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Potential fungal attack for wood in Mato Grosso state, Brazil

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ABSTRACT: This work characterizes the temporal and spatial distribution of Fungal Attack Potential (FAP) for wood in Mato Grosso state, Brazil. The meteorological data of temporal series of 7 years (2008-2014) were used, from 30 automatic weather stations (AWS 's) of the stations network of the National Institute of Meteorology (INMET). The monthly average of air temperature and the number of days with rain over than 0.30 mm the month were used. The interpolation by Arcgis 10.0 software was used, with FAP discretization in months, dry and rainy and annual season. The results showed a great variation of FAP to Mato Grosso, with the highest and lowest rates, occurred in January and July. In the dry season, there is a low potential wood deterioration by the fungus (FAP between -2.70 to 3.40). In contrast, in the rainy season, FAP ranged from 16.60 to 25.90, depending on the concentration of days with precipitations over 0.30 mm. The total annual sum of FAP ranged from 119 to 198, and the north of the state showed the highest values by having high rainfall rates. It is recommended attention on drying and storage of wood in the rainy season (October to April) to the North, Northwest, Northeast and West of Mato Grosso state.

Keywords: biodeterioration, wood decay fungus, environmental variables.

Potencial de ataque fúngico para madeiras no estado do Mato Grosso

RESUMO: Este trabalho caracteriza a distribuição temporal e espacial do Potencial de Ataque Fúngico (PAF) para a madeira no Estado do Mato Grosso. Utilizou-se os dados meteorológicos de series temporais de 7 anos (2008-2014) de 30 estações meteorológicas automáticas (EMA's), da rede de estações do Instituto Nacional de Meteorologia (INMET). Utilizou-se as médias mensais de temperatura do ar e o número de dias com chuva acima de 0,30 mm no mês. Empregou-se a interpolação pelo *software* Arcgis 10.0, com discretizações de PAF em meses, estações seca e chuvosa e anual. Os resultados apresentaram grande variação de PAF para o Mato Grosso, tendo os maiores e menores índices ocorrido em janeiro e julho. Na estação seca ocorre um baixo potencial de deterioração da madeira por fungos (PAF entre -2,70 à 3,40). Em contrapartida, na estação chuvosa, PAF variou de 16,60 a 25,90, em função da concentração de dias com precipitações acima de 0,30mm. O somatório total anual de PAF variou de 119 a 198, tendo a região norte do Estado os maiores valores por possuir altos índices pluviométricos. Recomenda-se atenção na secagem e armazenamento da madeira na estação chuvosa (outubro a abril) para as regiões Norte, Noroeste, Nordeste e Oeste do estado de Mato Grosso.

Palavras-chave: biodeterioração, fungos xilófagos, variáveis ambientais.

1. INTRODUCTION

Brazil has an immense amount of forest resources, highlighting the wide variety of native species, which together with good soil and climate conditions for the implementation of fast-growing species, they favor the development of forestry activities (SHIMIZU 2007). For having good chemical, physical, and mechanical properties, and high decorative value, wood has great applicability in engineering and architectural projects, musical instruments and other products. However, due to the environment exposure, biological agents may damage it, especially fungus, which has a rapid development of the environments of wood use. Being developed in warm and moist environments, cut and stored logs in the forest are soon contaminated by wood-destroying fungus, as they found a favorable environment and the main nutrients necessary for their survival in this material (LEVY 1983; MORESCHI 2013).

Funguses are bio-deterioration agents and can compromise wooden structures that are located also above ground (SCHMIDT 2007). The temperature and humidity of the wood are the main factors that interfere with the fungal attack because their characteristics favor the metabolism and cell wall degradation by the fungus (MORRIS 2011). Some conditions are required for the fungus development in the wood, such as the oxygen availability (higher than 20%); pH in the acidic range (4.5 to 5.5); a temperature between 25 and 30 °C, and particularly, wood moisture content higher than 20%. The absence of these conditions limits the development of most fungus in the wood (MORESCHI, 1980). In this sense, to control the wood moisture content becomes a fundamental instrument for their protection, especially when its use is exposed to the atmosphere. Therefore, substances repellent to moisture can be used, leaving it away from liquids or reducing the accessibility of cell walls to water (RINGMAN et al., 2014).

