Cattle influence on the population structure of yerba mate (*Ilex paraguariensis*) in Araucaria Forest

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ABSTRACT: *This study characterized the demography and spatial pattern of a yerba mate (Ilex paraguariensis A.St.-Hil) population covering areas with different use histories (Presence and Absence of Cattle) in a Araucaria Forest. Data collection was performed in three ha, half in each area. The frequency of individuals by height, spatial distribution pattern, diameter distribution (for reproductive individuals) and sexual ratio were evaluated. An inverted "J" pattern predominated, being exclusive to an area with Cattle Presence, a place which presented a lower density of individuals. The predominant spatial distribution pattern was aggregated, and the reproductive individuals have a preferentially random pattern at the shortest distances. Results indicated that cattle presence changes the density of I. paraguariensis individuals and the proportion of individuals in the evaluated demographic classes.*

Key words: *spatial distribution, demographic dynamics, Ripley's K-function.*

Influência do gado na estrutura populacional de erva-mate (*Ilex paraguariensis*) em Floresta com Araucárias

RESUMO: *Foi caracterizada a demografia e o padrão espacial de uma população de erva-mate (Ilex paraguariensis A.St.-Hil) abrangendo áreas em diferentes históricos de uso (presença e ausência de gado), em Floresta com Araucárias. A coleta de dados foi realizada em três ha, metade em cada área. Foi avaliada a frequência de indivíduos por classe de altura, padrão de distribuição espacial, distribuição diamétrica (para indivíduos reprodutivos) e razão sexual. O padrão "J" invertido foi predominante, sendo exclusivo para área com presença de gado, local que apresentou uma menor densidade de indivíduos. O padrão de distribuição espacial predominante foi o agregado, sendo que os indivíduos reprodutivos possuem preferencialmente padrão aleatório nas menores distâncias. Os resultados indicam que a presença do gado altera a densidade de I. paraguariensis e a proporção de indivíduos nas classes demográficas avaliadas.*

Palavras-chave: *distribuição espacial, dinâmica demográfica, função K de Ripley.*

INTRODUCTION

Ilex paraguariensis A.St.-Hil (yerba mate) is the most relevant species of its kind from an economic perspective, and it presents a high sociocultural importance for the southern region of Brazil (REIS et al., 2018). It is well known and exploited for its stimulant drink and also for formulating drugs and cosmetics. It is a dioecious species native to South America, which mainly colonizes the understory of the Araucaria Forest (AF), a formation belonging to the Atlantic Forest (CABRAL et al., 2018). Its phytophysiognomy has been fragmented and altered by logging and non-

timbering operations conducted without ecological criteria or usage management, with only 12.6% of its original coverage remaining (RIBEIRO et al., 2009; VIBRANS et al., 2011).

Leaves and branches of *I. paraguariensis* in the Atlantic Forest constitute an important Non-Wood Forest Product (NWFP) from forest extraction (REIS et al., 2018). High exploitation rates occurring in natural areas due to economic instability have caused a significant decline in its populations (SMALL & CATLING, 2011).

Although, the scientific literature addresses the ecological behavior of the species, few publications describe the demography in natural environments (i.e. CANALEZ et al., 2006; MATTOS,

2015). Understanding demographic aspects such as height and diameter distribution, density, mortality, recruitment of individuals, the number of reproductive indices and their life cycle (e.g. longevity) can help provide more knowledge on its dynamics in natural populations which are considered basic premises to develop management and conservation strategies (REIS et al., 2018; MONTAGNA et al., 2018). Studies indicated that dispersal and recruitment may be considered determinant for the spatial pattern of plants. In addition, the habitat heterogeneity and other ecological interactions influence the generation of structural and spatial patterns (LARA-ROMERO et al., 2016).

We can highlight intrinsic issues, disturbances and anthropic pressures such as Forest Tropical fragmentation which alter biotic and abiotic environmental factors and thereby influence the population structure and dynamics (RIBEIRO et al., 2009; AVILA et al., 2016). Among anthropogenic actions in forest ecosystems, the impact of extensive cattle (herbivory and trampling) can damage natural regeneration, germination, seedling density, and genetic drift in the long term (ZAMORANO-ELGUETA et al., 2012). Extensive livestock farming occurs within approximately 50% of AF fragments in the state of Santa Catarina (VIBRANS et al., 2011).

