Correlations of the Growth and Dynamic with Climatic Variables in A Native Forest in Southern Brazil

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ABSTRACT

This study aims to evaluate the relationship between the dynamic processes of the forest and the climatic variables. It was sampled individuals of 10 permanent plots of 1 ha each, for a period of 10 years in the National Forest of São Francisco de Paula, Rio Grande do Sul State, Brazil. All individuals were identified botanically and grouped by species and botanical families. Through the horizontal structure calculations, were identified the most important families and species of forest. Information about the number of individuals and growth were correlated with precipitation, relative humidity and average temperature for the same period using Spearman’s correlation, at 90% confidence probability. The botanical families with higher importance in the forest were Myrtaceae, Araucariaceae and Lauraceae, representing 54.1% of the value of importance. Regarding the species, Araucaria angustifolia (Bertol.) Kuntz was the most important in the forest (18.8% of importance value) and coupled with other eight species, represented 52.7% of the total importance value. The most species and botanical families did not show significant correlations, indicating the forest resilience capacity that maintain regular the number of individuals and continued growth, despite the weather fluctuations. Araucaria angustifolia indicated higher growth during periods of lower precipitation, as well as the Rutaceae family. Families with pioneer species (Anacardiaceae, Primulaceae, Solanaceae) or climax species (Celastraceae) showed great tendency to correlate their dynamics with precipitation. The relation between dynamics and average temperature indicated significant correlations in three different families (Annonaceae, Campanulaceae and Verbenaceae), wherein on the hottest years, the number of individual increased. Five families indicated correlations between relative humidity and growth (Apocynaceae, Cardiopieridaceae, Podocarpaceae, Rubiaceae and Verbenaceae), however, relative humidity affected differently the families growth (higher or lower growth).

INTRODUCTION

Forests have an important social function and are essential for the maintenance of the environment. Because of this, studies that may provide more knowledge into the aspects related to dynamics and forest growth in front of environmental conditions that they operate are essentials.

Forest growth is a result of the availability of environmental resources, such as light, water, nutrients, space, genetics, which can affect in different ways the growth (Pooter and Bongers, 1993), and also the ability of the individuals to take advance of these available resources. For Husch et al. (1982), growth is a result of climatic factors, soil factors, geomorphological characteristics, competition with other living beings, beyond the influence of genetic makeup and habitat (Lamprecht, 1990).

The Atlantic Forest biome that extends from southern to northern Brazil, although it has suffered different exploration cycles, concentrates a great diversity and number of endemic species. Among the vegetation types of this biome, there is the Araucaria’s Forest, which has occurrence mainly in the Brazilian southern plateau (IBGE, 1992). This forest typology has a great importance in economic development and environmental maintenance in the South of Brazil (Ebling et al., 2013).

Therefore, this study aims to evaluate the relationship of growth and dynamics forest with climatic variables in a remnant of Araucaria’s Forest.
MATERIALS AND METHODS

The study area is located in the national forest of São Francisco de Paula municipally (29°24′ and 29°27′ south latitude and 50°22′ and 50°25′ west longitude), Rio Grande do Sul state (Southern Brazil). The local vegetation corresponds to a remnant of 1,606 ha of Araucaria’s Forest, insert inside of the Atlantic Forest biome. In this kind of vegetation, Araucaria angustifolia specie is very important, which occurs in the Brazilian Southern Plateau and in neighboring countries, such as Paraguay and Argentina (Roderjan et al., 2002). The local vegetation is inserted in a protected area, free from human interference and in an advanced succession stage.

The vegetation database was obtained in the continuous forest inventory with full repetition, accomplished between the years 2000 to 2009. The samplings were carried out in 10 permanent sample plots with 1 hectare of area each, where information concerning to diameter at breast height (DBH) were collected on the individuals with diameter equal or greater than 9.5 cm. The botanical identification was realized according APG system (2009).

The individuals sampled were grouped into their respective species and families, making the average annual growth as well as the dynamics of mortality (individuals that died by senescence, pests, storms) and recruitment (individuals that have reached the minimum diameter inclusion of 9.5 cm in DBH). Then, were determined the periodic increment in diameter and the number of individuals sampled by species and botanical family level for each year. Through the calculations of the horizontal structure were identified species and families with higher importance value in the forest.

Whereas the data do not follow a standard parametric, was used the nonparametric Spearman’s correlation ($\rho$) to evaluate the correlations among periodic increment in diameter and dynamic, with data related to climate as average temperature, precipitation and relative humidity (Equation 1). The correlation were evaluated for all families and for the species that totaling 50% of the importance value, considering the descending order of this.  

$$\rho = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$  \hspace{1cm} (1)

Where: $x$ and $y$ are variables.

The significance of the correlations were assessed using the “t” test, with a confidence probability of 90%. Only correlations statistically significant were presented.

$$t_n = - \frac{\rho}{\sqrt{\frac{n}{n-2}}} \text{Eq.}$$  \hspace{1cm} (2)

Where: $\rho$ is the value of the Spearman’s correlation; $t_n$ corresponds to Student’s distribution “t” with n-2 degrees of freedom.

