SHRUB FUEL CHARACTERISTICS IN THE PRIVATE NATURAL HERITAGE RESERVE CAMINHO DAS TROPAS, PARANÁ – BRAZIL

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Resumo

Caracterização do Material Combustível Arbustivo da Reserva Particular do Patrimônio Natural Caminho das Tropas, Paraná - Brasil. Esta pesquisa foi realizada na Reserva Particular do Patrimônio Natural (RPPN) Caminho das Tropas localizada no município de Palmeira**,** estado do Paraná, em região com predominância de campos naturais. O objetivo foi caracterizar o material combustível arbustivo da Estepe Gramíneo-Lenhosa da área. Para as amostragens, foi delimitada uma área de 25 hectares e demarcadas 100 parcelas com tamanho de 50 x 50 metros (0,25 ha). As parcelas foram agrupadas em dois tratamentos: com mais de 50% e com menos de 50% de densidade e distribuição regular da vegetação arbustiva. A carga média de material obtida para o primeiro tratamento foi de 1,2886 $Mg.ha^{-1}$, sendo 0,9667 $Mg.ha^{-1}$ de material vivo e 0,3219 $Mg.ha^{-1}$ de material morto. Para o segundo tratamento, a carga foi de 0,9328 $Mg.ha^{-1}$, com 0,6516 $Mg.ha^{-1}$ e 0,2812 $Mg.ha^{-1}$ de material vivo e morto respectivamente. O teor médio de umidade do material do primeiro tratamento foi de 87,90% e para o segundo, de 81,49%. As características encontradas no material combustível arbustivo da área de estudo são compatíveis com os resultados encontrados na literatura para vegetação de campos naturais do Brasil.

Palavras chave: Campos naturais, biomassa e prevenção de incêndios florestais.

Abstract

This research was carried out in the Private Natural Heritage Reserve (PNHR) “Caminho das Tropas”, located in Palmeira, Paraná state - Brazil, in an area dominated by natural fields. The objective was to characterize the shrub fuel of the grassy-woody steppe in the area. For the sampling, an area of 25 hectares was fenced and 100 plots sized 50 x 50 m (0.25 ha) were allocated. The plots were grouped into two treatments: one containing over 50% density and the other less than 50% density and regular distribution of shrub vegetation. The average load of fuel obtained for the first category was 1.2886 $Mg.ha^{-1}$, being 0.9667 $Mg.ha^{-1}$of living material and 0.3219 $Mg.ha^{-1}$ of dead material. For the second category, the load was 0.9328 $Mg.ha^{-1}$, with 0.6516 and 0.2812 $Mg.ha^{-1}$of live and dead fuel respectively. The average moisture content of the fuel in the first treatment was 87.90% and in the second, 81.49%. The characteristics found in the shrub fuel of the study area are compatible with the results found in the literature for Brazilian natural grasslands vegetation.

Key words: indigenous grasslands, biomass and forest fire prevention.

INTRODUCTION

According to Maack (2012), the Grassy-Woody Steppe region of the second plateau in Paraná stare is evolutionarily a relic of an old semi-arid climate from the Quaternary Era. As the climate changed, getting warmer and humid after the last glaciation which peaked around 10,000 years ago, the region began to be taken over by the forests that gradually expand through the fields composing a typical landscape of forest enclave.

The soils derived mainly from Furnas Sandstone and sandy units of the Itararé Subgroup. They are shallow and relatively dry and poor in nutrients. These pedological conditions determined area vegetation to be composed mostly by creeping plants (herbaceous) and small plants (shrubs), with forest islands (Araucaria forest) on more fertile soil spaces (DALAZOANA *et al*., 2018).

Thus, similarly to other Brazilian southern fields, the vegetation of the Grassy-Woody Steppe in Paraná state also suffered several disturbances due to anthropic action over hundreds of years. The continuous use of fire to renew pastures has damaged the natural succession of forests in this biome. The indigenous vegetation of the fields has also been impacted by changes which intensified in more recent years, when agriculture and forestry advanced throughout the region.

Regarding forest fires, the vegetation of the Grassy-Woody Steppe presents great danger of ignition. Therefore, the research on the characterization of forest fuel is relevant to support effective firefighting management and control systems in areas with this vegetal typology. As one of the components of the fire triangle, the fuel has a great influence on the occurrence and spread of forest fires (SOARES; BATISTA, 2007). The

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estimation of the amount of existing fuel (dry matter mass per unit area) contributes decisively to planning, prevention and combat fires. Being so, the knowledge of the amount of fuel per unit area consists of one of the most important information related to the behavior of fire, and it can directly support actions that ensure the efficiency of forest fires combat.

