Vol. 13(41), pp. 2239-2248, 11 October, 2018
DOI: 10.5897/AJAR2015.10445
Article Number: 413968358767
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Distribution of rainwater by species of caatinga vegetation

Ane Cristine Fortes da Silva[1*], Jacob Silva Souto[2], José Augusto da Silva Santana[3], Patricia Carneiro Souto[2] and José Adeilson Medeiros do Nascimento[4]

[1]Department of Technology in Environmental Management, Federal Institute of Paraíba – IFPB, AC Rodovia PB 426, S/N, Sítio Barro Vermelho, CEP: 58755 – 000, Princesa Isabel - PB, Brazil.
[2]Department of Forest Engineering, Federal University of Campina Grande – UFCG, Campus Patos, Brazil.
[3]Department of Forest Engineering, Federal University of Rio Grande do Norte – UFRN, Escola Agrícola de Jundiaí, Brazil.
[4]Department of the Technical Course in Agriculture, Federal Institute of Ceara – IFCE, Campus Tianguá, Brazil.

Received 25 September, 2015; Accepted 30 March, 2017

This study aimed to estimate the redistribution of rainfall in a Caatinga vegetation fragment of about 50 years in fallow system, in late stage of regeneration. To quantify the throughfall, rainfall collectors were installed in six individuals of the species *Croton blanchetianus*, *Mimosa tenuiflora*, *Cnidoscolus quercifolius*, *Aspidosperma pyrifolium* and *Poincianella bracteosa*, totaling 30 rainfall collectors. For the stemflow, collecting system set around the stems of the six subjects in each of the five selected species was used, consisting of collecting gutters in a spiral. In addition, a rain gauge was installed in an open location to quantify the open precipitation, which during the study period was equal to 1173.56 mm. The *C. quercifolius* species had the highest average of throughfall; probably this may be related to the peculiarities in relation to architecture and canopy shape. The stemflow has lower shares in gross precipitation in *A. pyrifolium* and *C. quercifolius* species, representing 15.25 to 12.48% of the total rainfall, respectively. The values obtained for the interception losses were greater than 60% in all species.

Key words: Forestal hydrology, throughfall, stemflow.

INTRODUCTION

The vegetation play a key role in the Earth System as it can control the soil erosion, the runoff generation, the infiltration process, and the soil properties (Cerdà and Doerr, 2005; Keesstra et al., 2009; Keesstra, 2007; Barua and Haque, 2013; Novara et al., 2011; Cadaret et al., 2016; Archer et al., 2016).

Rainfall participates in nutrient cycling, after contacting the forest canopy, as rainwater has its physical and chemical attributes modified by leaching of the metabolites of leaf tissues, stems and branches. In addition, rainfall washes the particles derived from dry deposition that subsequently accumulates in the dry

*Corresponding author. E-mail: ane.silva@ifpb.edu.br. Tel: +55 84 9 81708294.

period, being the broad-leaved species, the ones that have greater leaching, compared to the conifers (Oki, 2002).

Rain comprises, therefore, a significant compartment in the internal dynamics of nutrients in a forest ecosystem (Parker, 1983), delivering the nutrients that are dissolved to be absorbed by the roots.

During the water cycle, part of the volume of rainfall entering the ecosystem is retained by the leaves of the canopy, evaporating because of the temperature, solar radiation and wind. Another part reaches the forest floor, after washing the canopies and stems, with the possibility to suffer percolation or to be superficially drained (Delitti, 1995).

The percolated water, when exceeds the holding capacity of the soil, moves to the groundwater leaching some nutrients, leaving the ecosystem. Yet the water stored in the soil constitutes the soil solution where nutrients are in forms that are assimilable by plants, representing the reservation that plants will absorb to perform the metabolic activities (Britez, 1994).

The volume of water that cannot infiltrate the soil drains superficially. In high rainfall, when the volume and energy of the drained water are higher, fine soil particles are carried along with the water, leading to erosion, often intense, especially in areas with low vegetation, like the degraded areas of Caatinga. The plant biomass contributes to rainwater interception, providing its storage in the soil and the increase in infiltration rates (Olson, 1963).

Forest cover has significant influence on the redistribution of rainfall in all ecosystems, thus, the study of redistribution of rainwater in forest ecosystems is important for understanding the processes of interception, infiltration, percolation, uptake, transpiration and cycling of nutrients in forest ecosystems.

