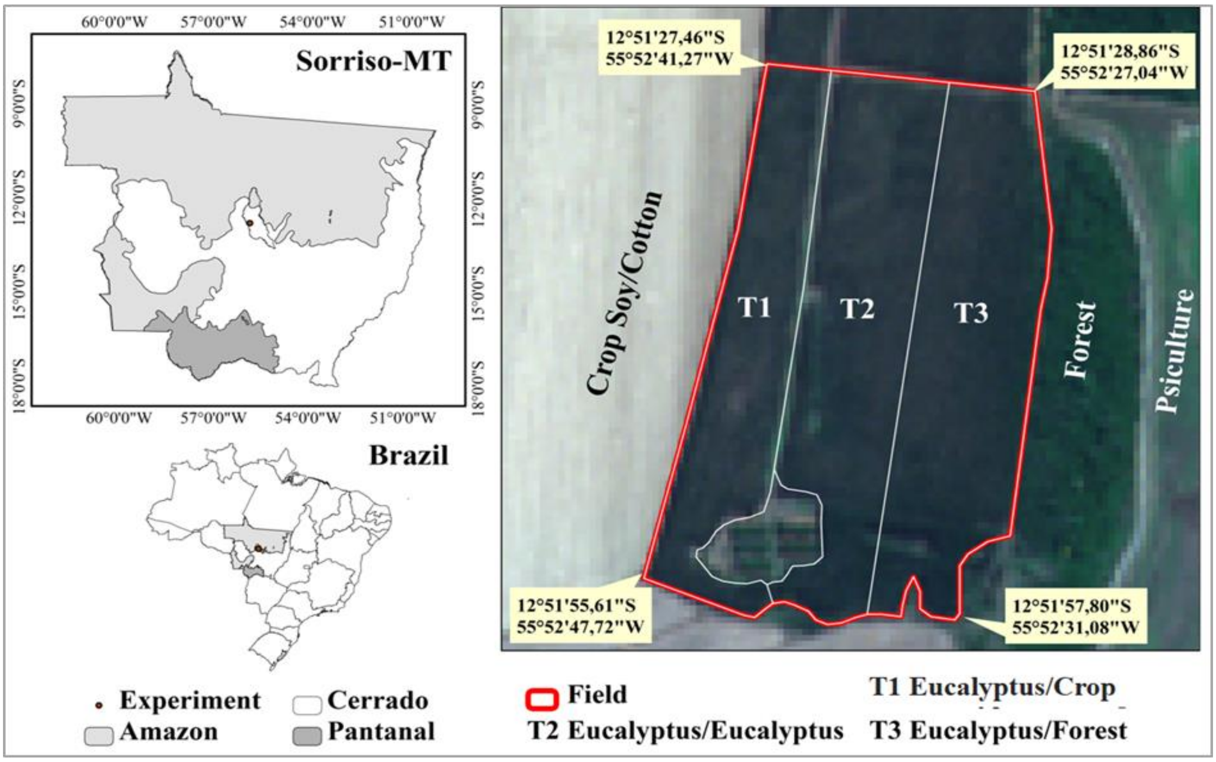

Figure 1. Experimental Area of *E. urograndis* (clone H13) with the arrangement of the environmental interfaces in Sorriso, state of Mato Grosso, Brazil.

The experiment consisted of performing several prescribed burnings in the direction of the wind in 5.5-year-old *Eucalyptus urograndis* (clone H13) areas, planted in 3×3 meters (row x inter-row). The plots of 20×3 meters (length x width) were installed in the borders of eucalyptus/crop (EC), eucalyptus/eucalyptus (EE), and eucalyptus/forest (EF) environmental interfaces. The plots were subdivided in time, forming a factorial design with nine zenith angles and three environmental interfaces. The arrangement of plots, burning performance, and procedures to observe the fire behavior are described by Alves *et al*. (2017) and Lima et al. (2020).

