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Population Dynamics of *Croton blanchetianus* Baill. in a Caatinga Area in the Brazilian Semi-Arid

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Abstract

The vegetation of the Caatinga, present in the dry areas of the Brazilian Semi-arid region has been little studied, when it relates to population dynamics of their species. The objective of this study was to evaluate the mortality and recruitment rates of a *Croton blanchetianus* Baill. population in a two-year interval (January/2013 to January/2015), in area of caatinga in the semi-arid Paraiba. Monitoring of structural changes in the vegetation was carried out in 96 10 × 10 m contiguous plots. The phytosociological survey conducted in January 2013 sampled 1078 individuals of *C. blanchetianus*, occurring in the 96 plots studied. The years of 2012 and 2013 had rainfall below the annual average. Take into consideration the evaluation period; there was a high mortality rate (M = 47.33% $year^{-1}$) and a low recruitment rate (R = 0.18% $year^{-1}$) for the population of *C. blanchetianus*. The real gain (RG) of the population was significantly negative (−93.91% $year^{-1}$) since the number of dead individuals was much higher than the recruited ones in the population. The highest height class, composed of individuals of 4.1 to 5.0 m height, was the most tolerant to water scarcity, resulting in 53.85% of surviving individuals. Therefore, the results demonstrated that periodic droughts compromise the recruitment, development, survival, and establishment of individuals in natural systems in the Brazilian semi-arid region.

Keywords

Marmeleiro, Populational Structure, Ecosystemic Dynamic, Seasonality, Dry Forests

1. Introduction

Caatinga is the predominant vegetation of the semi-arid region. It is potentially susceptible to climate changes, leading to intensified thermal regimes, thereby reducing water availability [1], which is considered as the climatic parameter that most influences the vegetation. The IPCC's fourth report states that the increase in the average temperature of the Earth over the last hundred years is the result of anthropic activities, mainly related to the burning of fossil fuels and tropical forests [2]. In Pernambuco, climate changes caused a rise of 4˚C in the maximum daily temperature from 1961 to 2009 and an average reduction of 275 mm in the total annual rainfall. In this state, the annual decrease in rainfall was followed by an increase in the maximum drought periods from 20 to 35 days and increase in frequency of intense precipitation events from five to nine events per year [3].

The little information on the forest dynamics in dry conditions led researchers, like [4], to state that seasonal dry forests have lower dynamic rates than rainforests. However, studies carried out in regions of dry climates have shown that, in these regions, there are also high rates of recruitment and mortality [5] [6]. In dry seasonal forests, disturbances related to sporadic precipitation change dynamic rates, especially in relation to the increase in mortality of individuals [7].

Several studies have demonstrated that, among the species of the Caatinga, *Croton blanchetianus* Baill. plays an important role in the dynamic processes in this biome. Thus, among the main results of number of individuals, the density, frequency, and importance and cover values stand out in the phytosociological parameters of adult and regenerating communities in environments at different levels of conservation [8] [9] [10] [11].

According to [12], like *Croton heliotropiifolius* Kunth, *C. blanchetianus* also has characteristics related to water economy, such as dense indument and the presence of phenolic compounds, which can be interpreted as adaptations to the Caatinga semi-arid environment. The variation in water availability (lack and excess) is a factor that causes stress to the Caatinga plants [13], so the variations in this resource is a determining factor in the dynamic processes in this region.

Studies on the vegetation dynamics of caatingaas affected by prolonged droughts are scarce. These studies are important because they allow the monitoring and forecasting of transformation processes in populations and plant communities after natural or anthropic disturbances [14] [15]. This is the first study evaluating the population dynamics of *C. blanchetianus* in an adult community with data on mortality and recruitment rates in relation precipitation variations over time.

Therefore, this study aimed to assess mortality and recruitment rates of a population of *Croton blanchetianus* Baill., in a two year interval (January/2013 to January/2015), in an area of caatinga in the semi-arid Paraiba. The findings of this study are important information for strategies of vegetation conservation in ecosystems of this environment.