Although weather variables directly influence on forest fire occurrence, the fuel is certainly one of the most important factors to spread fire. Describing forest fuels and quantifying them is important for understanding the behavior of fire, as it provides information for fire management activities, including prescribed burning, difficulty in suppression, hazard assessment and fuel treatment (SOARES; BATISTA, 2007). The characteristics of forest herbaceous and shrub vegetation fuels and their importance in the ignition and spread of fires have been the object of study by several authors (SAGLAM *et al*., 2008; FIDELIS *et al*., 2010; REINER *et al*., 2010; RIBEIRO *et al*., 2011; CASTEDO-DOURADO *et al*., 2012; KUNST *et al*., 2012; FERNÁNDEZ *et al*., 2013; BIANCHI; DEFOSSE, 2014; WHITE *et al*., 2014; PERREIRA *et al*., 2016; WHITE *et al*., 2017; SEGER *et al*., 2018).

Due to the importance of knowing the characteristics of forest fuels for fire management in field vegetation, this paper aimed to characterize the fuel of the shrub stratum present in the Grassy-Wood Steppe at PRNH Caminho das Tropas. Composed predominantly by small plants, the shrub stratum consists of vegetation that generally covers all species with diameter at breast height (DBH) less than 5 cm and height ranging between 0.5 and 3.0 meters (RIBEIRO *et al*., 2011; KEANE *et al*., 2012). As it generally presents an average height below 1.8 m, it is basically composed by surface fuel (SOARES; BATISTA, 2007).

The hypotheses that guided the research were: the fuel load of the shrub layer of the study area is much less representative when compared to the herbaceous layer; and the danger of starting fire by shrub fuel is very low considering the thickness of the fuel and the physiological conditions of the plants.

MATERIAL AND METHODS

Study area

The study was carried out at PRNH Caminho das Tropas, central coordinates (UTMs) of 620334 west and 7196739 south. Created in the year 2008 by means of Ordinance No. 188/08 of the Paraná Environmental Institute (PEI), the PRNH Caminho das Tropas has an area of 189.70 hectares, being part of the Santa Rita Farm located in Palmeira – PR, Brazil. As it is a State Conservation unit, the study was carried out under the research authorization number 470,131 issued by PEI. The area of study is covered mostly by undergrowth vegetation composed mainly by grasses (Poacaea) of the genera *Paspalum, Axonopus, Andropogon, Aristida* and *Eryanthus*, and shrub species of the families Asteraceae and Myrtaceae, the area was abandoned from productive activities from the year 2005, with the typical field vegetation recovering without suffering any more interference.

The climate of the region where the RPNN is located, is Cfb according to the Köppen classification, characterized as temperate. In Paraná, this climate is predominant in the highest portions of the plateaus, at altitudes above 1000 meters. Frost is a regional climate variable that directly influences plant ecology, as they usually cause the death of a large part of the vegetation (herbaceous and shrub), causing increase in dead fuel amount, which increases the danger of fires in the period of winter/post-winter. According to Seger *et al*. (2012), for the central-eastern region of Paraná (where the study area is inserted), the winter months are the most critical regarding the occurrence of forest fires, being responsible for 53% of the average annual wildfire records. In addition to the increase in dead fuel amount, lower rainfall levels and air relative humidity also contribute to a greater risk of fires during the coldest season of the year in the region.

Sampling

Samples of shrub forest fuel were collected between June and November 2013. For this, an area of 25 hectares (500 m x 500 m) was selected and subdivided into 100 plots of 2,500 m2 (50 m x 50 m). Using the vegetation stratification method, the plots were separated into two categories for data processing: the first, covering those with density and regular distribution of shrub vegetation in more than 50% of the plot area, and, the second, with density and regular distribution of vegetation in less than 50% of the plot. Of the 100 delimited plots, 40 were included in the first category and 60 in the second category (Figure 1). The separation of plots into two stratification categories aimed to homogenize the variance, making it possible to obtain sample sufficiency with a small and viable number of plots. The stratification of vegetation was carried out in a direct visual way while traversing the transects allocated on the lines that divided the plots. Both the stratification of vegetation and the sampling techniques (collection and forest fuel classification) adopted were supported by research carried out by different authors (SAGLAM *et al*., 2008; REINER *et al*., 2010; RIBEIRO *et al*., 2011; CASTEDO- DOURADO *et al*., 2012; FERNÁNDEZ *et al*., 2013).

