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Combustibility of fuel material for forest species

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Abstract. The work aimed to characterize the flammability of different forest species. The combustible materials were collected in two places with different phytophysiognomies, both in the state of Paraíba, Brazil. The plant materials used were: *Poincianella bracteosa*, *Aspidosperma pyrifolium*, *Luetzelburgia auriculata*, *Croton sonderianus* and *Pinus* sp. acicles and branches were used as a control. The burns were carried out in an open area located in the forest nursery, where approximately 0.5 kg of material was weighed on a precision scale. After the organization of the plots, the thickness of each pile was measured with the aid of a ruler graduated in centimeters. To determine the speed of fire propagation, the average time spent by the fire front ($m\ s^{-1}$) to travel pre-established distances during the fires was measured. It is observed that among the studied materials, Pinus was the one that presented the lowest weight after burning the material and was the species that presented the highest temperature after burning, followed by *C. sonderianus* and *A. pyrifolium*. Before burning, all species showed behaviors, ranging from 30 to 33 °C. It is extremely important to replicate this type of study in forest areas, since the variations found can influence the results. The effect of burning combustible materials on soil temperature was greater in treatments with *Pinus* and *C. sonderianus*.
Keywords: Flammability, Forest fires, Controlled firing

Introduction

The type of material influences the intensity of the heat, the ease of ignition and the speed of fire propagation. As a result, all organic matter, living or dead, present in the forest capable of ignite and burning, is characterized as a combustible material (White et al., 2014).

The knowledge of the type of vegetation occurring in the region makes it possible to understand the greater or lesser speed of fire propagation. The type of fuel is the main enhancer or retarder of propagation, since the other variables are practically uncontrollable, such as climate, weather and terrain relief (Souza & Vale, 2019).

Therefore, the importance of knowing the flammability of fuel materials of different phytophysiognomies, observing that in the semi-arid regions, in the dry period, there is a higher concentration of biomass in the forest floor, which will influence the speed of fire propagation. In more humid environments, such as the Atlantic Forest, the biomass contribution is seasonally regular, keeping the plant material of the forest floor more humid, which hinders the combustibility, that is burning speed and the consummability of this material, in case of fire.

The impact of forest fires can result in reduced regeneration of some species of native plants (Rocky & Mligo, 2012). The most affected plant species are those most sensitive to the impacts of fire, so fire can result in changes in the composition and distribution of plant species in affected regions.

Controlled firing is used in fire-prone environments around the world to reduce the propagation of future forest fires. Structures of forest habitat, such as large trees, dead trees and trunks are highly flammable, but are also essential for animal species that require cavities such as shelter, reproduction and breeding sites (Flanagan-Moodie et al., 2018).

Based on this principle, the research sought to answer the following question: Will knowledge of the behavior of fire in different plant species facilitate combat in the event of a forest fire?

Considering the importance of knowledge about the characteristics of different combustible materials for fire management in vegetation, this work aimed to characterize the flammability of combustible material from different forest species and the influence of fire on soil temperature before and after firing.

Methods

Collection of fuel materials

The combustible materials were collected in two locations with different phytophysiognomies, in the state of Paraíba, Brazil. The materials from the Caatinga biome were collected at the Cachoeira de São Porfírio experimental farm (06º 48’ 35” S and 36º 57’ 15” W), municipality of Várzea, and *Pinus* sp. was collected in a forest planting located in the municipality of Areia (06° 58’ 12" S and 35° 42’ 15’’ W).

The collected material was packed in paper bags, collecting enough to supply the flammability test for each species. Before the firing was carried out, the ambient temperature and relative humidity of the air were checked using a digital thermohygrometer, the wind speed with a digital anemometer, and finally, the firing time of these plant materials was noted.

Determination of the moisture content of fuel materials

The moisture content of the combustible materials was determined in 50 g subsamples of each material that were packed in paper bags and placed for drying in a forced air circulation oven, at a temperature of 65±5 ºC until constant weight. The moisture content of the combustible materials was estimated using the following equation:

$$\%MC = (\frac{WM - DM}{DM}) * 100$$

Being: %MC = %MC = moisture content of the fuel material (%); WM = wet mass of the fuel material at the moment (g); and DM = dry mass of the fuel material after drying in an oven at 65 °C (g).

Organization of fuel materials and procedure for firing

After the collection of plant materials made up of thin branches, leaves and needles of Pinus, they were spread in an environment with air circulation for natural drying, carefully separating each species. Samples of Catingueira (*Poincianella bracteosa* (Tul.) LP Queiroz), Pereiro (*Aspidosperma pyrifolium* var. Molle (Mart.) Müll.Arg.), Pau-pedra (*Luetzelburgia auriculata* (Allemão) Ducke) and Marmeleiro (*Croton sonderianus* Müll. Arg.) were collected in the Caatinga. As a control treatment, the needles and branches of *Pinus* sp. were used, due to their high flammability, reported in studies related to the behavior of fire.

The firing was carried out in an open area located in the forest nursery, where approximately 0.5 kg of material for each treatment were weighed on a precision scale and distributed in 0.50 m x 0.50 m plots on the ground. In all plots, the soil temperature was measured before firing and after the flame was extinguished, using a digital thermometer (Figure 1).

Figure 1. Measurement of the soil temperature before and after firing the fuel material using the digital thermometer.

Fire behavior assessment

After the organization of the plots, the thickness of each pile was measured with the aid of a ruler graduated in centimeters. Then the burns were carried out, observing the rate of propagation and height of the flames. The speed of fire propagation was estimated using standard procedures adopted internationally (Rothermel, 1972; Rothermel & Deeming, 1980).