2. Material and Methods

2.1. Study Area

The study was conducted in the Cariri Region, municipality of Sumé, Paraíba state (7˚39'38.8"S and 36˚53'42.4"W; 538 m of altitude). According to the [16], the current population of Sumé is estimated at 16,060 people. The land area encompasses 864 km^2, is located at an altitude of 532 m above sea level and 250 km of João Pessoa, state capital.

The climate is characterized by low rainfall and high temperatures, causing high evaporation rates. The dry season is between June and January, with an average temperature of 24˚C, and average annual insolation index of 2800 hours. The soil and subsoil have low permeability, and the predominant vegetation is a dense hyperxerophilic caatinga, of the shrub-tree type, typical of the Cariri Region [17] [18].

The study was carried out within the limits of the municipality of Sumé, comprising an area of 1.02 ha (**Figure 1**). The climate in this area is classified as BSh type and described as hot semi-arid [19], and the vegetation is characterized as caatinga. The history of use and occupation shows that the area underwent anthropic interference and was in the initial process of secondary succession, with six years of isolation for research purposes.

2.2. Data Collection and Analysis

Monitoring of structural changes in the vegetation was carried out in plots 96 contiguous of 10 × 10 m. Inclusion criteria were to sample live and dead-standing individuals with stem diameter at ground level (DGL) ≥ 3 cm and total height ≥ 1 m. Individuals were marked with numbered labels. Girths at ground level were measured with a tape and then converted into diameter. Plants with multiple trunks had every branch that met the inclusion criteria measured. The height of the individuals was determined with a 4-m measuring stick. For taller individuals, height estimates were made by comparison with the stick.

The field data were summarized in a Microsoft Excel® spread sheet 2010 to characterize the following parameters: number of individuals, basal area (BA), absolute and relative density (AD and RD), absolute and relative frequency (AF and RF) and absolute and relative dominance (ADo and RDo) [20]. From the related parameters were calculated the importance value (IV) and the cover value (CV). The analyzed parameters are described below with their respective formulas.

Basal area

$$BA = P^2 / 4\pi$$

where:

P = perimeter of the stem of an individual (cm)