A fungus causes stains on wood by the results of the light reflection on the pigmented hyphae, mainly releasing pigments in the empty spaces of the wood. The cell walls keep their natural and practically intact color when attacked by strainers and moldy fungus, or they show small perforations caused by appressoria for the passage of the hyphae from a cell to another. The installation of the fungus in the wood causes the mischaracterization of its color due to the presence of pigments in its cavity, and causes obstruction of the scores of cell walls, thus making a barrier when it needs to dry out or impregnate the wood with some preservative substances (MORESCHI, 2013).

Application of Fungal Attack Potential (FAP) for wood represents the risk of decay, where the wood is submitted by climatic variations, and it is considered an important tool to support better use of wood in different regions (MARTINS, 2003).

Therefore, this study aimed to characterize the temporal and spatial distribution of the fungal attack potential for wood in Mato Grosso state.

2. MATERIAL AND METHODS

2.1. Location

The state of Mato Grosso has two defined seasons: dry (May to September) and rainy (October to April). The weather is characterized as Aw (Savannah Tropical Weather) - tropical weather with average temperatures above 18 °C every month, where autumn and winter represent the dry season and the rainy season spring/summer and Cwa (Temperate or Altitude Tropical Weather) – is the weather with dry winter, where the hottest month temperatures are above 22 °C (SOUZA et al., 2013).

2.2. Data collection

Meteorological data were obtained from the National Institute of Meteorology (INMET), collected in the network of automatic stations (AWS's) installed in the state of Mato Grosso, covering the period from 2008 to 2014, and represented by 30 AWS's (Table 1 and Figure 1).

2.3. Fungal attack potential

For the determination of Fungal Attack Potential (FAP) the SCHEFFER methodology (1971) was used and adapted by MARTINS (2003) (Eq. 1) to the Brazilian climatic conditions. The values were monthly obtained through the average temperatures and the mean number of days with precipitation above 0.30 mm, each month.

$$\text{FAP} = \frac{(T-2)(D-3)}{16.7} \quad (1)$$

Table 1. Automatic weather stations in the state of Mato Grosso, Brazil.
Tabela 1. Estações meteorológicas automáticas do estado de Mato Grosso, Brasil.

Code	City name	Lat. (S)	Long. (W)	Hei. (m)
A-908	1. Água Boa	-14.0161	-52.2122	432
A-924	2. Alta Floresta	-10.0672	-56.7522	294
A-910	3. Apiacás	-9.5639	-57.3936	220
A-905	4. Campo N. d. Parecis	-13.7833	-57.8333	570
A-912	5. Campo Verde	-15.3139	-55.0808	749
A-926	6. Carlinda	-9.9703	-55.8272	300
A-913	7. Comodoro	-13.4231	-59.4546	591
A-918	8. Confresa	-10.6539	-51.5668	237
A-919	9. Cotriguaçu	-9.9061	-58.5719	261
A-901	10. Cuiabá	-15.5594	-56.0628	240
A-930	11. Gaúcha do Norte	-13.1847	-53.2575	379
A-906	12. Guarantã	-9.9500	-54.8833	320
A-932	13. Guiratinga	-16.3417	-53.7661	526
A-933	14. Itiquira	-17.1750	-54.5014	585
A-914	15. Juara	-11.2803	-57.5267	260
A-920	16. Juína	-11.3750	-58.7750	374
A-928	17. Nova Maringá	-13.0386	-57.0922	353
A-929	18. Nova Ubiratã	-13.4111	-54.7522	518
A-927	19. Novo Mundo	-12.5219	-58.2314	431
A-917	20. Pontes de Lacerda	-15.2511	-59.3467	256
A-935	21. Porto Estrela	-15.3247	-57.2264	145
A-907	22. Rondonópolis	-16.4500	-54.5666	284
A-936	23. Salto do Céu	-15.1247	-58.1275	303
A-931	24. Santo Ant. do L.	-14.9278	-53.8836	648
A-921	25. São F. do Ar.	-11.6189	-50.7278	218
A-903	26. São J. do R. C.	-13.4500	-56.6666	350
A-917	27. Sinop	-11.9822	-55.5658	371
A-904	28. Sorriso	-12.5452	-55.7113	380
A-902	29. Tangará da Serra	-14.6500	-57.4315	321
A-922	30. Vila Bela S. T.	-15.0628	-59.8729	222