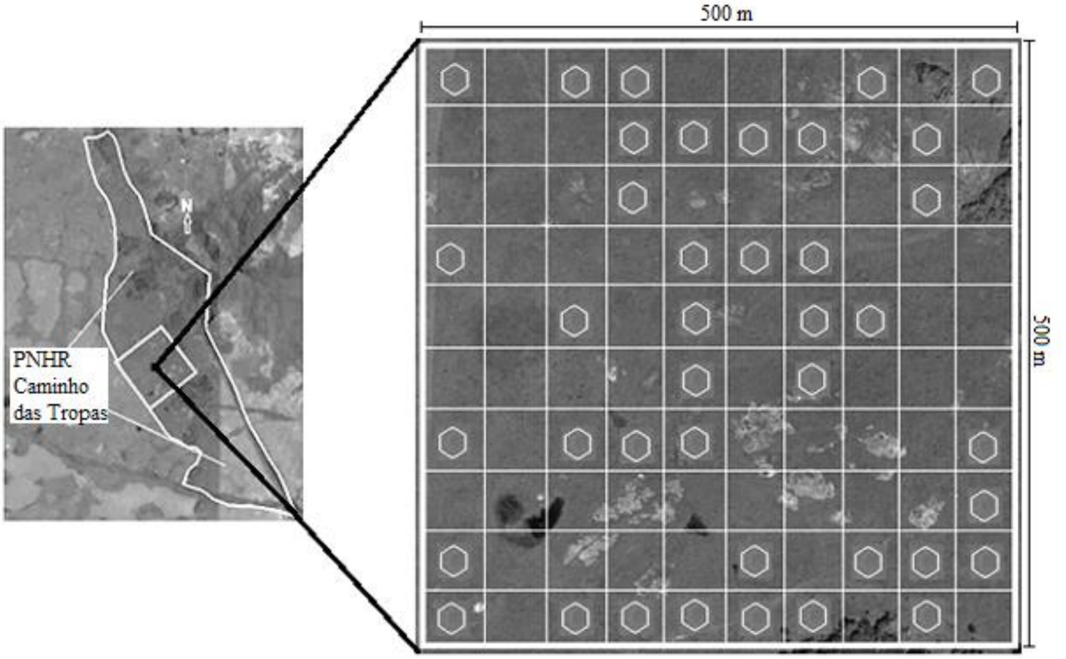

Figure 1. Sampling area with indication of plots with more than 50% of shrub density (with indicators) and less than 50% (without indicators) of shrub density.

Figura 1. Área de amostragem com indicação de parcelas com mais de 50% (com indicadores) e menos de 50% (sem indicadores) de densidade arbustiva.

After stratification, 4 plots for sampling were chosen for each category (treatments). The selection of these plots was carried out systematically through the demarcation of two transversal lines (drawing a cross) from the central point of the study area. The plots chosen were those located at the ends of the lines that formed the cross (Figure 2).