For Ferreira et al. (2005), the interception of rain by the plant canopy is a vitally important component to understand the hydrological cycle since this varies according to the morphological aspect of the vegetation (age, canopy, architecture), to the dominant precipitation regime in the region and the time of year. Yet the precipitation that runs through the canopy (incident rainfall) and reaches the forest floor depending on the nature and density of the vegetation, since this coverage temporarily retains certain amount of incident precipitation.

According to Bruijnzeel (1990), tropical forests, in general, reach variations of throughfall between 75 and 96%, the stemflow varies between 1 and 2%, and the interception by vegetation between 4.5 and 24% of the gross precipitation. However, it appears that the interception, internal precepitation and stemflow are parameters that have widely varying values within one or more ecosystems (Arcova et al., 2003; Ferreira et al., 2005; Oliveira Júnior and Dias, 2005; Germer et al., 2006; Oliveira et al., 2008; Medeiros et al., 2009; Izidio et al., 2013; Sousa et al., 2016).

The type of vegetation involves different characteristics in the soil and water properties in a given ecosystem; forest degradation has significantly favored the erosion in vast areas, with damage to hydrological processes and biodiversity (Freitas et al., 2013). Despite the relevance of the water study in forest areas, especially in degraded and susceptible to erosion' environments, there are few studies related to the distribution of rainwater in areas of Caatinga. This study aimed to estimate the redistribution of rainfall in a Caatinga vegetation fragment of about 50 years in fallow system, in late stage of regeneration.

MATERIALS AND METHODS

Study area

The research was conducted in an area of Caatinga located in Cachoeira of São Porfirio Farm's, Várzea district, microrregion of Western Seridó, Paraíba backwoods, placed in the coordinates 06° 48' 35" S and 36° 57' 15" W, with an average altitude of 271 m.

The climate of the study area is characterized as semi-arid, BSh' type (hot and dry) according to the Köppen classification. The average annual rainfall is between 400 and 600 mm, with a dry period of nine to ten months and average temperatures higher than 18°C in all months of the year; peak means around 33°C and minimum of 22°C (IBGE, 2002).

The study area soils are of crystalline origin, being shallow, stony and with high susceptibility to erosion, prevailing the association of Litholic Neosols, Luvisols and rocky outcrops.

The location where the research was implemented consists of an open arboreal-shrubby Caatinga vegetation with varying degrees of anthropism, with medium-low trees not exceeding 7.0 m in height. The natural vegetation of the area was cleared for the implementation of agricultural crops, mainly for cotton planting, being subsequently used as areas of goats and cattle grazing, occurring regeneration of the vegetation.

In the study area, we demarcated a transect 20.0 m × 50.0 m in size. The area has about 50 years of fallow, vegetation type in the most advanced stage of successional development, constituting a complex and with high floristic diversity community.

METHODOLOGY

In an open area located in about 200 m from the study area, the gross precipitation (P) was recorded by one (01) rainfall collector, made of wooden and polyethylene terephthalate (PET) gauges. The hand-made rain gauges are made up of a funnel with a circular opening of 9.2 cm in diameter and 2 L containers and installed 1.5 m above the ground (Figure 1a). The water accumulated in these rainfall collectors was conducted by hoses located at the lower end, this being stored in PET plastic containers fixed on the ground. This water is considered as a control, corresponded to the water that precipitated directly on the ground, without passing through the leaves or flowing through the stem.

Rainfall collectors like the previous ones were used to estimate the throughfall, distributed below the canopy of five Catinga species (*Croton blanchetianus* Baill, *Mimosa tenuiflora* Poiret, *Cnidosculus quercifolius* Pohl, *Aspidosperma pyrifolium* Mart, and *Poincianella bracteosa* (Tul.) L.P. Queiroz). These species were selected following the importance value (IV) determined by Sousa (2011). For each species, six replicates, totaling 30 individuals.