Absolute density

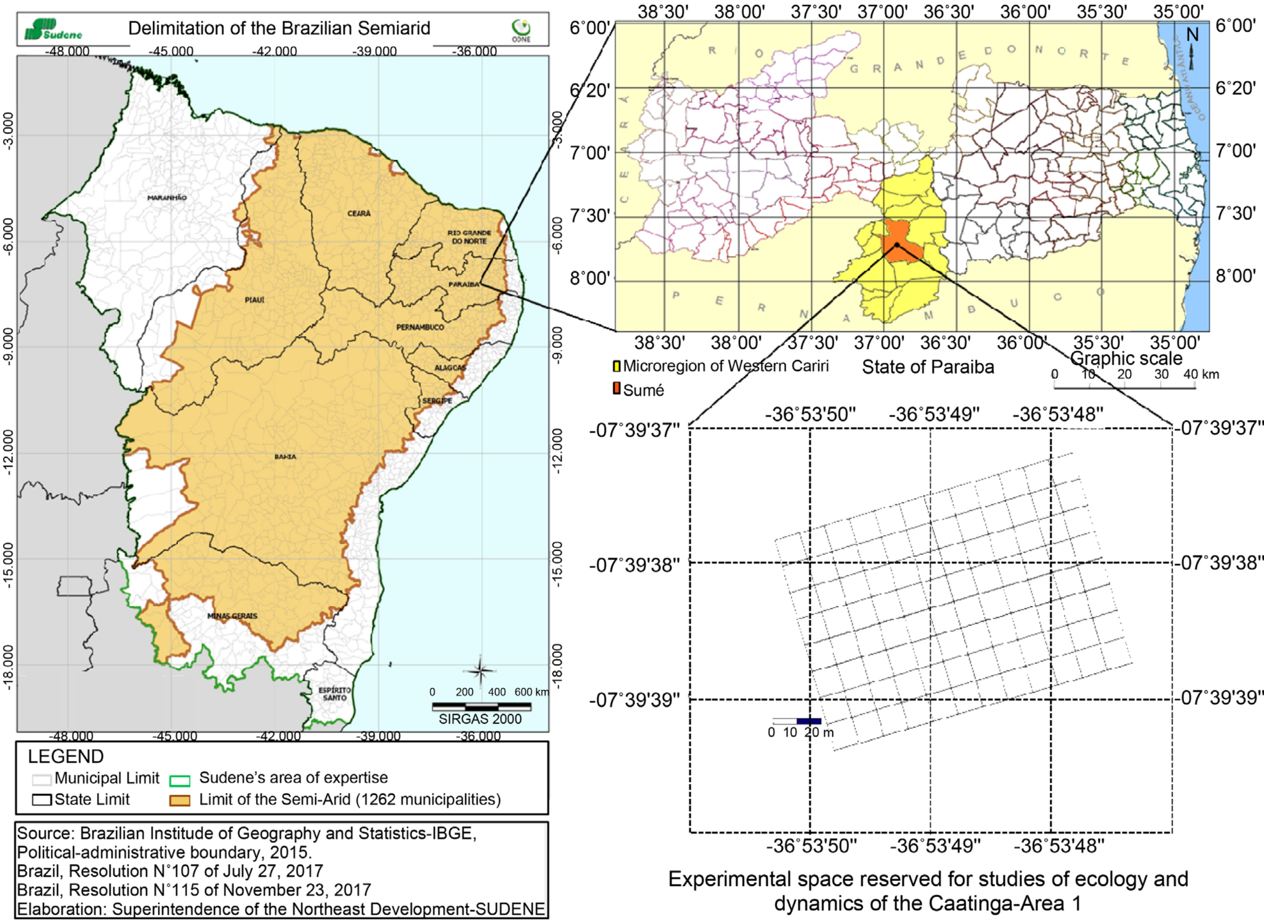


Figure 1. Picture of the plots distributed in the experimental area, in the municipality of Sumé, semi-arid region of Paraiba.

$$\text{ADi} = \text{Ni}/\text{A}$$

where:

ADi = Absolute Density of species i

Ni = number of individuals of species i

A = area sampled in hectare

Relative density

$$\text{RDi} = (\text{Ni}/\text{Nt}) \times 100$$

where:

RDi = Relative Density of species i

Ni = number of individuals sampled from species i

Nt = total number of individuals sampled from all species

Absolute Frequency

$$\text{AFi} = (\text{ni}/\text{Nt}) \times 100$$

where:

AFi = Absolute frequency of species i

ni = number of plots with species i

Nt= total number of plots sampled

Relative Frequency

$$RFi = \left(AFi/\Sigma AFa\right) \times 100$$

where:

RFi = Relative frequency of species i

AFi = Absolute frequency of species i

ΣAFa = sum of the absolute frequencies of all species

Absolute Dominance

$$ADoi = BAi/A$$

where:

ADoi = Absolute Dominance of species i (m^2/hectare)

BAi = Basal area of species i (m^2)

A = total area sampled (hectare)

Relative Dominance

$$RDoi = \left(BAi/BAt\right) \times 100$$

where:

RDoi = Relative Dominance of species i

BAi = Basal area of species i (m^2)

BAt = sum of basal areas of all species sampled.

Value of Importance

$$VI = RFi + RDi + RDoi$$

where:

VI = Import Value of species i

RFi = Relative frequency of species i

RDi = Relative Density of species i

RDoi = Relative Dominance of species i

Coverage value

$$CVi = RDi + RDoi$$

where:

CVi = Coverage value of species i

RDi = Relative Density of species i

RDoi = Relative Dominance of species i

In 2015, in the same month of the initial sampling, all live individuals present in the same 96 plots were measured by the same inclusion criteria. All individuals which emerged or had not met the inclusion criteria were considered as recruited. Individuals marked in 2013 which were no longer alive or have not been found in 2015 were considered as dead. The difference between the numbers of individuals in 2013 and in 2015 was named population real gain and corresponds to the difference between dead and recruited individuals.