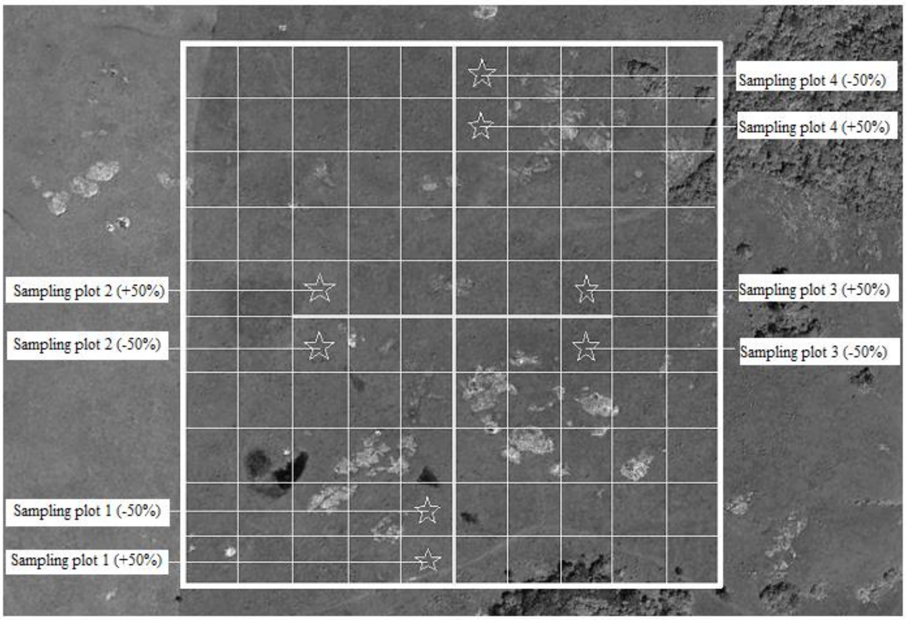

Figure 2. Location of the chosen plots for the samples with more than 50% and with less than 50% of density of shrub coverage.

Figura 2. Localização das parcelas escolhidas para as amostragens com mais de 50% e com menos de 50% de densidade e cobertura arbustiva.

In all the chosen plots, subplots (squares) with dimensions of 5 x 5 m (25 m2) were sequentially demarcated. The demarcation of the subplots was carried out equitably in the 4 plots (of both treatments), according to the necessary number to achieve sampling sufficiency (N) for the different classes of material analyzed, based on the results of the analysis of variance.

The calculation of the sampling sufficiency was done through the sequential method of Stein, using the following formula (BATISTA, 1990):

$$N = (\mathrm{t}^2.\mathrm{s}^2)/\mathrm{E}^2$$

Where: N = number of samples (subplots); t^2 = value of t in the Student table; s^2 = variance and E^2 = sampling error.

Obs. For the determination of E^2, the value of 15% was used as a limit of sampling error, therefore, $E^2 = (0.15 * \text{Average})^2$.

Determination of fuel load

To determine the load (mass) of the shrub forest fuel, initially all different shrubs species individuals present in the subplots were classified according to height and diameter at the base of the stem. Regarding height, the classification was: 0.00 to 0.50 m; 0.51 to 1.00 m; 1.01 to 1.50 m; 1.51 to 2.00 m and 2.01 to 2.50 m. As for the diameter at the base of the stem, the material was classified into 3 classes: <0.7 cm; > 0,71 ≤ 2,5 and > 2.51 cm, according to the principle of response time of fuels in relation to atmospheric humidity (SOARES; BATISTA, 2007). After the classification, the number of individuals of each species was then counted according to the height and diameter of the stem base they presented. The height was determined using a metal ruler with a 5 cm scale (Figure 3A), while for measuring the basal diameter, a wooden template was used (Figure 3B). Then the material was collected by cutting at the base of the plants, close to the soil. All individuals (living and dead) collected were cut into pieces, separating the fuel according to the diametric thickness (Figures 3C) in the following classes: fine fuel ≤ 0.7 cm (live and dead leaves and fine woody material), medium fuel > 0.71 ≤ 2.5 cm (live and dead woody material) and thick fuel > 2.51 cm (live and dead woody material). The live and dead fuel classes with a diameter greater than 2.51 cm in thickness appeared very rarely in the sampling plots. Therefore, they were disregarded for this study due their very low representativeness (less than 1%), which would have very little or no interference in the general load estimation of the shrubs fuel in the study area.

Then the masses of fresh (wet) fuel of the analyzed classes were determined using a scale graduated in grams, with a maximum capacity of 2,500 grams (with 20-gram division). After determining the mass of fresh fuel in the field, subsamples of the fuel classes of all species collected in each subplot were separated. These subsamples were immediately packed in well-sealed plastic bags to avoid loss of moisture to the external environment, thus not changing the determination of the moisture content of the material in relation to its fresh state. All bags were identified with an adhesive label containing information regarding the plant species, material class, number of the plot and the sampling subplot. The subsamples were then taken to the forest fire laboratory at the Paraná Federal University where the masses of the fuel classes were determined and then dried. In the drying process, the fuels were packed in paper cartridges and deposited in electric greenhouses with a constant temperature of 75 ° C (Figure 3D). The thin fuel (≤ 0.7 cm) remained in the greenhouses for a period of 48 hours, while the thicker fuel (> 0.71 and ≤ 2.5 cm) remained for 72 hours. These periods of time were sufficient for the complete drying.

