THE INFLUENCE OF *ARAUCARIA ANGUSTIFOLIA* ON FOREST EXPANSION OVER GRASSLANDS IN SOUTH BRAZIL

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INTRODUCTION

Natural forest expansion is an ecological process that has been observed at a global scale over several types of open vegetation, from deforested areas and old fields to savannas and grasslands. Land - use history and distance from seed source are factors that influence the spatial distribution of organisms defining different patterns of expansion. However, anthropogenic disturbance such as cattle grazing and fire can act in controlling this process (Pillar 2003). Open fields excluded from this kind of disturbance usually presents two patterns of forest expansion: gradually, from forest edge (Oliveira & pillar 2004), and through isolated establishment of woody species in open areas (Duarte *et al.*, 2006).

In South Brazilian highlands, vegetation is a mosaic consisted by grasslands (*Campos*) and forest (knows as *Araucaria* forest), with a distinguished contact zone between this two vegetation types (Rambo 1956). Paleo - palinological evidences indicate that grasslands were the predominant vegetation and just 3000 years ago *Araucaria* forest has been expanding over *Campos* grassland, mainly due to a more humid and dry climate (Behling *et al.*, 2004). In this context, *Araucaria angustifolia* (Bertol.) O. Kuntze is the dominant species in this forest formation and is frequently found colonizing *Campos* grassland. Also, it has been considered a pioneer species (Reitz & Klein 1978) and the major nurse species (Duarte *et al.*, 2006) of the expansion process.

Moreover, *A. angustifolia* is a zoochorical species and colonization process over *Campos* grassland depends on how seed dispersers will explore the environment, determining seeds' deposition sites and distance from forest edge where seeds are provided. Thus, variations in herbaceous' communities structure during succession process (e.g. increasing of herbaceous and woody biomass) must change the way seed dispersers explore grasslands, and therefore seed dispersal patterns of *A. angustifolia*. Other relevant characteristic is the formation of tree annual rings from seasonal climate variations. Tree rings in *A. angustifolia* annually shows a period of cambial activity followed by a dormancy period, influenced mainly by temperature patterns in South Brazil (Oliveira 2009). In this study, dendrochronology is used as an instrument that helps to describe the colonization patterns of *A. angustifolia* over *Campos* grassland.

OBJECTIVES

Thus, the objectives of this paper are (1) link *A. angustifolia's* age structure to distance from forest edge, and (2) evaluate the role of this species on the diversity of other woody species, relating this diversity to the age of *A. angustifolia's* individuals.

MATERIAL AND METHODS

Study site

The study was conducted at 28º13'S, 51º10'W in Aracuri Ecological Station (A. E. E.), located in Muitos Capões, Rio Grande do Sul State, southern Brazil. Waechter *et al.*, (1984) identified four vegetation types in A. E. E.: wetland, grassland, "vassoural" (grassland with tall herbaceous's layer and shrubland) and *Araucaria* forest. Our study was restricted to grasslands and vassoural types. Although A. E. E. was created in 1981, the area had been release from human disturbance (grazing and fire) since 1974 (P. L. de Oliveira, per. com.). A 1965's aerial photography (before disturbance exclusion) indicates that the area was characterized by *Araucaria* forest patches (capões) surrounded by *Campos* grassland, which were sustained mainly by grazing. Hence, the two vegetation types considered in this study were probably *Campos* grassland before disturbance exclusion.

Sampling methods

We used the A. E. E. vegetation map (Cestaro 1986) to locate systematically 150 sampling points over grassland and vassoural areas, 100m distant from each other. From those 150 points we randomly sampled 10 points considering each of the following distance classes from forest edge: 0 to 100m; 101 to 200m; 201 to 300m; 301 to 400m; 401 to 500m; and

up to 501m. In each point, we randomly sampled in two directions, and in each one we choose the *Araucaria* tree closer to the point but with a diameter breast height (DBH) equal to or bigger than 10cm. If there was no tree in such direction, another one was randomly sampled again. Then, we fixed two circular plots (3m radius): one under *A. angustifolia's* crown, taking into account tree stem as the plot center; and another one outside *A. angustifolia's* crown but next to it. Plots were consider as a block and the outside one was used as a control, just to evaluate *A. angustifolia's* role as a natural perch.

Vegetation sampling considered all woody individuals above 1m height. All species were sampled, including shrubs and forest species, and all of them were classified into species level following APG II (2003). They had their diameter soil height (DSH) measured. The species were also grouped considering their habitat: exclusive forest species, transition species (those which appears in *Araucaria* forest or in *Campos* grassland, and even in forest edge) and exclusive grassland species. Later, we classified species' dispersal syndrome in: zoochoric, anemochoric and autochoric. To analyze it, we grouped these last two categories in only one: non - zoochoric.

Individuals of *A. angustifolia* considered in vegetation sampling were also used in dendrochronological evaluations. The cores were fixed on woody supports, air - dried and mechanically polished with sandpaper. The growth rings were inspected with a stereomicroscope and dated according to the methods described in Stokes & Smiley (1968).

Data analysis

Each tree was considered as a sampling unit described by its age and its forest edge distance. The relationship between these variables was evaluated through linear regression; the age as the response variable and forest edge distance as the independent factor. Regression model's significance was tested in MULTIV (Pillar 2008).

To examine if there was any difference in diversity and abundance between communities under and next to *A. angustifolia's* crown, we used ANOVA with randomization tests (Pillar & Orlóci 1996). Permutations were restricted to plots considering vegetation sampling in blocks, just to remove variations related to non - controlled factors, such as soil and distance from forest edge. Plots were compared by Shannon's Diversity index (H') and it was calculated to three species' groups: those with only zoochoric dispersal syndrome (H'z), those with non - zoochoric dispersal syndrome (H'nz) and the entire species sampled (H'e).