Rates were calculated for mortality (M), recruitment (R) and real gain (GR), using the algebraic equation of annual rates [21], according to the following equations:

$$M = \left\{1 - \left[\left(N_0 - m\right)/N_0\right]^{1/\Delta t}\right\} * 100$$

$$R = \left\{\left[\left(N_0 + r\right)/N_0\right]^{1/\Delta t} - 1\right\} * 100$$

$$GR = \left\{\left[\left(Nr/N_0\right)\right]^{1/\Delta t} - 1\right\} * 100$$

where N_0 is the number of individuals in the first survey, *m* is the number of dead individuals in the time interval, *r* is the number of individuals recruited, Δt is the time interval between the surveys ($t_1 - t_0$) and Nr is the number of individuals in the second survey.

The individuals were also stratified by height classes with an interval of 1 m [22].

3. Results and Discussion

The survey carried out in the study area, in 2013, sampled 2860 live standing individuals and 62 dead standing individuals. Live individuals were distributed among 13 species, 13 genera and 8 families (**Table 1**).

Among the total live individuals sampled 1078 were *C. blanchetianus*, corresponding to 1931 m^2 BA. Absolute density was 1.122 ind ha^{-1}, and RD was 36.89%. Absolute frequency was 100%, Ado was 2.010 $m^2 \cdot ha^{-1}$ and RDo was 21.13%. The CV was 58.02, and the IV value was 74.92.

Croton blanchetianus contributed with the largest number of individuals in the community, which resulted in the highest values of absolute and relative densities, having a wide distribution and occurring in all sampled plots. Because it is a shrubby species with small diameter, the BA was the second largest due to the large number of individuals, leading the population studied to the second place for the parameters ADo, RDo, IV and CV.

A comparison of the structure data of this study with those carried out semi-arid region of Paraiba and Pernambuco showed that *C. blanchetianus* stood out as one of the predominant species in these environments. A study carried out in the Private Reserve of the Natural Patrimony Fazenda Almas (PRNP) [23], showed that the only species present in 100% of the sample units was *C. blanchetianus*, with the highest number of individuals (568) and importance value (63.54).

In the floristic and phytosociological survey of a vegetation community in the Cariri, [24] also found *C. blanchetianus* as one of the most dominant species, with 637 individuals and the third in importance value (35.60). In the municipality of Teixeira, hinterland of Paraiba, reported that the largest numbers of individuals and highest importance value belonged to this species [25], indicating the importance of this tax on for the Caatinga ecosystem.

Considering the evaluation period started in 2013 and the last evaluation performed in this study in January 2015, a high mortality rate (M = 47.33% $year^{-1}$) was observed for the *C. blanchetianus* population. Initially composed of 1078 individuals, in January 2013, this species had its population reduced to 299