In each rain event, the stored precipitation volumes measured in

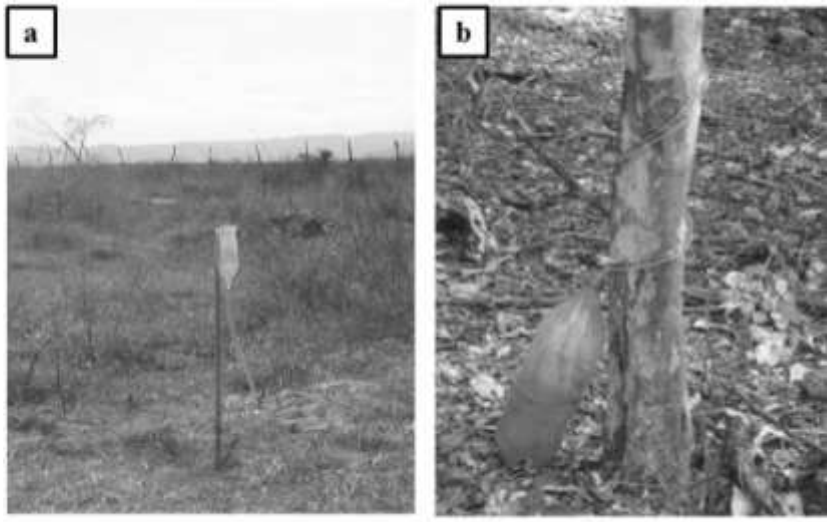

Figure 1. (a) Rainfall collector, (b) Stemflow collector.

milliliters in the field and, based on the dimensions of the containers, then converted into millimeters using the equation described in Gênova et al. (2007):

$$Precipitation = measured\ volume\ (mL) x\ 0.1504$$

For quantification of the stemflow, a collecting system set around the stems of the six individuals of each of the five selected species was developed, consisting of plastic hose of an inch, cut longitudinally, and thus becoming "collecting gutters" for the captation of the amount drained (Figure 1b). The collecting gutters were fixed in the form of spiral, following the circumference of the tree trunks, being used, for that, nails and glue based on cassava mass. Rainwater captured was directed to PET plastic containers positioned vertically and fixed to the ground, methodology adapted from Moura et al. (2009).

The stemflow was estimated in millimeters of water, by the mean of the volume stored in tanks and a conversion factor of 113.64 m², namely, due to its populational density, which has been estimated by dividing the values of size of the experimental area by the five species selected.

After obtaining the data, interception losses were estimated according to the equation defined by Helvey and Patric (1965):

$$I=P - (T + Sf)$$

where I = interception losses, P = gross precipitation, T = throughfall, and Sf = stemflow.

To study the behavior of throughfall, stemflow and standards of interception losses among species, were estimated for leaf area, canopy projection area (CPA), diameter at chest level (DCL) and basal area (g).

The determination of the leaf area was carried out considering the dimensions of 102 leaves of varying sizes including from the smallest to the largest sizes, which were collected randomly throughout the canopy of individuals of the species. The leaves collected were accommodated in cooler in order to avoid the loss of turgor during the determinations. The leaves were scanned on white background material, and for the direct measurement of leaf area, the digital images were manipulated using the ImageJ® Software (Powerful Image Analysis), calculating the actual total area of each leaf (Jadoski et al., 2012).

DCL measurement of each individual of the species studied was held using tape measure, used in determining the basal area of each individual. To study the canopy, four each individual canopies radii were measured, following the north-south-east-west orientation, getting the average canopy diameter (CD) for calculating the canopy projection area (Wink et al., 2012).

Statistical analyses

For the analysis of throughfall and stemflow among the studied species, first, the normality of the distribution was verified by the Lillifors test and the analysis of variance (ANOVA one-way) performed. Means were compared by 5% Tukey test. As for the analysis of throughfall and stemflow during the months studied, the species were analyzed separately.

RESULTS AND DISCUSSION

The gross precipitation data recorded in the study area shows the irregular distribution of rainfall during the study period (Figure 2).

The gross precipitation in the study area in the twenty-three months of study was estimated to be 1,173.56 mm. In 2011, the gross precipitation in the study area was 961.5 mm, as expected in the region, considering the average annual rainfall (300 to 1000 mm). The highest monthly rainfall was of 345.92 mm, corresponding to May/2011. In March/2012, only 4.00 mm was recorded.

No rainfall was recorded during the months of November/2010, July, September, November and December/2011. In addition, there was no water storage in rainfall collectors in the months of June and August/2011 and March/2012, which may be related to low rainfall that occurred in those months. Therefore, thirteen months of rainfall events was used in this study.