We installed nine plots per interface, each representing a zenith angle (time of burning). The burnings occurred between 08:00 and 16:00 local time, thus allowing an evaluation of the influence of the zenith angle (IQBAL, 1981). The following zenith angles (Z) were correspondent to the times: 8:00 (67 Z), 9:00 (53.7 Z), 10:00 (40.6 Z), 11:00 (29.4 Z), 12:00 (22.8 Z), 13:00 (24.9 Z), 14:00 (34.1 Z), 15:00 (46.4 Z), and 16:00 (60,0 Z). The plots were sectioned in 2×3 m (length x width) strips, with 10 replications of the fire behavior and combustible material variables.

The characterization of the combustible material consisted of collecting destructive samples of 1×1 m, with four replications per plot. The combustible material was separated into the following classes: leaf, shell, herbaceous material, branch with a diameter (d) $\leq$ 0.7 cm, and branch $0.7 \leq d \geq 2.5$ cm. After the classification, the wet mass was determined in the field, and later the dry mass and moisture were determined using a forced air oven at 103 °C (± 2 °C) until constant mass. The density of the combustible material was obtained by the product of the combustible layer height and the total dry mass collected in 1.0 m².

The microclimatic conditions were monitored during prescribed burning using a portable meteorological station (INSTRUTEMP weather station model) with readings every minute of the air temperature (°C), relative humidity of the air (%), wind speed (m s^{-1}), and wind direction (°).

The fire behavior was determined by measuring the flame length (m), fire spread rate (m.min^{-1}), and fire intensity estimated by Byram's (1959) equation, with a calorific value of 21,000 kJ kg^{-1} (Fernandes et al., 2011; Alves et al., 2017).

The normality tests of Shapiro Wilk and the analysis of variance (ANOVA) of the factorial design (zenith angles x environmental interfaces) were performed for the combustible material and the microclimatic variables; when differences were found, means were compared by the Scott-Knott test at 5 % probability. The linear regressions was adjusted between fire behavior (dependent variable) and the zenith angle (independent variable).

RESULTS AND DISCUSSION

Combustible material

The total combustible material of *E. urograndis* did not present significant differences among the environmental interfaces analyzed, varying from 19.58 to 23.21 metric ton per hectare (ton. ha^{-1}) in the eucalyptus/crop (EC) and eucalyptus/forest (EF) interfaces (Table 1). The values we found were higher than those reported by Alves et al. (2017), who reported in August of 2015, in a monoculture of 4.5-year-old E. urograndis, a density of combustible material between 13 and 16 metric ton per hectare (ton. ha^{-1}). However, Carmo et al. (2018) observed a density from 17.91 to 17.03 metric ton per hectare (ton. ha^{-1}) of 5-year-old *Eucalyptus urograndis* (clone H13) plantations in the eucalyptus/crop (EC) and eucalyptus/forest (EF) interfaces.

Areas with a combustible material density greater than 16 metric tons per hectare (ton. ha^{-1}) and low moisture content present higher risks of forest fires (White et al., 2013). In general, older forests have an increase of combustible material accumulation per area (Redin et al., 2011). This indicates susceptibility of *Eucalyptus* sp. areas to fires throughout the crop cycle, and justifying the need to adopt silvicultural techniques, such as prescribed burning as a preventive method for firefighting in planted forests (Eckerberg and Buizer, 2017).

The classes of the combustible material were present in the three environmental interfaces; a larger volume of leaves, from 10.43 to 12.29 metric ton per hectare (ton. ha^{-1}), were found in the interfaces eucalyptus/crop (EC) and eucalyptus/forest (EF), followed by branches $0.7 \leq d \geq 2.5$ cm, from 7.72 to 6.06 metric ton per hectare (ton. ha^{-1}) in the same EC and EF interfaces. These distributions corroborate the findings of Tonini *et al*. (2016), who assessed an area of *E. urograndis* submitted to pruning in the first years of implantation, observed an increase in the number of thin branches and leaves.

The moisture content of the combustible material did not differ among the environmental interfaces evaluated; in all the classes, the moisture content varied from 8 to 11 %, except in the class of herbaceous material. The moisture content values indicate the flammability risk of areas to forest fires (Yebra et al., 2013), and the combustible material below 24% humidity is highly flammable (Soares, 1985).