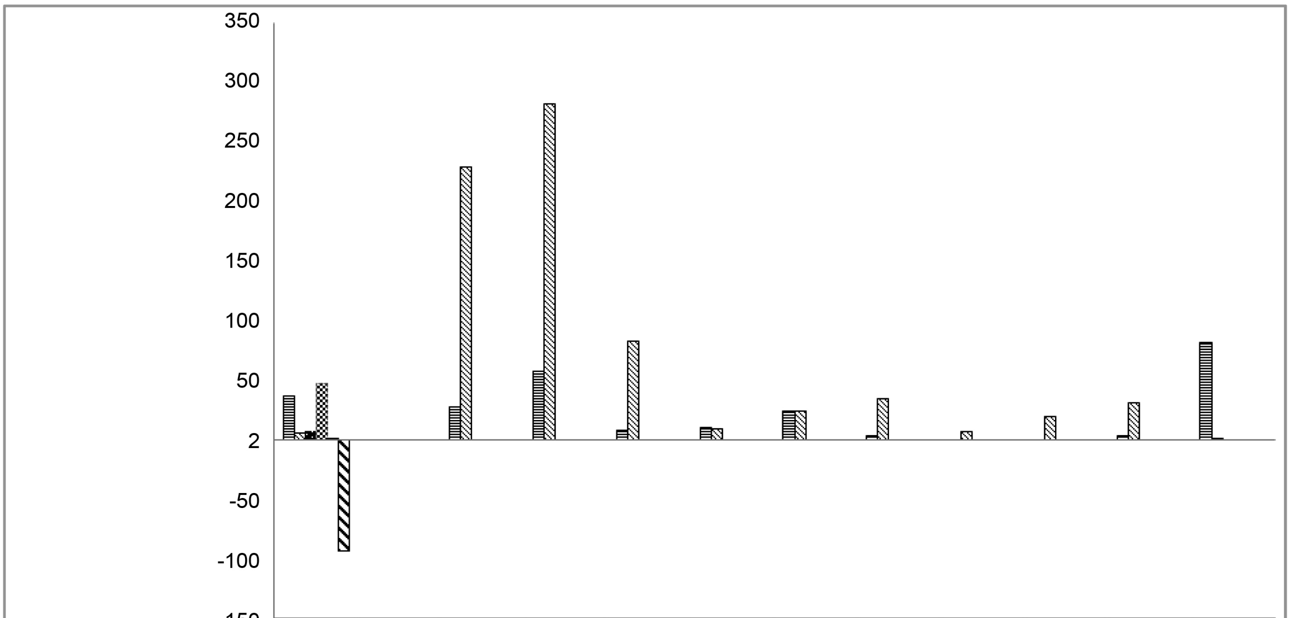
Table 1. List of families and species recorded in the floristic survey carried out in the Experimental area reserved for studies on caatinga ecology and dynamics of the laboratory of Ecology and Botany—LAEB/CDSA/UFCG), in the municipality of Sumé, Semi-arid region of Paraíba State.

Family Species	Popular name	Habit
Anacardiaceae		
Schinopsis brasiliensis Engl.	Baraúna	Arboreal
Apocynaceae		
Aspidosperma pyrifolium Mart. & Zucc.	Pereiro	Arboreal
Boraginaceae		
Varronia leucocephala (Moric.) J. S. Mill.	Moleque duro	Shrubby
Cactaceae		
Cereus jamacaru DC.	Mandacaru	Arboreal
Pilosocereus gounellei (Weber) Byles e Rowlwy	Xique-xique	Shrubby
Capparaceae		
Morisonia flexuosa L.	Feijão bravo	Arboreal
Combretaceae		
Combretum leprosum Mart.	Mofumbo	Shrubby
Euphorbiaceae		
Croton blanchetianus Baill.	Marmeleiro	Shrubby
Ditaxis malpighiacea (Ule) Pax & K. Hoffm.		Shrubby
Jatropha mollissima (Pohl) Baill.	Pinhão bravo	Shrubby
Fabaceae		
Fabaceae subfam. Caesalpinioideae		
Poincianella pyramidalis (Tul.) L.P. Queiroz	Catingueira	Arboreal
Fabaceae subfam. Mimosoideae		
Anadenanthera colubrina (Vell.) Brenan	Angico	Arboreal
Mimosa ophthalmocentra Mart. ex Benth.	Jurema de imbira	Arboreal

plants in January 2015. In this period four new individuals were recorded, making this population with a recruitment rate (R) of only 0.18% ano^{-1}. When analyzing the real gain (RG) of this population, a significantly negative value (−93.91%) was observed, since the number of dead individuals was much higher than the number of recruited individuals in the population. These data are related to the high rainfall oscillations in recent years (Figure 2).

According to data from the last historical series, the average annual rainfall in the municipality of Sumé is 584.9 mm. It should be noted that in the years of 2012 and 2013 the rainfall was only 27 and 254.4 mm, respectively, with a period of rainfall below the annual average, especially in 2012 (Figure 3).