The meteorological stations selected to compose the climatic data form a triangulation with the study area, which is located in the center of the triangle. The weather stations are located on the following coordinates: station nº 83919 (-28°66’ latitude; -50°43’ longitude), station nº 83946 (-29°05’ latitude; -50°13’ longitude), station nº 83942 (-29°16’ latitude; -51°02’ longitude). Their respective altitudes are 1047.5 m, 905 m and 759.6 m. The information obtained from stations were converted to annual values, equaling the same number of observations of the forest sampling data. Subsequently, the arithmetic average for each year was calculated for each variable of interest among the three stations.

RESULTS AND DISCUSSIONS

Through the floristic analysis were identified 117 arboreal species, belonging to 75 genera and 43 botanical families, indicating a higher forest wealth in relation to other studies in the same phytogeographic region (Herrera et al., 2009).

The Myrtaceae botanical family showed greater wealth, with 10 genera and 22 species, representing 18.8% of the total number of species and 25% of the number of individuals, indicating great adaptability in the environment (Klein, 1990). The Lauraceae family was the second with highest number of species (9 species), followed by Fabaceae (8 species), Salicaceae and Solanaceae (6 species each) and Aquifoliaceae (5 species). Together, these six families totaled half of the sampled tree species.

The others families found in the area were Anacardiaceae, Annonaceae, Apocynaceae, Araliaceae, Araucariaceae, Areceaceae, Astereaceae, Bignoniaceae, Cannabaceae, Cardiopodiaceae, Celastraceae, Clethraceae, Cunoniaceae, Cyatheaeeae, Dicksoniaceae, Elaeocarpaceae, Euphorbiaceae, Loganiaceae, Malvaceae, Melastomataceae, Meliaceae, Monimiaceae, Nyctaginaceae, Phytolaccaceae, Picramniaceae, Podocarpaceae, Primulaceae, Proteaceae, Rhamnaceae, Rosaceae, Rubiaceae, Rutaceae, Sapindaceae, Styracaceae, Symplocaceae, Theaceae and Verbenaceae, totaling 43 families sampled.

The Myrtaceae family showed highest importance value in the forest, justified by the high density and frequency of this family. Araucariaceae was the second most important family, with high values of density and dominance. Lauraceae family, in turn, did not indicate just one component of the horizontal structure with very high values, however, maintained the density, frequency and dominance with high and similar values, being the third most important family. Together, these three families totaling 54.1% of the value of importance (Table1).
Regarding the arboreal species, Araucaria angustifolia presented the highest importance, mainly due to its high dominance when compared to other species. Usually, Araucaria angustifolia form groups with other species as Myrtaceae (Blepharocalyx salicifolius (Kunth) O. Berg), Aquifoliaceae (Ilex brevicuspis Reissek, Ilex paraguariensis A. St.-Hil) and Lauraceae (Cryptocarya aschersoniana Mez, Nectandra megapotamica (Spreng.) Mez), which also are among the most important species sampled in that forest. These species, added to Casearia decandra Jacq., Sebastiania commersoniana (Baill.) L.B. Sm. & Downs and Sebastiania brasiliensis Spreng totaled half of the importance value of study area (Table 2).

| Table 1: Structural analysis of the top five botanical families found in the National Forest of São Francisco de Paula. |
|-----------------|-----------------|-----------------|-----------------|------------------|
| Family          | Density (%)     | Frequency (%)   | Dominance (%)   | Importance value |
| Myrtaceae       | 25.2            | 26.5            | 15.8            | 22.5             |
| Araucariaceae   | 12.3            | 8.0             | 35.9            | 18.8             |
| Lauraceae       | 11.5            | 12.7            | 14.3            | 12.8             |
| Subtotal        | 49              | 47.2            | 66              | 54.1             |
| Remaining families | 51              | 52.8            | 34              | 45.9             |
| Total           | 100             | 100             | 100             | 100              |

Significant correlations were not observed for the most species among the growth and dynamics with temperature, relative humidity and precipitation. However, Araucaria angustifolia indicated a strong negative correlation ($\rho = -0.73$) when evaluated its diameter increment with precipitation, interpreted as a greater diameter growth of this species in the years which occurred less volume precipitation. In this sense, Zanon and Finger (2010) evaluated the lower growth of Araucaria angustifolia correspond to periods where there are lower temperatures and excess water in the soil. The same behavior was observed for the family Rutaceae, which remained negative correlation with the precipitation ($\rho = -0.68$). However, this was the only botanical family that had significant correlation between its increase and the precipitation.