After drying, the dry fuel mass of the sub-samples was determined, using scales with a capacity of 2600 grams and subdivisions of 1 gram. Through the values obtained from the initial mass (fresh fuel) and the mass of the dry fuel, the moisture content was determined, using the formula presented below (BATISTA, 1990).

$$U\% = \left[\frac{Mf - Ms}{Ms}\right].100$$

Where: U% = moisture content (%); Mf = mass of fresh (wet) fuel at the time of collection (g) and Ms = kiln-dried mass of fuel (g).

With the determination of the moisture content of the sub-samples, the total dry mass was then calculated for all species and fuel classes in each sampling subplot. With the sum of the load of all the subplots, the amount of the dry fuel was determined for the two treatments in grams per square meter (gm^{-2}), after converted into megagrams (= ton) per hectare ($Mg.ha^{-1}$).

Figure 3. Determination of height (A) and basal diameter (B), cut into parts and separation in diametric fuel classes (C) and drying in electric oven to determine the dry load of the fuel (D).

Figura 3. Determinação da altura (A) e diâmetro basal (B), corte e separação em classes diamétricas de material combustível (C) e secagem em estufa elétrica para determinação da carga seca do material (D).

Statistical data processing and analysis

The data obtained was compiled and tabulated in Microsoft Office Excel 2007 spreadsheets and processed and analyzed with the STATGRAPHICS Centurion XV software. The statistical tests used for data analysis and comparison were: analysis of variance, means comparison test (SNK) and “t” test.

RESULTS

The shrub forest fuel of PNHR Caminho das Tropas is composed of common vegetation from the Grassy-Woody Steppe region of the second plateau in Paraná state. It is represented mainly by plant species of the Asteraceae and Myrtaceae Families, and in a smaller amount Myrsinaceae, Euphorbiaceae, Fabaceae, Melastomataceae, Rhamnaceae, Rutaceae and Solanaceae (CERVI *et al*., 2007; DALAZOANA; MORO, 2011; DALAZOANA *et al*., 2018).

For plots with more than 50% density and regular distribution of shrub vegetation, the sampling sufficiency for determining the load of the different fuel classes was achieved by collecting samples in 60 subplots. For plots containing less than 50% density and regular shrub distribution, sampling sufficiency was achieved by collecting samples in 35 subplots.

Fuel material load by height class and basal diameter

Table 1 shows the results of the number of shrubs individuals and the load of live, dead and total fuel by height and diameter class.

Table 1. Fuel load of height and basal diameter classes.
Tabela 1. Carga do material combustível por classe de altura e de diâmetro basal.

Plots with more than 50% density and regular shrub distribution						
Height (m)	Diameter class at stem base (cm)	N° of living individuals	Load of live fuel (Mg.ha^{-1})	N° of dead individuals	Load of dead fuel (Mg.ha^{-1})	Total fuel load (Mg.ha^{-1})
0,00 - 0,50	≤ 0,70	35	0,00311	0	0	0,00311
0,51 - 1,00	≤ 0,70	30	0,00355	1	0,00018	0,00373
1,01 - 1,50	≤ 0,70	2	0,00021	32	0,00257	0,00278
1,51 - 2,00	≤ 0,70	0	0	0	0	0
2,01 - 2,50	≤ 0,70	0	0	0	0	0
Total		**67**	**0,00687**	**33**	**0,00275**	**0,00962**
0,00 - 0,50	> 0,71 ≤ 2,5	3	0,00042	1	0,00017	0,00059
0,51 - 1,00	> 0,71 ≤ 2,5	816	0,32144	130	0,07363	0,39507
1,01 - 1,50	> 0,71 ≤ 2,5	778	0,48481	381	0,23430	0,71911
1,51 - 2,00	> 0,71 ≤ 2,5	94	0,14649	5	0,00971	0,15620
2,01 - 2,50	> 0,71 ≤ 2,5	5	0,00658	1	0,00147	0,00805
Total		**1696**	**0,95974**	**518**	**0,31928**	**1,27902**