The total rainfall in 2014, which was above average for the region, did not caused changes in the dynamic context of the population regarding the permanence of live individuals within the system, given that the low rainfall in the two previous years caused a severe water stress that was not tolerated by the majority



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Precipitation 2013 (mm)	37.3	0	28.2	57.5	8.1	10.9	23.7	3.2	0	0	3.1	82.4
Precipitation 2014 (mm)	5.5	0	229.3	282.4	82.8	9.6	24.1	34.3	7	19.8	31.2	0.1
Precipitation Jan 2015 (mm)	7.2											
Mortality 2015 (% year^{-1})	47.33											
Recruitment 2015 (% year^{-1})	0.18											
Real Gain (% year^{-1})	-93.91											

Figure 2. Recruitment, mortality and real gain of *Croton blanchetianus* Baill. during two years of study in relation to precipitation variations in an area of Caatinga in the Semi-arid region of Paraíba, Brazil.

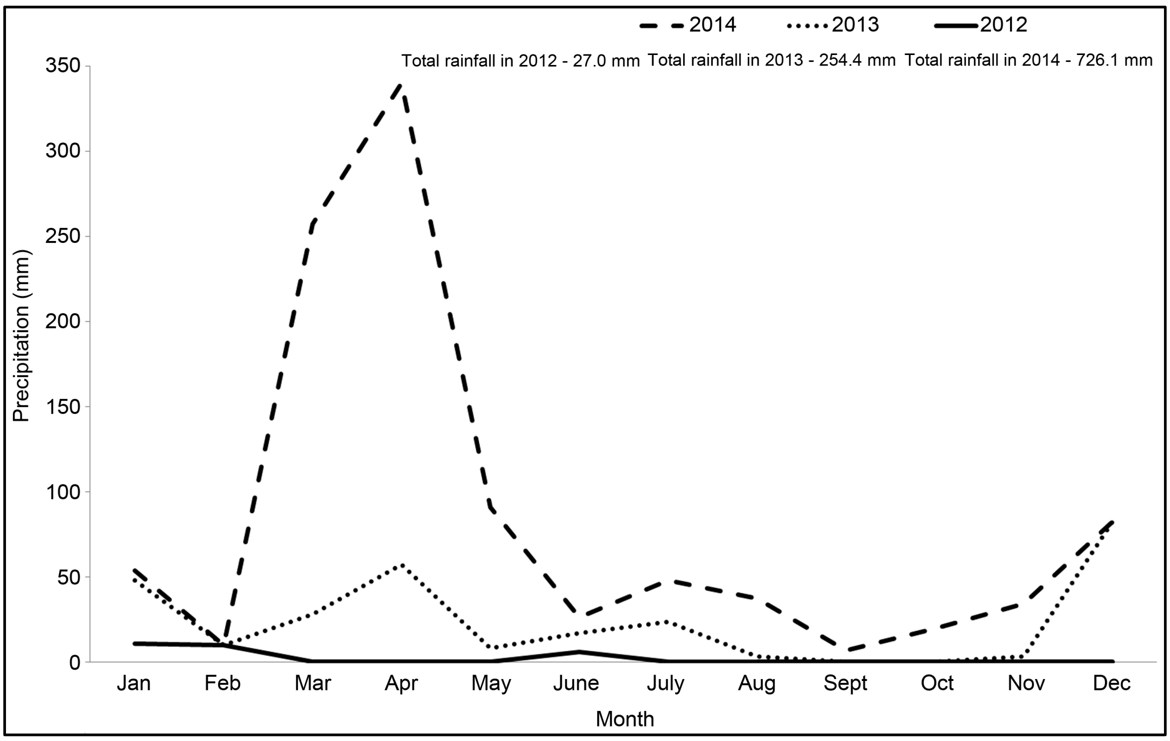


Figure 3. Average monthly and annual precipitation (mm) from 2012 to 2014. Sumé weather station (Latitude (degrees)—7.6736; Longitude (degrees)—36.8964), Cariri Region, Paraiba.

of the *C. blanchetianus* individuals, which became fragile until they died.