Meteorological elements

In general, with the reduction of the zenith angle (Z) meteorological oscillations occurred (Table 2) with increasing air temperature and wind speed and reducing the relative humidity of the air in relation to the exponential increase of the saturation pressure of water vapor (Santos et al., 2013). The interaction among these meteorological variables allows greater chances of fires (Blanch and Leonard, 2005). The oscillations of the wind speed in the different zenith angle (Z) values are important to understand the fire spread rate in the area and are essential in the actions aiming to protect against forest fires (Batista et al., 2013).

Table 1. Dry weight and moisture content of combustible material in the area 307 with 5.5-years-old *E. urograndis* (clone H13) at different environmental interfaces.

Combustible Material		**Environmental Interfaces**		
		EC	**EE**	**EF**
Dry weight (t ha^{-1})	Leaves	10.43 a	11.47 a	12.29 a
	Branches $d \leq 0,7$ cm	2.98 a	2.50 a	3.69 a
	Branches $0,7 \leq d \geq 2,5$ cm	4.72 a	3.23 a	6.06 a
	Herbaceous material	0.00 a	0.06 a	0.51 b
	Shell	0.54 a	0.45 a	0.66 a
	Total	19.58 a	17.71 a	23.21 a
Combustible Material		**Environmental Interfaces**		
		EC	**EE**	**EF**
Moisture content (%)	Leaves	9.34 a	8.15 a	11.96 a
	Branches $d \leq 0,7$ cm	9.43 a	10.99 a	11.62 a
	Branches $0,7 \leq d \geq 2,5$ cm	11.42 a	9.51 a	11.25 a
	Herbaceous material	0.0 a	11.92 a	152.43 b
	Shell	10.29 a	8.60 a	12.63 a

*Means followed by the same capital letter in the column did not differ in Scott-Knott test, with 5% of probability. Plots in eucalyptus/crop (EC) interface, plots in center of eucalyptus/eucalyptus (EE) area interface, and plots in eucalyptus/forest (EF) interface.

Table 2. Temperature air, relative air humidity, and wind speed in different zenith angles and environmental interfaces.

Zenith Angle (Z)	Temperature air (°C)		
	EC	**EE**	**EF**
67.0	27.98 b	27.21 b	26.17 a
53.7	32.14 c	30.35 b	27.56 a
40.6	34.47 c	33.21 b	29.67 a
29.4	35.30 b	35.30 b	35.25 a
22.8	36.50 b	33.23 b	34.36 a
24.9	37.18 b	35.12 a	34.48 a
34.1	38.29 c	36.19 b	33.50 a
46.4	37.39 c	34.35 b	32.47 a
60.0	36.05 c	32.49 b	30.14 a
Mean	35.03 c	33.38 b	31.17 a
Zenith Angle (Z)	**Relative air humidity (%)**		
	EC	**EE**	**EF**
67.0	43.66 a	59.85 b	66.01 c
53.7	33.29 a	50.97 b	58.77 c
40.6	25.43 a	45.19 b	55.17 c
29.4	24.09 a	38.15 b	45.41 c
22.8	22.89 a	33.83 b	37.52 c
24.9	22.24 a	35.75 b	37.01 b
34.1	19.98 a	32.66 a	36.58 c
46.4	20.06 a	36.68 b	41.46 c
60.0	21.12 a	41.16 b	55.49 c
Mean	25.86 a	41.55 b	48.16 c
Zenith Angle (Z)	**wind speed (m s^{-1})**		
	EC	**EE**	**EM**
67.0	0.43 a	0.79 b	0.48 a
53.7	0.54 a	0.71 b	0.45 a
40.6	0.78 c	0.58 b	0.42 a
29.4	0.78 a	0.74 a	0.84 a
22.8	0.94 a	0.94 a	1.00 a
24.9	0.94 b	0.76 a	1.04 b
34.1	0.84 a	0.75 a	0.82 a
46.4	0.73 b	0.76 b	0.35 b
60.0	0.53 c	0.28 b	0.04 a
Mean	0.72 b	0.70 b	0.60 a
Zenith Angle (Z)	**Wind gusts (m s^{-1})**		
	EC	**EE**	**EF**
67.0	0.90 a	1.10 b	0.70 a
53.7	1.09 b	1.10 b	0.70 a
40.6	1.32 c	0.90 a	0.62 a
29.4	1.24 a	1.02 a	1.11 a
22.8	1.26 a	1.32 a	1.54 b
24.9	1.35 a	1.21 a	1.56 b
34.1	1.26 a	1.13 a	1.12 a
46.4	1.12 a	1.11 a	0.88 a
60.0	0.77 a	0.55 b	0.11 a
Mean	1.14 c	1.05 b	0.93 a