Extensive cattle can be considered a chronic anthropic disorder in the Planalto Serrano Catarinense (PSC), with the potential to delay forest succession process and cause floristic homogenization in the tree community (DALLABRIDA et al., 2017). In order to increase knowledge about *I. paraguariensis* ecology and conservation, we aimed to evaluate the demography and the spatial pattern of a population in AF areas in order to answer the following question: does the presence of cattle influence the populational structure of *I. paraguariensis*?

MATERIALS AND METHODS

The study area is located in the AF in the municipality of Urupema, Santa Catarina state, with the approximate elevation of 1350 ma.s.l. The climate of the region is classified as Cfb and contains Dystrophic Litholic Neosol and humic Alic Cambisol soils (EMBRAPA, 2013). The *I. paraguariensis* population has different usage histories: a) Cattle Presence – forest with influence of cattle, about 6 individuals.ha^{-1}, in which we considered that other anthropogenic activities (logging and NWFP uses) occurred in the last decades; however, in a less expressive way, and were not observed at the time of data collection (27º50'20''S and

55º27'22''W); b) Absence of Cattle – forest preserved without anthropic alterations in the last ten years, including the prohibition of NWFP use, inserted in the *RPPNE Complexo Serra da Farofa* (27º54'41''S and 49º52'59''W). The sampled areas have similar abiotic aspects (geological unit, topographic conditions, solar exposition) and floristic arboreal vegetation. In surveys conducted by MARTINS-RAMOS et al. (2011) and GOMES et al. (2017), the main tree species sampled in region were *Myrceugenia euosma* (O. Berg) D. Legrand, *Siphoneugenareitzii* D. Legrand, *Drimys angustifolia* Miers, *Persea willldenovii* Kosterm., *Myrceugenia oxysepala* (Burret) D. Legrand and Kausel, *Myrceugenia myrcioides* (Cambess.) O. Berg, *Cinnamomum amoenum* (Nees) Kosterm., *Ocotea pulchella* (Nees and Mart.) Mez, and the *Dicksonia sellowiana* Hook.

Six plots (50 x 100 m) were installed, half in each area, totaling three hectares in the sample area. All *I. paraguariensis* individuals were measured for total height (H), and those with height ≥ 1.30 m were measured for diameter at breast height (DBH). Two evaluations were performed in the Absence of Cattle with a one-year dynamic interval 2011-2012, where individuals with H less than three meters were measured again. In this same area, sexing of the individuals was performed according to the reproductive structure of the female (F) and male (M) individuals.

Four classes for the description of the demographic structure were defined based on the height of all individuals: class I (plants with H≤1.3 m), class II (plants with H>1.3 m and <3.0 m), class III (plants with H≥3.0 m and <5 m) and class IV (plants with H≥5.0 m). The reproductive (M and F) subjects for the Absence of Cattle were distributed into new classes according to the DBH, where the frequencies were calculated by the Sturges formula.

From the spatial position of each individual (Cartesian coordinates x and y in meters), the spatial distribution pattern was estimated by Ripley's Univariate K-function and included edge-corrections proposed by Ripley (DIGGLE, 2013). To do so, the radius (h) of one meter was used to estimate k (h) with a maximum distance of 25 m, which corresponds to the half of the smaller side of each plot, and we posteriorly applied the square root transformation (L - estimated) as it is more appropriate for use in simulation envelopes, while deviation from the Complete Spatial Randomness (CSR) was tested by means of the confidence interval (95%) obtained from 999 Monte Carlo simulations. The analyzes were implemented by the "Splancs" package (ROWLINGSON & DIGGLE, 1993) in R

language version 3.2.2 (R DEVELOPMENT CORE TEAM, 2018).