This distribution confirms the irregular pattern of rainfall

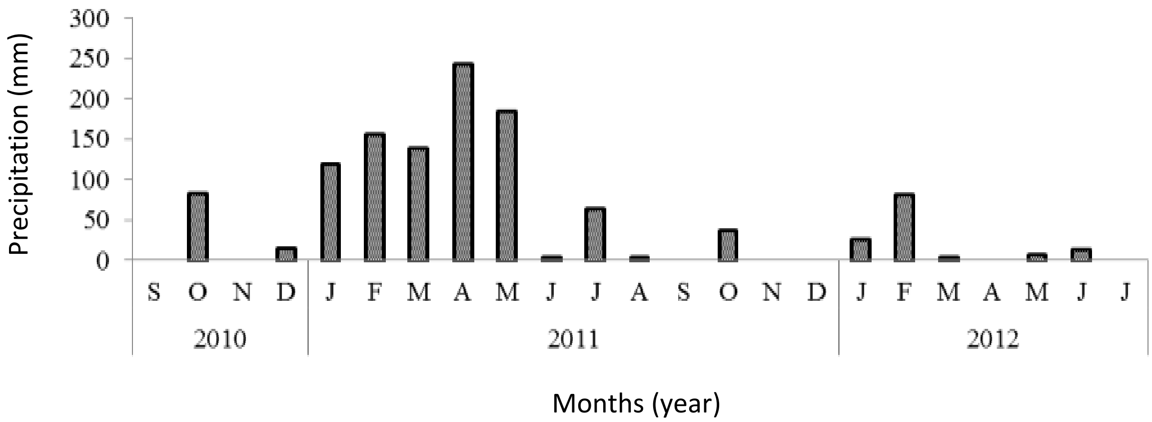

Figure 2. Monthly gross precipitation recorded in the experimental area.

Table 1. Total values of throughfall (T), stemflow (Sf), interception losses (I) and gross precipitation (P) in the experimental area from October/2010 to July/2012.

Species	T		SF		I		P
	mm	%	mm	%	mm	%	mm
Aspidosperma pyrifolium	247.35	21.08	179.22	15.27	746.99	63.65	
Cnidoscolus quercifolius	248.81	21.20	146.46	12.48	778.29	66.32	
Croton blanchetianus	180.88	15.41	287.69	24.51	704.99	60.07	1,173.56
Poincianella bracteosa	150.18	12.80	272.55	23.22	750.83	63.98	
Mimosa tenuiflora	188.69	16.08	216.55	18.45	768.32	65.47	

distribution in the study region with long periods of drought and high rainfall concentrated in a few months. The Caatinga is conditioned by the semi-arid climate, with high rates of potential evapotranspiration during the year and low annual rainfall (300 to 1000 mm), normally limited to 3 to 5 months with large temporal irregularity (Reddy, 1983; Santana, 2005).

The total amount estimated for the throughfall ranged from 12.80 to 21.20% between species during the study period, following the descending order: *C. quercifolius* > *A. pyrifolium* > *M. tenuiflora* > *C. blanchetianus* > *P. bracteosa* (Table 1).

In this study, the same rainfall characteristics and meteorological conditions, the differentiated rainfall distribution among the five species can thus be mostly attributable to their differences in morphological characteristics. *C. quercifolius* has a more open crown (Figure 3a), despite the larger leaf area (Table 2), which facilitates water flow in the throughfall.

The stemflow has lower shares in the total precipitated in *A. pyrifolium* and *C. quercifolius* species, representing 15.25 and 12.48% of the gross precipitation, respectively. These results are above those verified by Izidio et al. (2013) with 5.9% in dense Caatinga, Medeiros et al. (2009) with 6% in dense Caatinga, Moura et al. (2009) with 0.4% in the Atlantic Forest and Oliveira et al. (2008) with 1.7% in the eastern Amazon. Yet, the comparison of results obtained for stemflow with other work is hindered by the variability of methods of obtaining and processing the data.

The values obtained for the interception losses were greater than 60%, higher values when compared to Izidio et al. (2013) in dense Caatinga with 17.9% of the precipitate value. These results were obtained by species which still still exceed those found in other forest formations that are below 30% of total rainfall, as Lima and Nicolielo (1983) with 12% in tropical pine forests and 27% for the cerrado, and Franken et al. (1982) with 19.8% in the Amazon forest of solid ground type. On the other hand, Thomaz (2005) found 52.4% loss by capoeira interception, being the closest to the results reported in the present study. The higher evaporation rates, characteristic of the study region, as well as the predominance of events of low precipitation can cause more intercepted rainfall water back to air and thus reduced throughfall through the canopy.