*Means followed by the same capital letter in the column did not differ in Scott-Knott test, with 5% of probability. Plots in eucalyptus/crop (EC) interface, plots in center of eucalyptus/eucalyptus (EE) area interface, and plots in eucalyptus/forest (EF) interface.

The different environmental interfaces showed different microclimatic characteristics, regardless of the value of zenith angle. The average air temperature was from 31 °C to 35 °C, while the relative humidity ranged from 25 % to 48 %, and the average of the wind speed ranged from 0.72 to 0.60 m. s^{-1} in the eucalyptus/crop and eucalyptus/forest interfaces, respectively. The influence of the environmental interface is important to understand the border effects on eucalyptus/crop interfaces, which allows the intensification of fire spreading due to the increase of air circulation (Alves et al., 2017).

The increase of zenith angle (Z) promotes a greater incidence of solar radiation in the area with *E. urograndis* and results in meteorological variable oscillations (Torres et al., 2010; Santos et al., 2013). In the environmental interfaces were observed different microclimates in function of zenith angle (Z), with greater effect in the eucalyptus/forest interface. Higher levels of shading and higher humidity occur in this environmental interface, deriving from the native forest remnants and the lake present in the proximity of the area. Higher humidity level changes the air temperature and pressure centers, influencing the behavior of the wind and the humidity of the air (Alves et al., 2017).

Fire behavior

Table 3 shows the fire behavior in the diurnal evolution evaluated in different times of prescribed burning, showing the flame length, fire spread rate, and fire intensity increased between 10:00 and 14:00 (Santos et al., 2015). The eucalyptus/crop–EC and eucalyptus/forest–EF interfaces showed a flame length of 1.04 and 1.03 meters, the fire spread rate of 0.88 and 0.87 meters per min^{-1}, and the fire intensity of 485.93 and 703.15 kW s^{-1}, respectively. Similar values were found by Alves *et al.* (2017) who studied *E. urograndis and* observed a flame length of 0.95 meters, an average fire spread rate of 0.54 meter per min^{-1}, and average fire intensity of 289.59 kW s^{-1} in the month of August. Lima et al. (2020) in prescribed burnings (without water and without fire retardants of short duration), in the central positions of butchers (EE interface) with this same type of eucalyptus at 6.0 years of age, found average variations in propagation speed from 0.71 to 0.77 m min^{-1} and flame lengths between 85 and 90 cm.

Table 3. Flame length, fire spread rate, and fire intensity in different zenith angles and environmental interfaces.