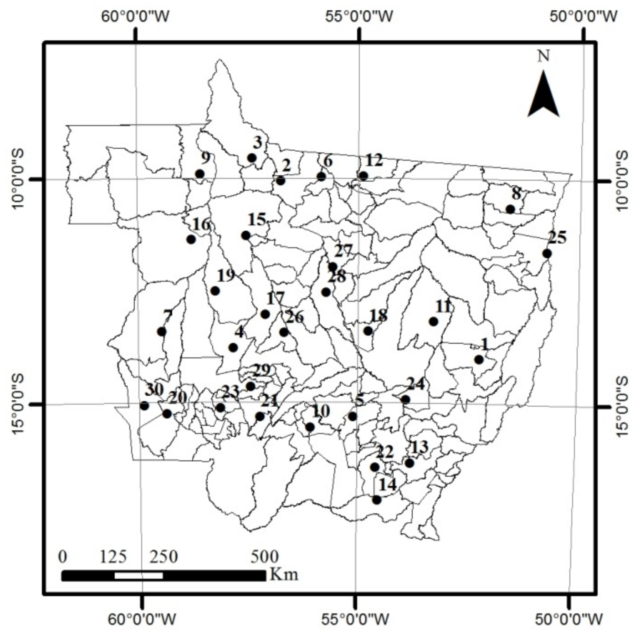

Figure 1. Spatial distribution of automatic weather stations assessed to estimate the FAP, Mato Grosso state, Brazil.
Figura 1. Distribuição espacial das estações meteorológicas automáticas avaliadas na estimativa do PAF, Estado de Mato Grosso, Brasil.

where: FAP = Fungal Attack Potential suspended in wood; T = average temperature in the month, D = number of days with rainfall over 0.30 mm in the month.

Therefore, the larger the FAP value, the greater the fungal attack potential on wood.

2.4. Maps

For the processing of spatial data, the ArcGIS 10.0 software was used, and the monthly average values of FAP of AWS's were inserted and, in a second stage, the data were grouped into two periods, the months that correspond to the dry season (May to September) and rainy season in the state of Mato Grosso (October to April). Finally, the total sums of each AWS's were performed.

Thus, the interpolations of FAP values were created through the Spatial Analyst Tools instrument; interpolation; IDW (Interpolation of the points by pondering the inverse of the distance), showing the values through maps with different values classes.

3. RESULTS AND DISCUSSION

The average annual temperatures ranged between 22.58 and 26.35 °C to Comodoro and Confresa, respectively (Table 2). The month of September showed the highest average monthly air temperature, regardless of geographical location and/or altitude of the AWS. The dry months showed larger daily amplitudes trends, corroborating Souza et al. (2013). The monthly thermic amplitude range varied from 1.64 °C (North Guarantã) 5.65 °C (Cuiabá), indicating that average monthly temperatures in the state did not show significant variations in the different biomes and the seasons.