There are few definitions of the Caatinga biome's functionality [26], and therefore studies are necessary to understand the temporal and spatial influences in the population structure. Some of the key processes that determine forest dynamics are recruitment and mortality, these variables, are fundamental to describe the forest population [27]. However, in the Brazilian semi-arid region, this is the first study evaluating the population dynamics in adult communities with data on mortality and recruitment rates in relation to precipitation variations over time, with *C. blanchetianus* being the first species studied at this level of detail.

Changes in the diameter of the stem during the dry season, which can result in decreased cell turgor and water loss through transpiration, have been reported for this species [28]. However, during the dry period, it was observed growth in height, which may require the use of water stored in tissues, resulting in reduction of the stem diameter. Researchers have emphasized the need for knowledge on the relationship between precipitation pulse and inter-pulse events and their effect on physiological determinants of plant growth [29].

The climate a major mortality agent in forest stands. The occurrence of drought or prolonged waterlogging may accelerate the death of aged, diseased or suppressed trees, and may also, although rarely cause death of healthy trees without the presence of such associated agents [30].

A study of the natural regeneration of *C. blanchetianus*, with monthly evaluations over a year showed that there was no significant difference in the population growth rate between the dry and rainy seasons, and that the mortality rates were recorded during all monitoring period [31]. It is worth mentioning that during the evaluation period, these authors recorded 646.2 mm in the rainy season and 304.4 mm in the dry season. These values significantly differ from the pluviometric data found in our study.

Some studies have shown the adaptation of Caatinga plants to the Brazilian semi-arid climate. Regarding *C. blanchetianus*, studies showed that this species has stomata in the abaxial face at the same level of the other epidermal cells that are protected by the dense indumenta [12]. According to these authors, the fact that the stomata are protected by trichomes can reduce water loss through the leaf. Phenolic compounds, which are responsible for reducing the passage of light through epidermal cells, protecting the plant against excess solar radiation, were also found.

In evaluations of the variations of the in morphological and ecophysiological parameters of *C. blanchetianus* during a year, it was observed that the two well-defined seasons (dry and rainy) have adaptation and evolution strategies with the environment in which it is inserted, showing that *C. blanchetianus*is a species well adapted to the environment in which it is inserted [32].

It is worth noting the lack of studies that evaluate the adaptation of Caatinga species such as *C. blanchetianus*, during periodic droughts, since, as it has already been shown, the few studies carried out to date deal only with seasonal droughts, which do not cause significant stress to the populations. In dry environments, such as the Caatinga, it is possible reductions in densities of communities in periods of severe droughts [33].

However, it is necessary to intensify studies focusing on population dynamics in areas of Caatinga, providing data to help understanding the increased mortality caused by environmental changes.

Regarding the distribution of individuals per height class, it was found that 66.14% of the population was distributed between classes 2.1 and 3.0 m, and only 1.20% of the population was distributed within the highest height class, *i.e.*, between 4.1 and 5.0 m. The highest height class stood out especially for comprising individuals that are most resistant to water scarcity, representing 53.85% of the survivors of the study population. The lowest rate of survivors was found in the lowest height class, between 1 and 2 m (**Figure 4**).

It is worth noting that the second height class of lower resistance to water scarcity, *i.e.*, between 2.1 and 3.0 m, comprised 66.14% of individuals recorded in 2013, which contributed significantly to the high population mortality. The biased relation of the greatest survivor index with the highest height class (**Figure 4**) may be related to the greater development of the root system and consequently better conditions of resource acquisition.