We also applied linear regression models with randomization tests (Manly 1991) to evaluate how difference in diversity between communities under and next to *A. angustifolia's* crown vary according to forest edge distance and to *A. angustifolia's* age. For these analysis we considered as response variables the species' diversity differences (H') in each block, which means that for each pair we used: $H'_{Araucaria}$-$H'_{Control}$; and as independent variables we considered five data groups, each one tested separately (DIS+AGE_r+INT; DIS+AGE_r; AGE_r; AGE e DIS), where DIS=forest edge distance; AGE=age, AGE_r=residual age and INT=interaction between two factors. Analyses were distinct to three species' group (H'_z, H'_{nz} and H'_e).

RESULTS AND DISCUSSION

Age structure x distance from forest edge

The result shows apparently two age cohorts of *A. angustifolia*: one with individuals established before and other established after disturbance exclusion in 1974. Trees established before it (34 years or more; N=12) were found until 150 m from forest edge while those individuals established after disturbance exclusion (34 year or less; N=97) reached 900 m. Linear regression model adjusted for trees established after disturbance exclusion clearly shows an exponential decline in the age of *A. angustifolia* by increasing forest edge distance. This model explains 58% of age data variation (p=0.001). Moreover, age range declines with increasing forest edge distance, varying from 10 to 30 years at 100m, and from 7 to 10 years in 600m.

Disturbances can influence the colonization dynamics of *A. angustifolia's* in two aspects: seed dispersion and seedling survival. Considering seed dispersion, managed grasslands can act as a selective barrier for transient animals that come from forest and use these boundary areas (Pedó 2005), restricting seed dispersion to areas close to forest edge. Considering seedling survival, seedlings as well as *A. angustifolia's* fruits (locally known as "pinhões") can be consumed and trampled by cattle, and may not survive to fire effects. This could explain the small number of individuals older than 34 years 150 m far from forest edge. In grasslands where cattle grazing is the traditional form of land - use, the survival of isolated individuals of *A. angustifolia* could be related to protected sites like those under rocks or fallen branches (Ferreira & Irgang 1979; Pillar 2003), or to less frequent burns, which would allow plants to growth enough to resist fire (Soares 1990). Thus, a small number of seedlings of *A. angustifolia* established after disturbance exclusion means a reduction of nucleation process, and these conditions should delay forest expansion. Considering the youngest age cohort, individuals established until 900m from forest edge have less than 34 years. This fact shows the important role of seed dispersers in the expansion process of *A. angustifolia* forest. Moreover, disturbance exclusion allowed an increase in the ongoing forest expansion from the edge.

Perch effect

We found differences between woody plant communities established under and next to *A. angustifolia's* crown, considering total abundance of individuals (p=0.0121) and Shannon's Diversity index, and considering H'_z and H'_e. However, there was no difference between plots considering only H'_{nz}. Then, we compared H' for non - zoochoric exclusive forest species and for non - zoochoric transition species and the results showed marginal differences between plots under and next to *A. angustifolia's* crown, considering only *Campos* grassland's species (p=0.0673). However, non - zoochoric transition species did not show difference between plots under and next to *A. angustifolia's* crown (p=0.4985). Statistical analyses did not allow comparisons with non - zoochoric species from exclusive forest habitat once there was no species in this category.

Linear regression models using the difference between communities under the crown influence and next to *A. angustifolia* presented a linear and positive relationship with dis-

tance from forest edge, regarding only H'$_z$ (r^2= 0.1053, p= 0.0309) and H'$_e$ (r^2= 0.122, p= 0.0192). However, regression model considering the age of *A. angustifolia* individuals didn't show significant relationship (r^2=0.0097; p=0.5079), considering the H'$_e$ and dispersal syndromes separately (H'$_z$ and H'$_{nz}$). The model that used "residual age" as an independent factor didn't explain the differences in diversity, although the model that considered IDA+IDA$_r$ showed significant results. Therefore we chose the model that considered only DIS as the independent factor.

There was higher diversity of zoochoric species under *A. angustifolia's* crown than next to it. Moreover, this effect disappears regarding only non - zoochoric species. These results suggest a "perch effect" (Pausas *et al.*, 2006) because if there were a "nurse effect", then the differences in diversity would have been observed for non - zoochoric species too. Our results also indicate that forest expansion was facilitated by the establishment of pioneer individuals of *A. angustifolia* from forest edge over *Campos* grassland. Other results showed that this species act as a seed dispersal facilitator to zoochoric species (perch effect). Nurse effect wasn't clearly observed by our data.

CONCLUSION

Araucaria angustifolia establishes in *Campos* grasslands that have been excluded from disturbance, and can reach 900m from forest edge in less than 34 years. The age of its individuals individual decreased as the distance from forest edge increased. The results indicate that disturbance exclusion (such as cattle and fire) and seed dispersers' activities are the most important factors for the establishment of *A. angustifolia* over *Campos* grassland. The species also acts as a perch, which facilitates seed dispersion of woody and zoochoric species. Shannon's Diversity Index showed a higher diversity, based on individual's abundance, for zoochoric species. We observed a linear positive relationship between forest edge and differences in community diversity for both groups. In summary, *A. angustifolia* seems to facilitate dispersal process (and not to restrict establishment) for zoochoric woody species under its crown; accelerates and conducts the forest expansion over *Campos* grassland in South Brazil.

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