Zenith Angle (Z)	Flame length (m)		
	EC	EE	EF
67.0	0.56 Aa	0.63 Aa	0.56 Aa
53.7	0.59 Aa	0.82 Aa	0.63 Aa
40.6	0.68 Aa	1.02 Bb	0.68 Bb
29.4	0.71 Aa	0.91 Aa	0.93 Ba
22.8	0.89 Ba	1.04 Ba	1.07 Ba
24.9	1.04 Ba	1.13 Ba	1.03 Ba
34.1	1.01 Ba	0.87 Ab	0.52 Ab
46.4	0.86 Ba	0.89 Aa	0.86 Ba
60.0	0.80 Ba	0.86 Aa	0.68 Aa
Mean	0.80 a	0.91 b	0.80 a
Zenith Angle (Z)	**Fire spread rate (m min^{-1})**		
	EC	**EE**	**EF**
67.0	0.23 Aa	0.29 Aa	0.20 Aa
53.7	0.30 Aa	0.41 Aa	0.21 Aa
40.6	0.36 Aa	0.61 Bb	0.28 Aa
29.4	0.42 Aa	0.66 Bb	0.60 Cb
22.8	0.75 Ba	0.75 Ba	0.67 Ca
24.9	0.88 Bb	0.63 Ba	0.87 Ca
34.1	0.75 Bb	0.53 Ba	0.46 Ba
46.4	0.55 Aa	0.42 Aa	0.38 Ba
60.0	0.42 Aa	0.34 Aa	0.31 Aa
Mean	0.52 b	0.51 b	0.43 a
Zenith Angle (Z)	**Fire Intensity (kW s^{-1})**		
	EC	**EE**	**EF**
67.0	164.84 Aa	178.53 Aa	154.84 Aa
53.7	201.50 Aa	355.34 Ab	169.58 Aa
40.6	211.33 Aa	476.42 Bb	234.06 Aa
29.4	269.13 Aa	493.14 Bb	587.00 Bb
22.8	434.98 Ba	548.66 Ba	585.99 Ba
24.9	485.93 Ba	444.49 Ba	703.15 Bb
34.1	501.34 Ba	412.06 Ba	358.53 Aa
46.4	416.80 Ba	313.39 Aa	319.42 Aa
60.0	265.08 Aa	262.00 Aa	239.57 Aa
Mean	327,81 a	387,12 a	372,46 a

*Means followed by the same capital letter in the column did not differ in Scott-Knott test, with 5% of probability. Plots in eucalyptus/crop (EC) interface, plots in center of eucalyptus/eucalyptus (EE) area interface, and plots in the eucalyptus/forest (EF) interface.