Plots with less than 50% density and regular shrub distribution						
Height (m)	Diameter class at stem base (cm)	N° of living individuals	Load of live fuel (Mg.ha^{-1})	N° of dead individuals	Load of dead fuel (Mg.ha^{-1})	Total fuel load (Mg.ha^{-1})
0,00 - 0,50	≤ 0,70	56	0,01278	0	0	0,01278
0,51 - 1,00	≤ 0,70	18	0,00795	0	0	0,00795
1,01 - 1,50	≤ 0,70	0	0	0	0	0
1,51 - 2,00	≤ 0,70	0	0	0	0	0
2,01 - 2,50	≤ 0,70	0	0	0	0	0
Total		**74**	**0,02073**	**0**	**0**	**0,02073**
0,00 - 0,50	> 0,71 ≤ 2,5	20	0,01736	0	0	0,01736
0,51 - 1,00	> 0,71 ≤ 2,5	246	0,22807	40	0,05696	0,28503
1,01 - 1,50	> 0,71 ≤ 2,5	176	0,29059	158	0,19990	0,49049
1,51 - 2,00	> 0,71 ≤ 2,5	15	0,05693	21	0,04782	0,10475
2,01 - 2,50	> 0,71 ≤ 2,5	3	0,01444	0	0	0,01444
Total		**460**	**0,60739**	**219**	**0,30468**	**0,91207**

Note: Mg.ha^{-1} = megagram per hectare; cm = centímeter

A total of 3067 individuals of different shrubs species were counted in the subplots to determine the load of shrubs fuel, with 2314 in the subplots with density greater than 50% and regular distribution of shrubs (average of 38.56 per subplot) and 753 individuals for subplots with less than 50% of regular shrub distribution, with an average of 30.12 per subplot. Regarding to height (adding living and dead individuals), the most representative class was 1.01 and 1.5 m, with 1527 individuals, which corresponded to 49.78% of the total collected. The second most representative class was 0.51 and 1.0 m, with 1281 individuals (41.76%) collected. These two classes represented 91.54% of the total of sampled individuals, which demonstrates that in the study area, the shrub stratum has mostly individuals with height ranging from 0.51 to 1.5 m. Regarding the stem base diameter, the material class >0.71 ≤ 2.5 cm was the most representative, presenting 2893 individuals which account for almost 95% of the total collected. Regarding the frequency of height x basal diameter classes, the most representative class was the one with a height of 1.01 and 1.5 m with a diameter >0.71 ≤ 2.5 cm, with 1493 individuals, making up 48.67 % of the total collected. Then, the class with a height of 0.51 and 1.0 m with a diameter >0.71 ≤ 2.5 cm, with 1232 individuals that represented 40.16% of the total collected.

Load of fuel diametric classes

The values found for the load of the different classes of forest shrub fuel analyzed are shown in table 2.

Table 2. Fuel load of the diametric classes analyzed.
Tabela 2. Carga de material combustível das classes diamétricas analisadas.

Plots with more than 50% density and regular shrub distribution		
Class	Load (Mg.ha^{-1})	Percentage (%) in relation to the total load
Live woody-leaf material with diameter ≤ 0,7 cm	0,4839	37,56
Live woody material with diameter > 0,71 ≤ 2,5 cm	0,4798	37,23
Dead wood material with diameter ≤ 0,7 cm	0,1188	9,22
Dead wood material with diameter > 0,71 ≤ 2,5 cm	0,2061	15,99
Total	**1,2886**	**100,00**
Plots with less than 50% density and regular shrub distribution		
Class	Load (Mg.ha^{-1})	Percentage (%) in relation to the total load
Live woody-leaf material with diameter ≤ 0,7 cm	0,3549	38,05
Live woody material with diameter > 0,71 ≤ 2,5 cm	0,2889	30,97
Dead wood material with diameter ≤ 0,7 cm	0,1001	10,73
Dead wood material with diameter > 0,71 ≤ 2,5 cm	0,1889	20,25
Total	**0,9328**	**100,00**

In both treatments, the results showed some equity regarding the load of live material from the two diametric classes analyzed. The same can be said for dead material, although the load of material with a diameter > 0.71 ≤ 2.5 cm was slightly higher. Of the overall total collected, the amount of dead material represented almost 25% for plots with more than 50% coverage of shrub vegetation, while for plots with less than 50% coverage this value was approximately 30%.

Regarding the statistical analysis, the comparison between the values obtained for the loads of the analyzed material classes (live and dead ≤ 0.7 cm and> 0.71 ≤ 2.5 cm) and the total material load between the two treatments, the results are shown in Table 3.

Table 3. Average load (Mg.ha^{-1}) of shrub fuels diametric classes analyzed.
Tabela 3. Carga média (Mg.ha^{-1}) das classes diamétricas de material arbustivo analisadas.