For FAP values, there was a great variability, especially when compared discretization's of January and July classes, and in January reached average up to 35.00; while in July occurred extreme values lower than -5.00, i.e., to Mato Grosso PAF suffers a variation of 40.00 units. This occurs due to the definition of the two climatic periods very different during the year. The months from October to May showed high-temperature values (Table 2) because in these months there is a low variation of the temperature throughout the day due to the presence of water vapor in the atmosphere, with a predominance of rainfall in this period (SOUZA et al., 2013). Monthly and yearly total rainfall variations are the result of the regional atmospheric circulation behavior throughout the year, together with local or regional geographical factors (PEREIRA et al., 2002).

The FAP regionalization trend was observed in the north and northwest regions when compared to the rest of the state (Figure 2). According to Nimer; Brandão (1989), the annual rainfall average in this region of the state can reach values greater than 2750 mm decreasing towards East, West and South, which results in a spatial and irregular temporal distribution rainfall throughout the year, with highs in summer and low in winter since the concentrations of 70% of the rainfall is between November and March (summer), and whose rainiest months are concentrated from January to March. During this quarter, the precipitation reaches 45 to 55% of the total annual rainfall (SETTE; RATE, 2000b). This behavior directly influences in the FAP seasonality in the state.

Table 2. Monthly and annual temperatures averages 2008-2014 (°C) in automatic weather stations of the National Institute of Meteorology network (INMET), in Mato Grosso state, Brazil.
Tabela 2. Temperaturas médias mensais e anuais de 2008 a 2014(em °C) nas estações meteorológicas automáticas da rede do Instituto Nacional de Meteorologia (INMET), no Estado de Mato Grosso, Brasil.

Stations	Months												Anual
	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mean
1.Água Boa	24.65	24.64	24.94	25.11	24.30	24.06	24.36	25.80	27.75	26.60	25.08	24.68	25.16
2.Alta Floresta	24.54	24.41	24.92	25.13	25.12	24.24	23.72	24.55	26.27	25.48	24.94	25.01	24.86
3.Apiacás	25.28	24.84	24.76	25.12	25.51	25.38	25.64	26.81	27.14	25.67	25.39	25.39	25.58
4.Campo N. d. P.	24.18	23.75	23.97	25.57	23.13	22.56	22.90	24.41	26.33	25.69	24.63	24.97	24.34