The H and DBH averages were compared between the F and M individuals by the unpaired t-test, and sex ratio were verified by the chi-squared test (χ^2). Differences in the proportion of individuals sampled between areas in the same H class were investigated by the proportions test. The distribution behavior of individuals in the H classes was verified by the Kolmogorov-Smirnov (K-S) test. These analyzes were performed using the R program version 3.2.2 (R DEVELOPMENT CORE TEAM, 2018).

RESULTS

Population structure

The number of individuals per height class and the mean density per area sampled for *I. paraguariensis* (Figure 1a) were measured.

Significant differences were observed by the K-S test (P=0.107) for the number of individuals among the H classes considering the evaluated areas. Thus, there is a difference in the distribution pattern of individuals in the classes for the two evaluated sites.

Figure 1c and 1d show results of frequency distributions of the six evaluated plots. An asymmetric curve can be observed to the right in the form of an inverted "J" for the Absence of Cattle in all the plots considering the adopted classes, which means that a marked decrease of individuals occurs as there is an increase in the H classes, and the same pattern was observed in plot 2 for the Absence of Cattle.

Structure of reproductive and dynamic individuals (Absence of cattle)

Results from monitoring the reproductive stage of the individuals in the Absence of Cattle enabled detection of 2.78% of the individuals at the
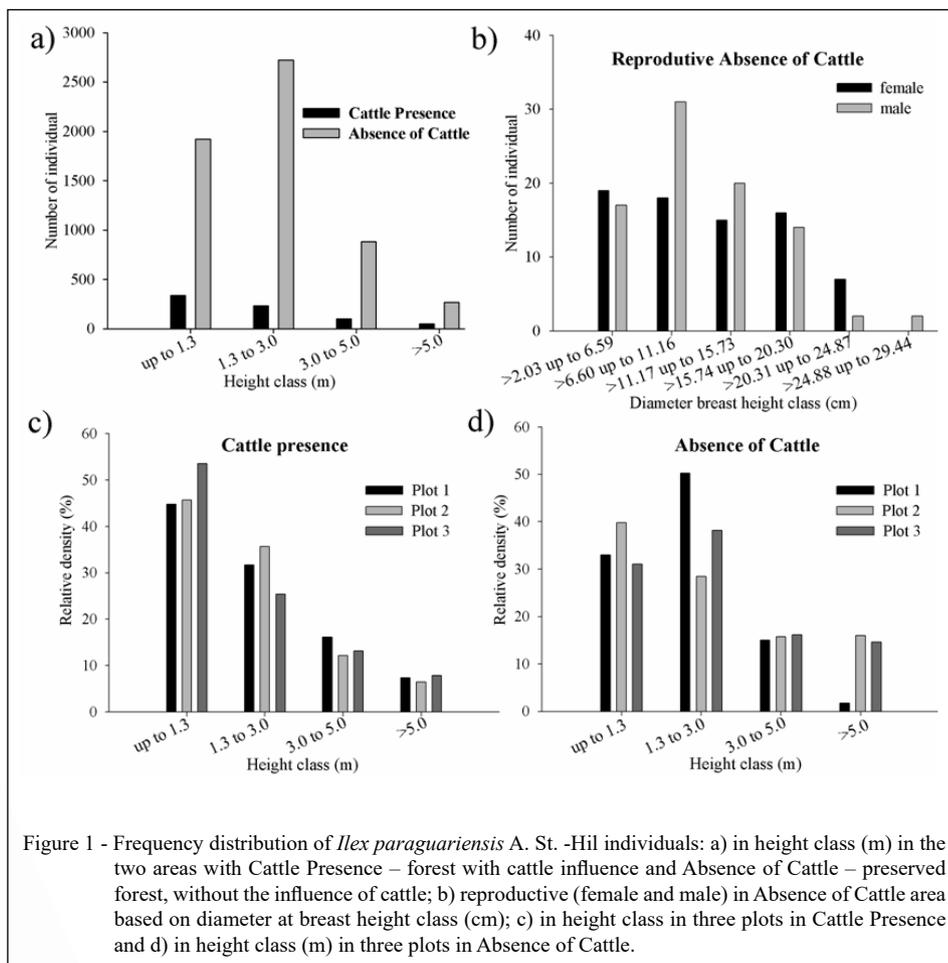