The results found for *C. blanchetianus* indicate a greater efficiency of the stemflow production and a smaller loss of interception than the other species, which has a significant competitive advantage to face periods of water deficit, characteristic of the region.

The results of throughfall, stemflow and interception

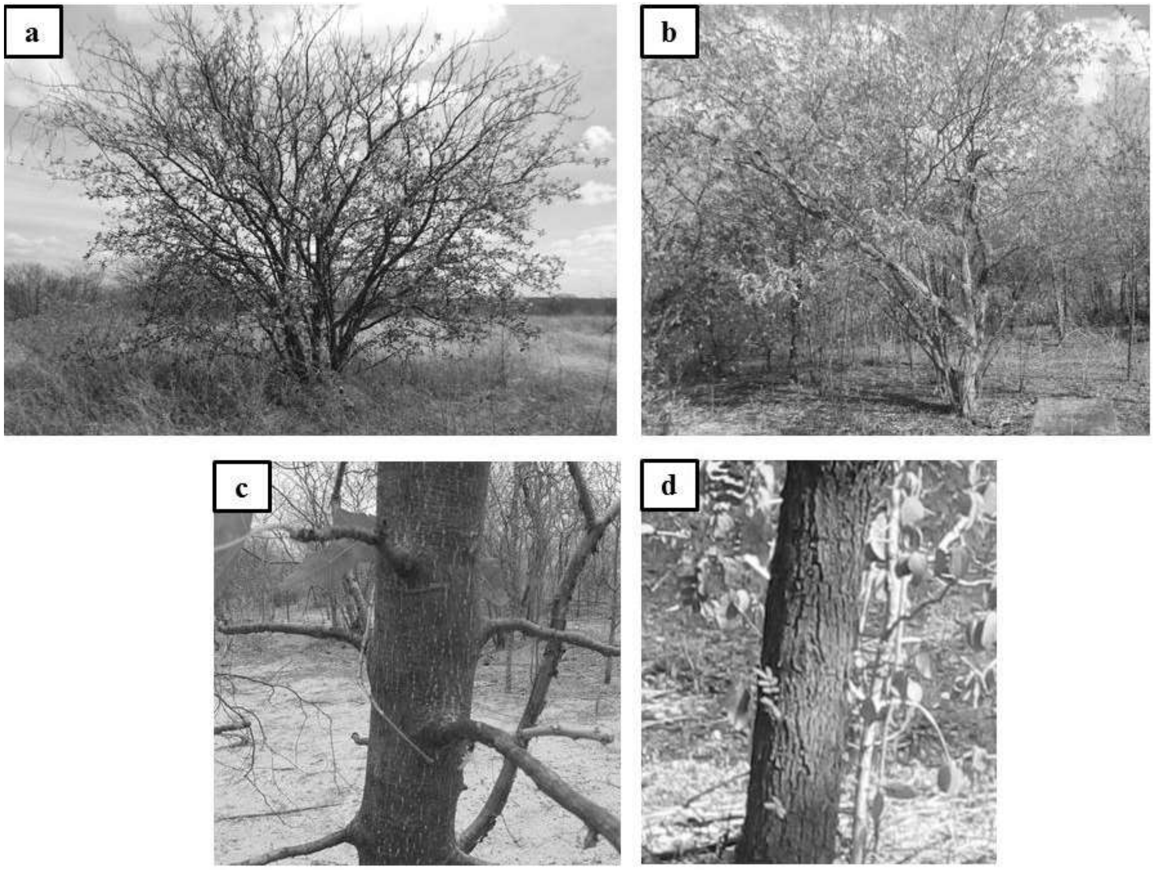

Figure 3. (a) Canopy of *Cnidoscolus quercifolius*, (b) Canopy of *Poincianella bracteosa*, (c) Bole of *Cnidoscolus quercifolius,* and (d) Bole of *Croton blanchetianus.*

Table 2. Average values of leaf area, canopy projection area (CPA), diameter at chest level (DCL) and basal area of the species studied.