5.Campo Verde	22.89	23.18	23.41	23.12	21.81	22.15	22.48	24.45	25.90	24.75	23.90	23.33	23.45
6.Carlinda	24.50	24.78	25.04	25.25	25.35	25.43	25.83	26.89	26.66	25.77	25.20	24.94	25.47
7.Comodoro	23.10	22.93	23.13	22.86	21.59	21.02	20.65	21.50	23.53	23.78	23.56	23.34	22.58
8.Confresa	25.24	25.33	25.97	25.98	26.39	26.01	26.14	27.46	28.66	27.12	26.07	25.77	26.35
9.Cotriguaçu	24.63	24.71	24.74	25.06	24.73	24.56	24.55	25.20	26.29	25.86	25.40	25.24	25.08
10.Cuiabá	26.23	25.53	26.60	26.76	24.41	23.87	23.45	25.51	29.11	28.02	27.28	26.77	26.13
11.Gaúcha do Norte	25.10	25.17	25.70	26.00	25.37	25.10	25.14	25.60	27.47	26.72	25.59	25.07	25.67
12.Guarantã do No.	24.91	25.09	25.37	25.72	25.50	24.87	24.86	25.57	26.50	25.99	25.46	25.19	25.42
13.Guiratinga	25.96	24.99	25.38	25.21	23.97	23.75	23.45	25.11	27.52	27.19	25.88	25.42	25.32
14.Itiquira	24.42	24.39	24.64	24.04	22.35	22.59	22.37	23.93	26.27	25.88	25.03	24.59	24.21
15.Juara	25.34	25.10	25.52	25.66	25.28	24.98	25.21	26.73	27.59	26.91	26.06	25.54	25.83
16.Juína	24.56	24.77	24.66	24.89	24.73	24.30	24.44	25.27	26.76	25.88	25.04	24.86	25.01
17.Nova Maringá	26.32	27.52	26.70	25.85	24.79	23.87	23.57	25.12	26.88	26.87	25.97	25.45	25.74
18.Nova Ubiratã	23.66	23.97	24.86	25.41	23.81	24.93	24.54	25.41	27.18	26.07	24.72	24.30	24.91
19.Novo Mundo	24.02	24.22	24.45	24.57	24.08	24.17	24.61	26.25	27.51	26.08	25.07	24.40	24.95
20.Pontes de Lacerda	25.67	25.22	25.60	24.98	23.45	23.08	23.11	24.87	26.89	27.05	26.31	25.96	25.18
21.Porto Estrela	27.60	26.21	26.39	26.07	25.32	23.50	22.75	24.35	27.36	27.67	26.94	26.50	25.89
22.Rondonópolis	25.43	25.33	25.55	25.13	23.23	22.71	22.63	24.78	27.73	27.80	26.43	25.92	25.22
23.Salto do Céu	25.35	25.05	25.17	24.44	22.71	22.21	21.88	23.30	25.78	26.26	25.90	25.49	24.46
24.Santo Ant. do L.	23.61	23.70	24.21	23.54	22.63	22.49	22.63	24.39	26.24	25.34	24.16	23.70	23.89
25.São F. do Ar.	25.35	25.72	26.16	26.60	25.67	24.17	25.83	27.39	28.72	27.23	25.13	25.44	26.12
26.São J. do R. C.	24.76	24.56	25.38	25.17	23.96	23.64	22.78	23.96	27.95	25.80	25.34	25.25	24.88
27.Sinop	25.07	24.57	25.16	24.99	24.44	24.26	24.65	26.19	27.08	26.09	25.30	24.94	25.23
28.Sorriso	24.92	24.91	25.54	25.91	25.10	24.87	25.44	26.96	28.05	26.58	25.50	25.33	25.76
29.Tangará da Serra	24.99	24.86	24.72	24.34	23.03	23.22	23.25	25.29	26.70	25.86	25.10	24.96	24.69
30.Vila Bela S. T.	25.64	25.32	25.75	25.23	23.85	23.12	22.93	24.29	26.45	26.73	26.47	26.08	25.15