Regular shrub density and distribution	Living material (cm)		Total material vivo	Dead material (cm)		Total dead material	Total material (alive + dead)
	≤ 0,7	> 0,71 ≤ 2,5		≤ 0,7	> 0,71 ≤ 2,5		
Plots with + 50%	0,4876 a	0,4798 a	0,9637 a	0,1188 a	0,2061 a	0,3249 a	1,2886 a
Plots with - 50%	0,3549 a	0,2888 b	0,6438 b	0,1001 a	0,1889 a	0,2890 a	0,9328 b
Average	0,4194	0,3843	0,8037	0,1094	0,1975	0,3069	1,1107

Note: Averages followed by the same letter in the column do not differ statistically by the "t" test.

Regarding the diametric classes, the statistical analysis showed that there were no significant differences between the results of live fuel ≤ 0.7 cm and dead fuel ≤ 0.7 and> 0.71 ≤ 2.5 cm for the two treatments. However, there was a significant difference between the two treatments for the load of live fuel of the class of diameter> 0.71 ≤ 2.5 cm, in the total of live material and also in the total general fuel load.

Fuel Moisture content

Table 4 presented the values for the moisture content for the different classes of fuel analyzed.

Table 4. Average moisture content (%) of the shrub fuel classes.
Tabela 4. Teor médio de umidade (%) das classes de material arbustivo.

Fuel classes	Plots with more than 50% density and regular shrub distribution	Plots with less than 50% density and regular shrub distribution
Live material with diameter ≤ 0,7 cm	174,98 a	155,67 a
Live material with diameter > 0,71 ≤ 2,5 cm	135,07 a	131,46 a
Dead material with diameter ≤ 0,7 cm	20,29 a	23,65 a
Dead material with diameter > 0,71 ≤ 2,5 cm	21,26 a	19,71 a
Total living material	155,03 a	140,57 a
Total dead material	20,78 a	22,41 a
Total material (alive + dead)	87,90 a	81,49 a

Note: Averages followed by the same letter in the column do not differ statistically by the "t" test.

According to the results in Table 4, it is noted that all classes of living fuel from plots with more than 50% of shrubs density had a higher moisture content than the same classes from plots with less than 50% of shrub density. The moisture content of the total live fuel shows that there was a difference of approximately 10% between both, with a reduction present for the plots with less than 50% of shrub density.

DISCUSSION

The shrub density of 3067 individuals per hectare found in the study area is in accordance with the estimated for field environment. Ottmar *et al*. (2001) found for seven different physiognomies of the phytogeographic region of the Cerrado in Brazil, a density of woody vegetation with a height of up to 2.5 meters, ranging from 946 to 4,445 individuals per hectare. Barbosa *et al*. (unpublished data) found between 1,606 to 4,580 individuals per hectare for the Savanas in Roraima, Brazilian north region. Regarding the height pattern of the shrub stratum of the area, this is also within the range presented in the literature. Ottmar *et al*. (2001) found for individual of woody-shrub with a diameter > 2.0 and < 3.0 cm in seven vegetation types of Cerrado fields, average heights ranging from 0.90 to 1.50 m, while Fernández *et al*. (2013) in shrub communities in northeastern Spain, found average heights ranging from 0.39 to 0.96 m. Castedo-Dourado *et al*. (2012), when studying the shrub combustible of the pine forest understory in northwestern Spain, found average heights ranging from 0.86 m to 0.96 m. Saglam *et al*. (2008) recorded for the shrub vegetation of two areas located in western Turkey, an average height of 0.91 m with a minimum and maximum of 0.30 and 2.30 m respectively.

The total load of shrub fuel obtained for plots with more than 50% density and regular shrub distribution was 1.2886 Mg.ha-1, while for plots with less than 50%, the value was 0.9328 Mg.ha-1. The average between the two stratifications was 1.1107 Mg.ha-1, and this result is being within a standard of load values obtained in research carried out in natural areas of Brazilian grassy-woody fields. Ottmar *et al*. (2001), obtained for shrub vegetation with diameter inferior to 2.5 cm in different Cerrado physiognomies, values from 0.410 to 2.290 Mg.ha-1. Miranda *et al*. (1996), also working in an area of Cerrado, founded an average value of 0.300 Mg.ha-1 for the shrub stratum. Ribeiro *et al*. (2011) in a survey carried out in an area covered by Cerrado, estimated an average load of 4.682 Mg.ha-1 of fuel for shrub vegetation. The same authors, through the review of papers carried out in the Cerrado biome in different states of Brazil, presented fuel load values for the shrub strata ranging from 2,629 to 3,200 Mg.ha-1.