Species	Leaf area (cm²)	CPA (m²)	DCL (cm)	Basal area (cm²)
Aspidosperma pyrifolium	6.72	8.90	5.25	21.66
Cnidoscolus quercifolius	31.14	5.23	5.62	24.84
Croton blanchetianus	8.14	6.29	4.40	15.23
Poincianella bracteosa	21.70	7.88	7.53	44.57
Mimosa tenuiflora	1.60	13.84	6.90	37.36

losses presented in this study, regardless of the species, differ in the proportion cited by Bruijnzeel (1990) in tropical forests, where 75 to 96% of the precipitation becomes throughfall, between 1 and 2% is converted into stemflow and between 4.5 and 24% is intercepted by the canopies of trees.

In studies reported for different forest types, the mean values of throughfall, stemflow and interception losses are discrepant. The throughfall was lower than those found by Fan et al. (2014) in native Banksia woodland, Macinnis-Ng et al. (2014) in lower montane tropical rainforest in Panama and Cao et al. (2008) in *Eucommia ulmoides, Vernicia fordii* and *Pinus massoniana*. The stemflow and interception losses was higher than Oyarzun et al. (2011) in Andean temperate rainforests, Macinnis-Ng et al (2014) in Panama, Aboal et al. (1999) in laurel forest and Carlyle-Moses (2004) in a semi-arid Sierra Madre Oriental matorral community.

The differences in the partition of gross precipitation are consequences of the characteristics of the forest community, such as species composition, height, basal area, canopy cover and rainfall characteristics, such as

Table 3. Pearson correlation coefficient (r) for the variables stemflow (Sf), throughfall (T), interception losses (I), leaf area, canopy projection area (CPA), diameter at chest lefel (DCL) and basal area.

Variable	Sf		T		I	
	R	*p*	r	*p*	r	*p*
Leaf area	-0.03	0.9696	0.70	0.2979	-0.92	0.0767
CPA	0.07	0.9096	-0.69	0.1941	0.74	0.1445
DCL	0.19	0.7565	-	-	-	-
Basal area (g)	0.26	0.6717	-	-	-	-

Table 4. Mean values of throughfall (%) and average gross precipitation.

Species	Classes (mm)		
	<177.97	117.97 - 231.94	>231.94
Poincianella bracteosa	10.13	8.08	32.75
Aspidosperma pyrifolium	15.57	23.55	44.57
Mimosa tenuiflora	11.61	12.12	48.37
Croton blanchetianus	11.17	12.84	43.48
Cnidoscolus quercifolius	17.67	18.69	27.72
Gross precipitation (mm)	39.15	218.08	345.92

intensity, and conditions controlling evaporation area.

These percentages below the average are compared to other studies related to the type of formation of the upper canopy leaves of the Caatinga region analyzed, since each ecosystem has distinct characteristics differentiating the redistribution of rainwater, especially the dendrological and phenological patterns of the species studied. The quantities of water involved in throughfall, in stemflow and interception are variable and depend on factors related to both the vegetation and the climatic conditions in which the forest is inserted (Leopoldo and Conte, 1985; Lima and Nicolielo, 1983).

The *C. quercifolius* species had the highest average of throughfall compared to the others, probably this can be related to the peculiarities of the species in relation to architecture and form of canopy, despite the species presents the highest average of leaf area, the projection area of its canopy was the lowest (Table 2).

Notwithstanding, *P. bracteosa* showed the lowest proportion of throughfall, that is, less water crossed the canopy of this species to reach the soil, which may be related to its higher leaf area (21.70 cm²), which favors the rainwater interception and the denser crown (Figura 3b).

Regarding the interception of rainfall precipitation, the *C. quercifolius* had the highest average, the possible explanation is the large leaf area of the species hindering the rain crossing through the canopy, favoring the evaporation of rainwater. Furthermore, the stemflow of this species was the lowest, influencing the calculation of the loss by interception. This low flow is due to the existing amount of branches along the stem of the species which interferes in the fixation of the collecting gutters, reflecting the obtained data (Figure 3c).

The low value lost by interception of the *C. blanchetianus* is closely related to the greater stemflow (24.51%) observed in the species. Despite the basal area and DCL were smaller in *C. blanchetianus*, a smooth and without ramifications stem favored the dripping to the ground (Figura 2d). In smooth stem species, the volume of flow is greater than in those with rough bark.

In Table 3, it shows the relationship between the variables stemflow, throughfall and loss by interception with the parameters leaf area, canopy projection area, DCL and basal area, one can observe that there was no significant correlation between them.

To Lima (1986), the throughfall varies highly in the same species and between species and requires the use of various gauges below the canopy to minimize this effect. The use of a considerable amount of gauges may facilitate the calculation of the average of the spaces in which occurs the concentration of water droplets, at some points in detriment of others (Regalado and Ritter, 2010).