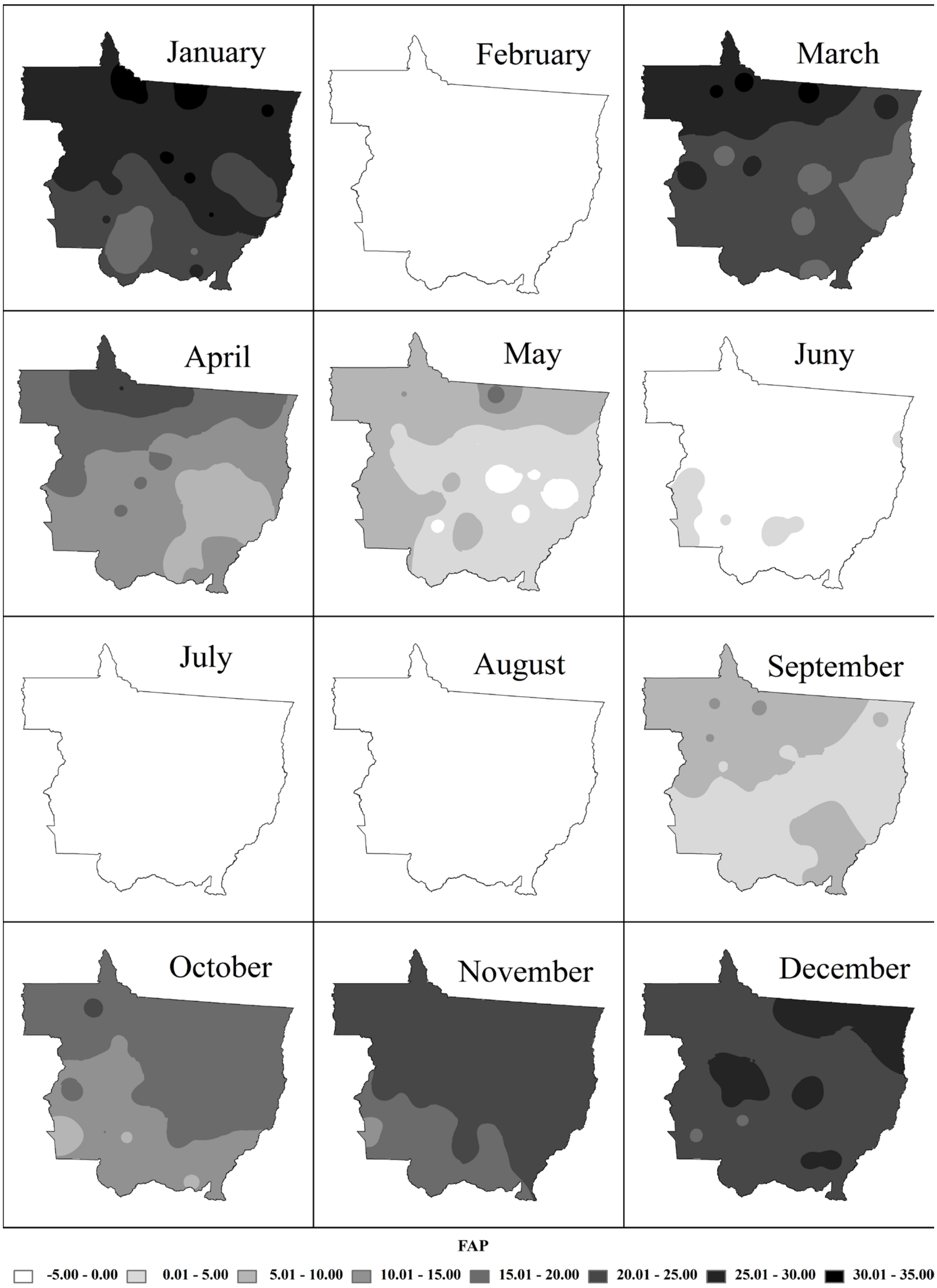

Figure 2. Maps of the spatial and temporal distribution from 2008 to 2014, the Fungal Attack Potential in Mato Grosso wood.
Figura 2. Mapas da distribuição espacial e temporal de 2008 a 2014, do Potencial de Ataque Fungico na Madeira em Mato Grosso.

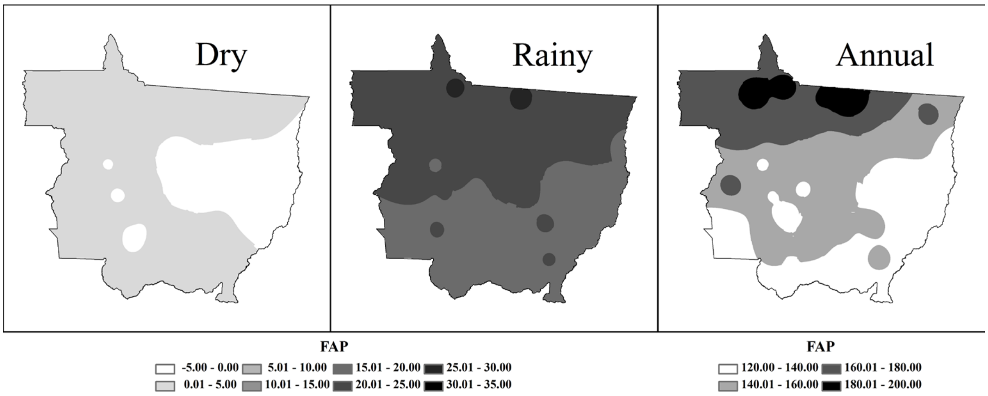

Figure 3. Maps of the spatial distribution in the dry and rainy seasons, and the total annual sum of Fungal Attack Potential in Mato Grosso wood, from 2008 to 2014.
Figura 3. Mapas da distribuição espacial nas estações de seca e chuvosa, e o somatório total anual do Potencial de Ataque Fungico na Madeira em Mato Grosso 2008 a 2014.