Munareto (2007) investigated the influence of precipitation and average temperature in four arboreal species in southern Brazil, identifying the growth was sensitive to weather conditions. Maria (2002) evaluated the growth of 23 tropical arboreal species in the Southeast region of Brazil and found that forest growth is strongly related to precipitation and water availability. The absence of significant correlations between growth and precipitation can be

| Table 2: Species with the highest value of importance found in the National Forest of São Francisco de Paula |
|-----------------|-----------------|-----------------|------------------|
| Species         | Density (%)     | Frequency (%)   | Dominance (%)    | Importance value |
| Araucaria angustifolia | 12.27          | 8.23            | 35.95            | 18.82            |
| Blepharocalyx salicifolius | 5.24          | 5.49            | 7.62             | 6.12             |
| Ilex brevicuspis | 5.63            | 5.04            | 7.55             | 6.07             |
| Casearia decandra | 5.92            | 6.15            | 1.38             | 4.48             |
| Ilex paraguariensis | 4.53           | 4.66            | 2.3              | 3.83             |
| Cryptocarya aschersoniana | 3.42         | 3.08            | 4.77             | 3.76             |
| Sebastiania commersoniana | 4.07         | 2.84            | 3.94             | 3.62             |
| Sebastiania brasiliensis | 4.41          | 4.51            | 0.88             | 3.27             |
| Nectandra megapotamica | 2.5            | 3.1             | 2.51             | 2.70             |
| Subtotal        | 47.99           | 43.1            | 66.9             | 52.67            |
| Remaining species | 52.09          | 56.9            | 33.1             | 47.33            |
| Total           | 100             | 100             | 100              | 100              |

Fig. 1: precipitation values observed and average precipitation in the period of 2000 to 2009.
explained in part due the low precipitation in the period, compared to annual precipitation that were 2.162 mm (Maluf, 1999), that may have limited the arboreal development (Figure 1). On the other hand, the lower precipitation period was not sufficient for changing the dynamics of the species, whereas the recruitment and mortality were not affected by the precipitation, although, Araucaria angustifolia and Blepharocalix salicifolius indicated moderate correlation ($\rho = 0.52$ and $\rho = 0.54$, respectively), however, the correlations were not significant ($t_{calc} = 1.60$ and $t_{tab0.05} = 1.89$).

When evaluated the precipitation with the dynamics of the forest, it was observed the periods with higher mortality coincided with periods of low precipitation, however, the recruitments did not indicate a tendency of increase or decrease with the precipitation, which can be explained due to lack of uniformity in the annual precipitation distribution observed. As example, the precipitation in the month of October 2005 was 278 mm, for the same month in 2006 this value was 52 mm. The period related to the end of the second semester of 2005, in which was resumed the rainy season, the precipitation was considered near to the normal value into the local, which may have favored the resumption of forest growth, that is responsible by the recruiting. On the other hand, the lowest precipitation between the years 2003 and 2004 resulted in a reduction of physiological activities, generating a state of stagnation of forest growth. Therefore, this unfavorable period for the growth is slightly interrupted by the increased of the precipitation in 2005, making a rapid growth and favoring a large number of recruitments in 2005 and 2006, which do not coincide with years where occurred greater precipitation, thus, not characterizing a significant correlation.

Considering the dynamics of botanical families with precipitation, from the 43 families evaluated, only four showed significant correlations with precipitation and they were Anacardiaceae ($\rho = 0.67$), Primulaceae ($\rho = 0.65$), Solanaceae ($\rho = 0.58$) and Celastraceae ($\rho = 0.77$). The first three families have in common the characteristic of being composed by species belonging to pioneering ecological groups, represented by Lithraea, Myrsine and Solanum genera, respectively. From these results, it is possible to infer the pioneer families have a more responsiveness to precipitation conditions (recruitment and mortality), whereas the number of individuals of these families increased with increasing precipitation and, in turn, reduced during periods of lower precipitation.

The Celastraceae family was represented by Maytenus eumymoides Reissek specie, considered as a climax specie tolerant to shade. The strong correlation between dynamics and precipitation suggests that have a strong dependence of the individuals belonging to this specie with the precipitation, which could be attributed to the high specificity of a climax group.

Besides the precipitation, significant correlations were obtained between dynamic and average temperature for Annonaceae ($\rho = 0.69$), Cunoniaceae ($\rho = 0.68$) and Verbenaceae ($\rho = 0.66$) families. The correlations occurred in the same direction, therefore, these families had higher number of individuals in years with higher average temperature and a smaller number of individuals in years with lower temperature.

Regarding to the relative humidity, significant correlations were observed with growth for Apocynaceae ($\rho = 0.59$), Cardiopiteridaceae ($\rho = -0.68$), Podocarpaceae ($\rho = -0.68$), Rubiaceae ($\rho = 0.73$) and Verbenaceae ($\rho = -0.60$) families. These correlations indicate different directions, where the Apocynaceae and Rubiaceae families showed greater growth in years with high relative humidity. On the other hand, the Cardiopiteridaceae, Podocarpaceae and Verbenaceae families show lower growth in years that occurred higher relative humidity in the forest.

Conclusions:
- Most of the species did not maintain significant correlations with climate variables. However, Araucaria angustifolia reported higher growth in the years with less precipitation. The same behavior was observed for the Rutaceae family;
- A tendency of precipitation values with the dynamics of the forest were observed, but was not obtained significant correlations, which can be attributed to irregular distribution of precipitation;
- Four families that have pioneering and climaxes characteristics indicated significant correlations between dynamic and precipitation;
- The significant correlations between average temperature and dynamic occurred in three families, indicating the number of individuals increases in years that occurred higher temperatures;
- Three families showed correlation between growth and relative humidity, but trend of increase or decrease between the pairs were not observed.

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