Figure 1 - Frequency distribution of *Ilex paraguariensis* A. St. -Hil individuals: a) in height class (m) in the two areas with Cattle Presence – forest with cattle influence and Absence of Cattle – preserved forest, without the influence of cattle; b) reproductive (female and male) in Absence of Cattle area based on diameter at breast height class (cm); c) in height class in three plots in Cattle Presence and d) in height class (m) in three plots in Absence of Cattle.

reproductive stage. Considering the H classes, a higher proportion of reproductive individuals occurred in class IV, representing 43.07% of the class (115 individuals), followed by class III where the reproductive ones represented 4.65% (41 individuals), and class II with only five individuals, representing 0.18% of the class.

Greater participation of male individuals was observed in the distribution of the reproductive individuals in their respective diametric classes (Figure 1b) in the class > 6.60 up to 11.16 cm (F=18; M=31; χ^2=7.04; P<0.05), and greater participation of female individuals in the class >20.30 up to 24.87 cm (F=7; M=2; χ^2=30.86; P<0.05).

The mean diameter did not differ statistically between males and females (DBH_F=11.68 cm, n=42; DBH_M=11.47 cm, n=44; t=0.83; P>0.05), while this also occurred for height (H_F= 6.51m, n =75; H_M=6.08 m, n=86; t=0.25; P>0.05). The sex ratio was 1.15, with no significant difference in the expected ratio of 1:1 between males and females in general (86:75, χ^2=0.47;P>0.05), and for plots where the following ratios were observed: in plot 1 (F=20; M=29), plot 2 (F=13;M=12) and plot 3 (F=42;M=45).

When considering the evaluation of the dynamics performed in the Absence of Cattle, a total of 56 individuals entering the population were registered, representing less than 1% in the previous year's evaluation. A mortality rate of 232 individuals (4% of individuals) was recorded. Of the 232 dead individuals, 175 belonged to class I, and the rest of the individuals belonged to class II. The population from one year to the other generally presented a deficit of 176 individuals.

Spatial pattern

An analysis of the spatial pattern performed for the six plots showed similar behavior in both plots (Figure 2), with an aggregated pattern best describing the population in a full 25-meter scale. A random distribution pattern was predominant in the shortest distances for the reproductive individuals in the Absence of Cattle.

DISCUSSION

Population structure

Areas under different usage histories tend to vary in the density of individuals according to the intervention intensity as a reflection of the anthropic changes generated to the environment. There was a lower density of *I. paraguariensis* individuals in this study in the area with Cattle Presence (481 ind. ha^{-1}) compared to the area without cattle (3863 ind. ha^{-1}). In

the same way, lower *I. paraguariensis* densities were observed by MATTOS (2015) for the Planalto Norte Catarinense (PNC) region in environments with cattle presence. In addition to this study, there is exploitation and management of *I. paraguariensis* populations in most of the AF fragments which contain them in their composition, occurring simultaneously with historical and recent evidence of wood use and presence of extensive cattle (VIBRANS et al., 2011).Thus, the impact caused by cattle trampling is evident, which generates modifications in the structure (density) of *I. paraguariensis*. This statement was reinforced by our sampling carried out in nearby areas which have similar characteristics, with common arboreal species communities and similar usage history, except for current use with Cattle Presence.