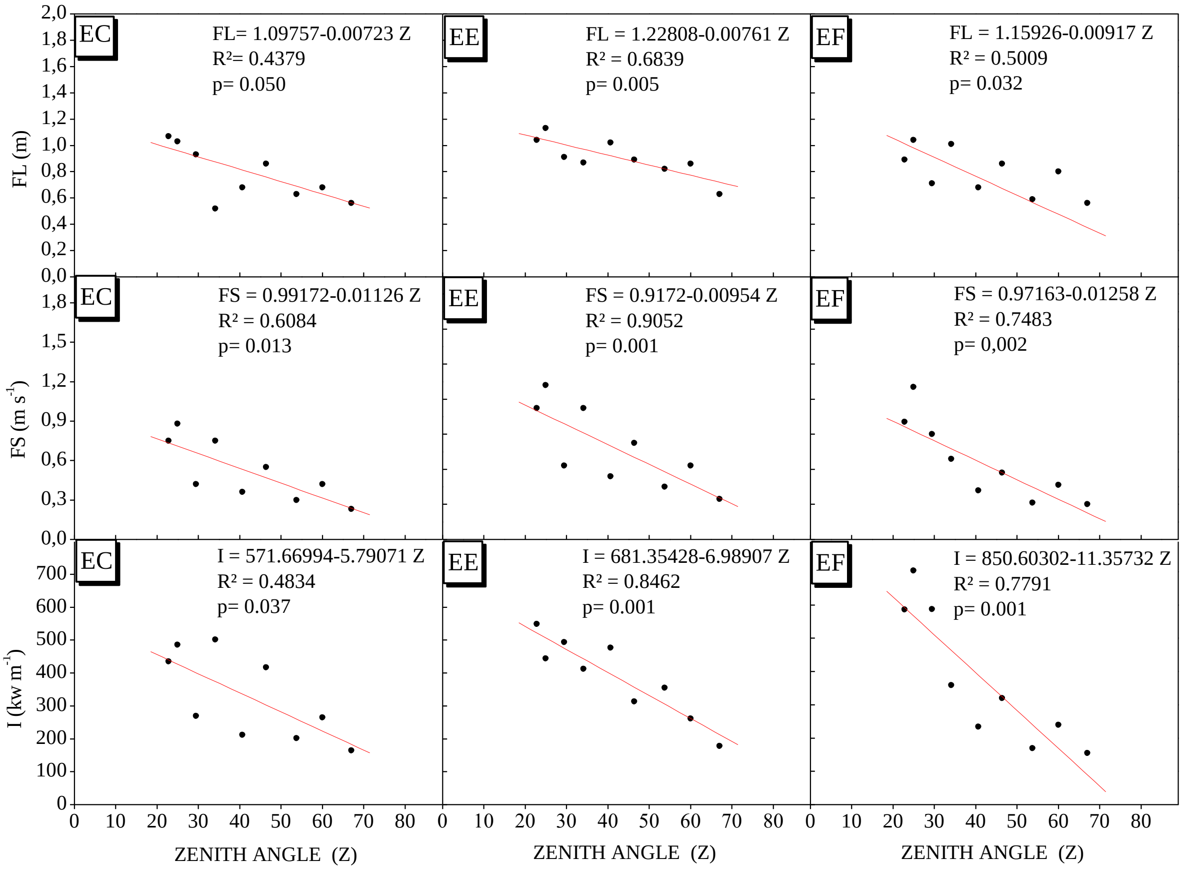

Figure 2. Flame length (FL), fire spread rate (FS), and fire intensity (I) in the eucalyptus/crop (EC), eucalyptus/eucalyptus (EE), and eucalyptus/forest (EF) interfaces in response to diurnal evolution of the zenith angle in area of *E. urograndis* (clone H13).

The intensification of fire behavior during this time of the day occurred due to the higher incidence of solar radiation, in response to the lower value of the zenith angle (Santos et al., 2013). The environmental interfaces affected the microclimate; the variable of the fire behavior gradually intensified in the eucalyptus/crop, eucalyptus/eucalyptus, and eucalyptus/forest interfaces, respectively.

Figure 2 shows the correlation analyzes between the zenith angle and the variables of fire behavior in the three environmental interfaces evaluated; the correlation for the flame length is higher than R^2=0.43, the fire spread rate is R^2=0.60, and the fire intensity is R^2=0.48. The best adjustments occurred in the eucalyptus/eucalyptus interface; in the eucalyptus/crop interface occurred the influence of the border effect; and the eucalyptus/forest interface had an interference from the microclimates of native forest and lake that changes humidity and consequently the moisture content of the combustible material in the area (Alves et al., 2017).

The variables described the fire behavior in the diurnal evolution of the zenith angle, they were presented in the form of attractors (Mello et al., 2013), which there is not the same pattern of response in the evaluated times. The diurnal evolution of solar radiation is practically the same from sunrise to noon, and from noon to sunset, but during the afternoon the average balance of the solar radiation is lower than in the morning due to the accumulation of energy in the environment in response to increasing cloudiness in the afternoon (Santos et al., 2013; Escobedo et al., 2014).

CONCLUSION

The diurnal evolution of the zenith angle directly affected the meteorological elements of air temperature, relative air humidity, and wind speed with the gradual increase of these variables from the interfaces eucalyptus/crop, eucalyptus/eucalyptus, and to the eucalyptus/forest.

The fire behavior, in response to the diurnal evolution of the zenith angle, showed the reduction of zenith angle potentiates the flame length, fire spread rate, and fire intensity in prescribed burning.

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Conflict of interest statement. The authors declare that there are no competing interests. Institute of Agricultural and Environmental Sciences of the Federal University of Mato Grosso, Brazil, approved the present study for its development.

Compliance with ethical standards. This article does not contain studies carried out with human beings, therefore, there was no need for approval by the Research Bioethics Committee of the Sinop University Campus of the Federal University of Mato Grosso, Brazil, for its development.

Data availability. The databases are available with the corresponding author (adilsonpacheco@ufmt.br or pachecoufmt@gmail.com) upon reasonable request.

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