Casavecchia et al. (2011) in FAP studies in 2007-2009 for the Sinop/Mato Grosso region, north of Mato Grosso, observed that because the region has a summer with average air temperatures around 25 °C and high rainfall, the months of the rainy season have the highest FAP indexes, corroborating MORESCHI (1980). This behavior is due to the hygroscopic potential of wood, absorbing higher water content available in the environment, allowing a favorable humid microenvironment for the development of fungus on the surface of the wood (Bordin, 1999; Accarini et al., 2000). Casavecchia et al. (2011) also stress the importance of the distribution of rainfall in the deterioration of wood, as in July 2007 Sinop/Mato Grosso accumulated 20 mm of rain, elevating the FAP to levels close to the rainy season.

In July and August (Figure 2), regardless of the region of the state, the FAP was null or very low. Generally, FAP rate depends on the average monthly temperature and the number of rainy days greater than 0.30 mm. Accordingly, the absence of rainfall and high temperatures during the dry period allowed the obtainment of negative FAP values. The South, Southeast, Southwest and Eastern state regions have the lowest FAP values, regardless of the time of the year.

According to Souza et al. (2013), winter is extremely dry in the state, with rare rains distributed in four to five days in the months of June, July, and August, with very low totals, between 20 and 80 mm. Generally, the winter rains in the state are the result of frontal formations, which are provided by the passage of polar fronts brought from the South by the polar anticyclone. The occurrences of rainfall in the extreme north of Mato Grosso are the troubled west circulation system consequences caused by winds brought by tropical lines instabilities (TI). In this context, regardless of the time of the year, there is a tendency of the North region (Amazon) showing a higher humidity compared to the Southern and Eastern regions (Cerrado).

Considering the rainy season (October to April), similarities with the average annual behavior is noted, demonstrating that there is a great dependence of the index on the number of rainy days above 0.30 mm (Figure 3). Meyer; Brischke (2015) studied the influence of moisture to the white rot fungus attack in a range of species and obtained high FAP values in those months. They indicated that the fungus attack could worsen during the following months, by the continuation of the rainy season.

The mean annual FAP classes values show an oscillation of 120 to 198, for the South and North of the state, respectively. Evaluating the FAP throughout Brazil, Martins (2003) found values ranging from 20 (northeast) 270 (north of the Amazon), and for most of the Mato Grosso state FAP was 120, and only the extreme north showed a value of 170, underestimating the fungal attack potential, mainly by using few weather stations in their studies, not showing the region of greater wood production of the state in a satisfaction way.

Studying different wood species in Europe Meyer et al. (2015) found that the minimum required moisture content was 19.2% to occur the biodegradation by fungus and this value varies from species to species and fungus to fungus.

In this sense, evaluating the moisture content of seven species of Amazon wood, in the city of Sinop/Mato Grosso, Cassiano et al. (2013) found values over 19.2% for woods of low density, in the months of December and January, indicating that in these months, vulnerability to fungal attack is very large, especially in areas of higher productivity as the results presented here.

4. CONCLUSIONS

The state of Mato Grosso presented a variation of the fungal attack potential between the dry and rainy seasons, with greater potential bio-deterioration of wood by fungus between October and April.

The North, Northwest, Northeast and West regions and Mato Grosso state show higher FAP in the rainy season, with higher fungal attack possibilities in the wood on this season.

This information can guide the adoption of drying techniques, storage and/or use of preservatives, and thus, extend the life of wood in use.

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