According to the K-S test, the representation of the individuals considering the evaluated demographic classes presented differentiated behavior between areas. The population presents a greater number of individuals in the initial phase of the life cycle for cattle presence (Figure 1c), having an inverted "J" structure pattern. In the Absence of Cattle, a different population structure was observed than in Cattle Presence (Figure 1d), indicating a possible "disequilibrium" in the population structure when compared to the inverted "J" pattern for plots 1 and 3, which presented a larger number of individuals in class II. This finding may be related to the Absence of Cattle history, where the forest was isolated from anthropic alteration sources ten years ago, aiming the conservation of nature and instituted as a conservation unit. In this case, the succession of the environment may have favored germination of the soil seed bank. *I. paraguariensis* seeds are dormant due to embryo immaturity (DICKEL et al., 2011) and can remain waiting for complete development and favorable germination conditions for long periods. Thus, more favorable periods (i.e. opening of gaps) may have benefited entry and/or maintenance of the individuals in class II. Conversely, this favoring may be related to the elimination of possible causes of anthropogenic degradation (logging and non-timber harvesting, burning, domestic animals, etc.) which negatively influence species development, affect the presence of dispersing agents, seasonality and propagule production. In a study that was developed in different landscape units of *I. paraguariensis* y*erba management and cattle grazing*, y*erba management and no cattle grazing* and *no management*, REIS et al. (2018) observed demographic peculiarities between and within the evaluated landscape in the PNC. It is also worth mentioning that microhabitat
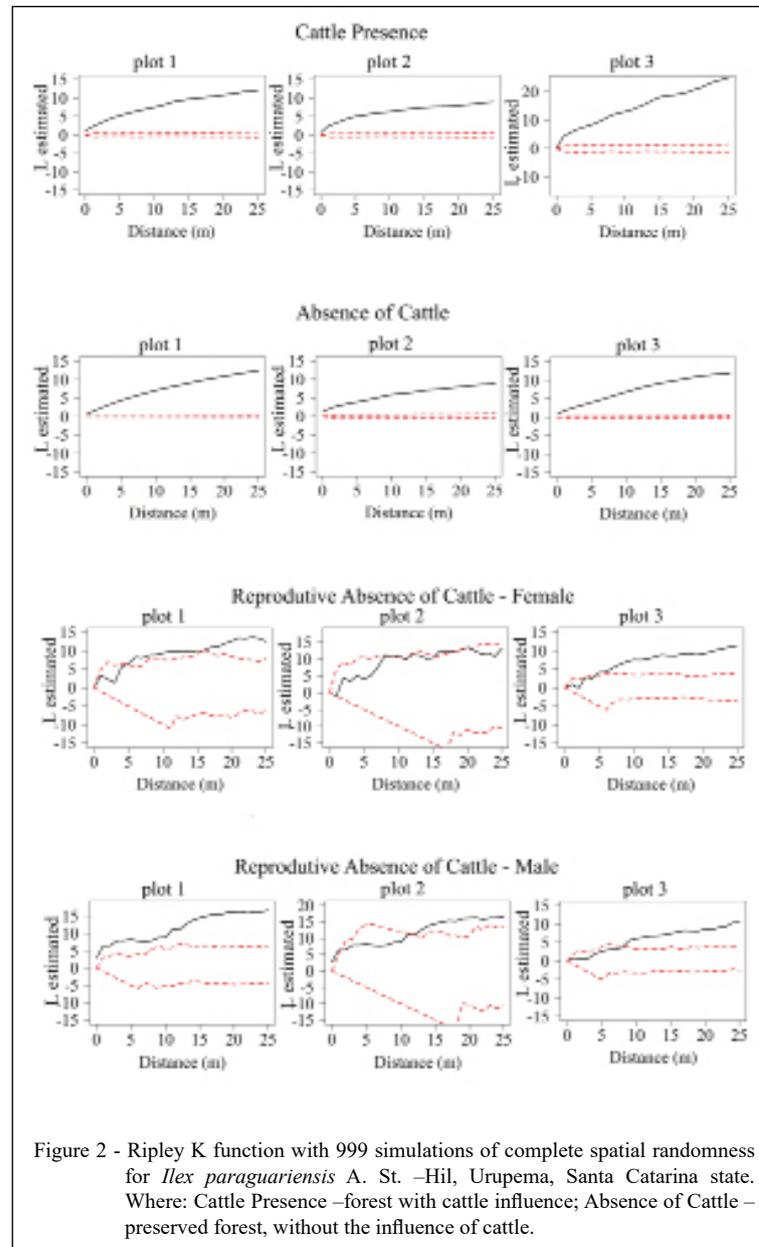
Figure 2 - Ripley K function with 999 simulations of complete spatial randomness for *Ilex paraguariensis* A. St. –Hil, Urupema, Santa Catarina state. Where: Cattle Presence –forest with cattle influence; Absence of Cattle – preserved forest, without the influence of cattle.

characteristics can influence the development of individuals that make up a population (RODE et al., 2010), and according to AVILA et al. (2016), *I. paraguariensis* can present a differentiated population structure within the same environment, as well as in the different sampled areas.