To determine the speed of fire propagation, the average time spent by the fire front (in m s^{-1}) to go through pre-established distances during the fires was measured (Rothermel & Deeming, 1980, Soares & Batista, 2007). For this purpose, stopwatches were used, initially measuring the time for the fire to travel 0.50 linear meters and the duration of the combustion time of the fuel material in each plot, until the flame extinguished.

To classify the speed of fire propagation, the classification by Botelho and Ventura (1990), shown in table 1, was taken as a basis.

Table 1. Classification of the speed of fire propagation.

Speed of propagation(m s^{-1})	Classification
< 0.033	Slow
0.033 – 0.166	Mean
0.166 – 1.166	High
> 1.166	Extreme

Botelho and Ventura (1990)

Results and discussion

Table 2 shows the values of the initial weight and after burning the plant material (leaf), and the moisture values for each fuel material. It is observed that among the studied materials, *Pinus* was the one that presented the lowest weight after burning the material, a fact that happened through the volume of the material, because the needles burn faster than the leaves of the other species under study, a fact also attributed to the lower moisture content. Very considerable information, since the moisture content is an important factor in the property of controlling the inflammability of the vegetation.

As well as to Fiedler et al. (2015), the intensity of the fire line showed results as expected, since the desire is to decrease the intensity of the burning. Finally, they concluded that the replication of this study in forest areas is extremely important, in order to consolidate the efficiency of the use of fire retardants, since the variations found in the field can influence the results.

It is observed in table 3 the propagation speed variables and their classification after the firing of the plant material. All species under study had a slow classification according to the classification of Botelho and Ventura (1990), with propagation speed <0.033. *Pinus* showed a good burn in relation to the other species, with light flames indicating high temperatures and still very strong, characterizing the eruptive flames. At the end of the combustion, only embers remained, indicating a high consumability for this species.

Table 2. Initial weight and after firing the plant material, followed by the moisture value.

Fuel material	Weight before firing (g)	Weight after firing (g)	Moisture (%)
P. bracteosa	500	240.00	11.94
A. pyrifolium	500	112.50	15.83
L. auriculata	500	102.50	9.60
C*. sonderianus*	500	61.00	8.00
Pinus sp.	500	0.58	7.34

Table 3. Variables of fire behavior during the firing of fuel materials.

Fuel material	Speed of propagation (m s^{-1})	Classification
P. bracteosa	0.0035	Slow
A. pyrifolium	0.0033	Slow
L. auriculata	0.0038	Slow
C*. sonderianus*	0.0112	Slow
Pinus sp.	0.0148	Slow

Ribeiro et al. (2012), relating their study to living and dead plant materials, highlight that there is a different amount of moisture in each fuel, whose living materials retain more water than the dead, thus requiring a greater amount of heat for ignition to occur. So, in the dry periods where there is a greater predominance of dead material, due to the drought periods, the increase in fire risks increases, so due to these conditions favorable to the occurrence of forest fires, monitoring should be intensified in these more critical periods.

Soil temperature data measured in each plot, before and after firing, are shown in figure 2. *Pinus* was the species that had the highest temperature after firing, followed by *C. sonderianus* and *A. pyrifolium*. Before firing, all treatments showed behaviors, ranging from 30 to 33 °C.

All treatments showed an increase in soil temperature, and *Pinus* had a higher behavior than the others, that is, the burning of this material on soil presents a high heat rate, which can cause irreversible damage to the surface edaphic biota. For this reason, the use of fire in an irregular way over time promotes changes that reduce the soil fauna, consequently, the increase in the degradation of these areas.

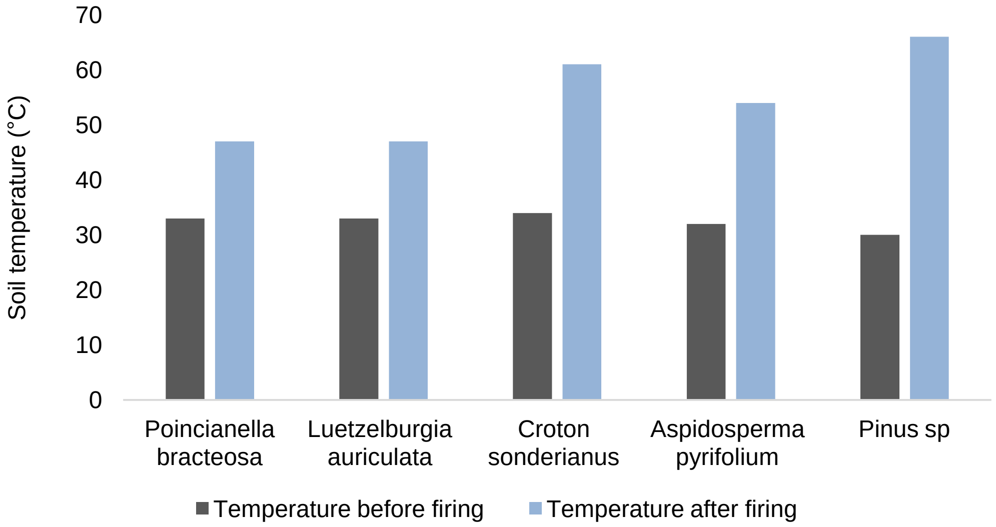

Figure 2. Soil temperature before and after firing different vegetable fuel materials.

Conclusion

The fuel material of *Pinus* sp. showed greater consumability in relation to the leafy species of the Caatinga.

The burning speed of the combustible material of the Caatinga species was slow, however, the material of *C. sonderianus* was consumed quickly by the fire, indicating high combustibility, according to the control specie (*Pinus* sp.).

The effect of firing fuel materials on soil temperature was greater in treatments with *Pinus* sp. and *C. sonderianus*.

It is extremely important to replicate this type of study in forest areas, since the variations in loco found can influence the results.

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