The biological activities of many species are interfered by the difference in environmental conditions, which affects the development of the plant [22] [28] [34]. Thus, the fact that some individuals can use a scarce resource (water) in the

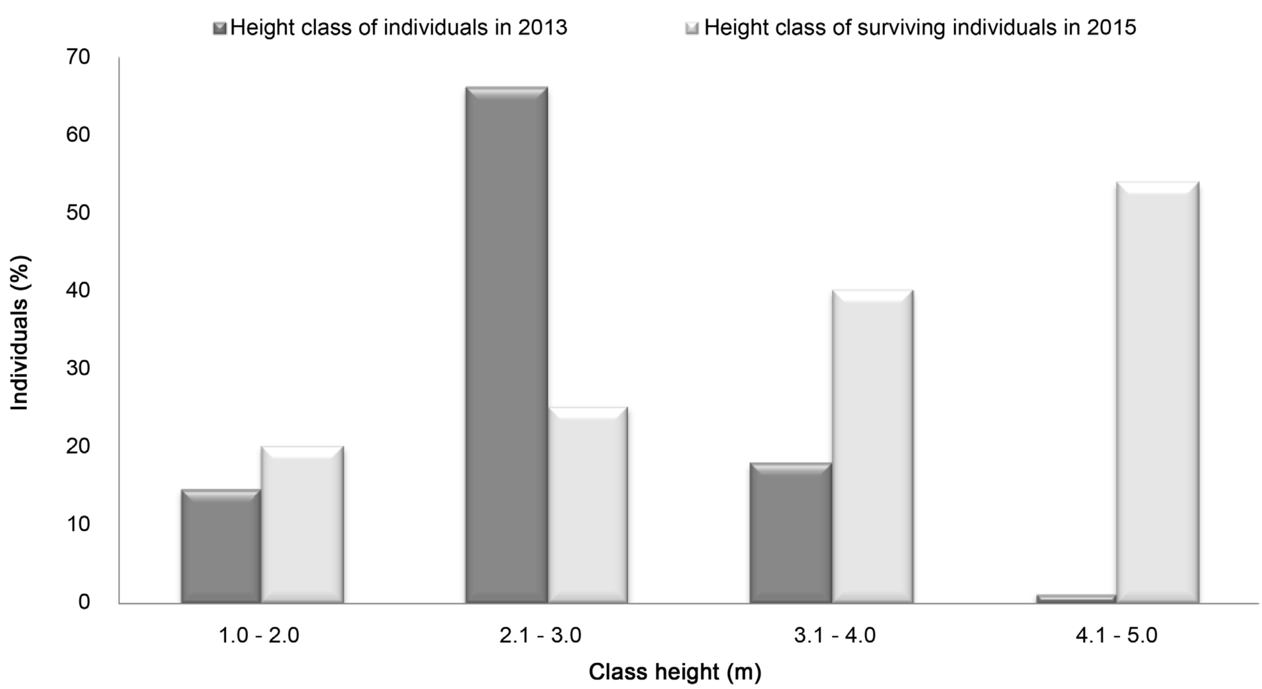


Figure 4. Class height (m) of surviving *Croton blanchetianus* Baill. individuals January 2013 to January 2015, in a Caatinga area of the semi-arid region of Paraiba, Brazil.

dry season, both for the maintenance of daily metabolic activities and for growth, points out the possibility of differences in the competitive ability among the individuals [28], and this needs to be defined as plant populations for a better orientation of the species management.

Croton blanchetianus is a pioneer species, very frequent and with high density in the Caatinga. According as researchers [35] the pioneer species have a high rate of mortality because the trees in tropical forests are more susceptible to senescence, drought, competition, the action of fungi and bacteria, or a combination of these factors.

4. Conclusion

The initial structural characterization of the adult community evaluated here defined *C. blanchetianus* with high representativeness. However, the temporal monitoring for the evaluation of the dynamics of this population showed that the periodic drought compromised the recruitment, development, survival, and establishment of the individuals, reducing their population, which expressed a high mortality rate and a low recruitment rate. The highest height class is the most tolerant to water scarcity, resulting in 53.85% of surviving individuals. Therefore, the data obtained in this study are relevant for the definition of the key species dynamics in the Caatinga in the semi-arid region of Brazil.

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