The proportions of individuals in class I, class II and class IV differed among sites according to the proportions test (P<0.01), emphasizing the differences in the population structure in the Presence and Absence of Cattle. These differences may have originated due to several factors such as microclimatic, edaphic conditions, interspecific competition, herbivory, presence of dispersers, or others such as the presence of cattle as investigated in this study. According to DALLABRIDA et al. (2017), cattle presence can be considered a chronic anthropic disturbance for the PSC region, with the potential to delay the process of forest succession, influencing the composition and modifications that occur in the tree communities. The presence of cattle negatively acts on population dynamics due to their herbivorous

habits, trampling and openings tracks which damage the natural regeneration of the forest (ZAMORANO-ELGUETA et al., 2012; MATTOS, 2015).

Structure of reproductive individuals and dynamics (Absence of cattle)

Regardless of sex, the reproductive individuals are mainly distributed in 20.30 cm of diameter (Figure 1b). Differently from expected, there was a greater participation of male individuals in the class>6.60 up to 11.16 cm and greater participation of female subjects in the class >20.31 up to 24.87 cm, which means there is a greater proportion of female individuals in the largest diameters. Female individuals of woody dioecious species usually proportionally allocate more resources for reproduction and defense, and less for maintaining higher growth rates (BARRETT & HOUGH, 2012). It is evident that female *I. paraguariensis* trees produce more biomass, and this species possibly presents a different pattern than most woody species (STURION et al.,1995).

When evaluating the dynamics in the Absence of Cattle, the mortality rate was 4.0% and the majority of the individuals sampled belonged to class I. For CUBAS et al. (2016), *I. paraguariensis* was the species that presented the highest mortality in the dynamics of a AF, with a mortality rate of 4.20% (above 10 cm of DBH), but maintained the same position of importance in the forest for five consecutive years with an annual ingrowth introductory rate of 1.86%. According to AVILA et al. (2016), *I. paraguariensis* has the potential to remain in the environment for a long time, being present in all forest regeneration mechanisms (seed rain, soil seed bank, seedling bank, natural regeneration and arboreal size), and presents population balance in more conservative environments.

Spatial pattern

Spatial distribution pattern assists in obtaining NWFP in an extractive way, aiming the conservation and use of the species, and facilitating management by aggregating individuals. This same pattern was described in Paraná by RODE et al. (2010), in which spatial aggregation occurs in a distance range of 2 to 38 m by Ripley's Univariate K-function, and CSR is accepted outside this range. CANALEZ et al. (2006) also reported the same aggregation pattern for *I. paraguariensis* in AF in Paraná based on the Morisita Index. The spatial pattern of I. paraguariensis is possibly directly related to the associated pollination and dispersal syndrome. Its seeds are pollinated and dispersed by animals (PIRES et al., 2014), common sense the formation of "seed shadows", which means

the agent dispersers the propagules and end up eliminating them next to the mother plant.

The aggregated distribution pattern detected in *I. paraguariensis* can also be considered predominant for tropical trees (RÉJOU-MÉCHAIN et al., 2011). This result comes from two factors, namely the short-dispersal and habitat heterogeneity (LARA-ROMERO et al., 2016).

CONCLUSION

The presence of cattle changes some demographic characteristics of *Ilex paraguariensis*, being one of the main factors in reducing the density of individuals and modifies the distribution pattern of the individuals in the height classes. *I. paraguariensis* has a population structure with a predominance of the inverted "J" pattern, which was predominant in the cattle presence areas. The predominant spatial distribution pattern for the species was aggregated, except for the reproductive individuals which have a random pattern at the shortest distances.

DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interests. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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