Regarding the statistical analysis between the two treatments, the non-significant difference presented for live fuel ≤ 0.7 cm can be explained by the homogeneity of its distribution in the area, considering that it covered all individuals in the stem diameter class ≤ 0, 7 cm, in addition to the fine material of the canopy (branches and leaves) of individuals in the stem diameter class with thickness > 0.71 ≤ 2.5 cm. For dead fuel, for class ≤ 0.7 cm and for class > 0.71 ≤ 2.5 cm, the significant statistical non-differentiation may be the result of the low representativeness of this type of material throughout the area during the period of collections. As for the significant differences observed between the two treatments in relation to the live fuel load of the diameter class > 0.71 ≤ 2.5 cm and between the total live fuel load and the total general fuel load (live and dead), a possible explanation for this may be the proportion of individuals with a height of 1.01 and 2.5 meters and a stem base diameter > 0.71 ≤ 2.5 cm for both treatments. While for plots with more than 50% density and regular shrub distribution, an average frequency of 14.62 individuals per subplot was observed, for plots with less than 50% the average frequency was 7.76 individuals per subplot. Individuals with greater height generally contribute with greater amount of thicker material because the stem tends to thicken and present greater biomass as the plant grows. Thus, with the highest proportion of individuals with these measures for plots with more than 50% density and regular shrub distribution, there was a much higher proportional load than those with less than 50%, resulting in a significant difference between the two treatments. Another comparison can be made between fuel loads with thickness ≤ 0.7 cm and > 0.71 ≤ 2.5 cm. For plots with more than 50% density and regular shrub distribution, the results were very close, with 0.4876 Mg.ha-1 for ≤ 0.7 cm and 0.4779 Mg.ha-1 for > 0.71 ≤ 2.5 cm. For plots with less than 50% density and regular shrub distribution, the values were 0.3549 and 0.2888 Mg.ha-1 respectively. The disproportion observed between individuals with a height of 1.01 m and 2.5 meters and a stem base diameter > 0.71 ≤ 2.5 cm in the two treatments directly reflected on the results of the total live fuel and the general total fuel (alive + dead) that also showed statistically significant differences between the treatments.

As for moisture content, Soares and Batista (2007) write that live and dead fuels have different mechanisms for retaining moisture with different responses to climatic variables. While the dead material is drier and the moisture content undergoes more sudden changes due to weather conditions (action of meteorological variables), the living material, in turn, is more humid and more stable, with the moisture content having a relationship with the physiology of the different species. The authors mention that the moisture of the foliage of live vegetation can vary from 300% in the initial stage of growth (sprouting) to 50% when it enters the stage of dormancy (yellowing). In this study, no statistically significant differences were found in the comparisons between the fuel classes analyzed between the two treatments. However, for all classes of living material, the moisture content was higher for treatment with more than 50% shrub density. A possible explanation for this differentiation may be linked to the sequence of the samplings, since these were initially carried out on plots with shrub density above 50%, and then on plots with less than 50% shrub density. The time between the samplings at the two treatments was approximately two months, a period in which it was noted that part of living individuals of some species that have a very short life cycle already showed signs of physiological changes (mainly in the leaves), indicating the plants process of dying, which in fact was recorded for the following months Therefore, the differentiation recorded may be related to the natural reduction in the moisture content of the plant tissues of several living individuals, who were at the time of the samplings in the final stage of their life cycle.

For the dead fuel the differences were very small, as all collects were made under similar weather conditions, with at least five days without rain.

CONCLUSIONS

According to the results obtained in this study, we conclude that:

- The height of the shrub vegetation recorded in the study area was relatively low, with an average of approximately1.0 m, but within a height range generally found for this vegetation stratum as presented in the literature.
- The estimated load of shrub fuel material for the study area is compatible with that presented in the literature for the vegetation of grassy-woody fields in Brazil.
- Compared to the herbaceous stratum, the shrub fuel load is much less expressive, as well as, presenting less ignition risk.
- Approximately 70% of the load of the shrub stratum consisted of living material containing high percentage of humidity, which represented low fire hazard index for this stratum in the period in which the study was carried out.

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