In May, 2011, throughfall was higher in *M. tenuiflora* with 48.37%. *M. tenuiflora* features open canopy, where there is a predominance of leaflets, which explains the higher throughfall that occurred. Throughfall values are influenced by canopy density and the shape of the canopy of trees, which will determine a higher or lower throughfall (Freitas et al., 2013).

In general, throughfall was higher in the class of higher amount of rain, regardless of the species (Table 4).

In the rains of smaller amplitude, most of the water is retained by the dried leaves and twigs and evaporated to the atmosphere. Yet in the most intense rains, part of the precipitated water is retained in the vegetation mass,

Table 5. Mean values of stemflow (%) and average gross precipitation.

Species	Classes (mm)		
	<177.97	**117.97 - 231.94**	**>231.94**
Poincianella bracteosa	24.84	8.74	6.70
Aspidosperma pyrifolium	16.53	4.44	4.99
Mimosa tenuiflora	19.53	8.19	4.90
Croton blanchetianus	26.37	7.26	9.51
Cnidoscolus quercifolius	13.13	4.54	6.11
Gross precipitation (mm)	39.15	218.08	345.92

Table 6. Mean values of interceptation losses (%) and average gross precipitation.

Species	Classes (mm)		
	<177.97	**117.97 - 231.94**	**>231.94**
Poincianella bracteosa	65.04	83.18	60.54
Aspidosperma pyrifolium	67.90	72.00	50.44
Mimosa tenuiflora	68.87	79.69	46.73
Croton blanchetianus	62.46	79.90	47.01
Cnidoscolus quercifolius	69.20	76.76	66.17
Gross precipitation (mm)	39.15	218.08	345.92

which is saturated, and the remaining water is then drained, increasing throughfall and stemflow. But these processes depend on the characteristics of the previous rainfall event, such as volume and intensity, the type and density of vegetation and the season (Balbinot et al., 2008; Medeiros et al., 2009; Izidio et al., 2013).

With regard to the monthly variation, it is observed that the water drained by the stem was recorded in all evaluated months, and in June, 2011 the species had the lowest proportions.

The *P. bracteosa* species, *M. tenuiflora* and *C. quercifolius*, had the highest percentages of stemflow in October, 2010, while *A. pyrifolium* and *C. blanchetianus* in March, 2012, when it rained only 4.00 mm.

The stemflow is effective in the reposition of water to the ground, since the friction of the water with the bark of plants, besides being directed close to the roots, which diminishes the superficial runoff, allowing this water to easily infiltrate into the soil, reduces the speed of arrival to the ground. Therefore, the stemflow is especially important during low rainfall occurring during the dry season, providing higher soil moisture close to the plant roots in the Caatinga and the maintenance of photosynthetic rates and other functions in their metabolism.

In Table 5, it is observed that in the precipitations of lower amplitude, the amount of water drained by the stem is higher regardless of species, and the *C. quercifolius* obtained the lowest percentage of the precipitation drained by the stem (13.13%) in this class.

C. blanchetianus had the highest average of water drained by the stem (26.86%) in the smallest class of precipitation, suggesting that the species has a better use of precipitated water during the lower rainfall, typical of the dry period, as well as *P. bracteosa*, that also recorded high value. This feature may reflect a longer time for the occurrence of senescence of leaves by the better use of water by the roots.

The interception losses in the studied species remained high during all months of study, peaking in June, 2011 with values above 92%. *P. bracteosa* obtained a low proportion of intercepted precipitation in October, 2010 (10.74%), compared with the other species. Probably the species was defoliated (dry season) by reducing the contact surface of the precipitated water. Yet *A. pyrifolium* intercepted almost the entire precipitation (99.35%) in June, 2011, when it rained 18.05 mm. This species has large leaf area, when compared with the other species of the study. Moreover, *A. pyrifolium* has dense canopy obstructing the passage of rainwater, favoring its loss by evaporation.

In the precipitations of intermediate amplitude, the amount of water lost by interception is greater, regardless of the species, and the *P. bracteosa* had the highest mean percentage of intercepted precipitation (83.18%) (Table 6). This occurs because in the intermediate class the volume of rain, although high, is retained in the leaves and twigs and the precipitations involved in this class occurred at the beginning of the rainy season (February, 2011), after prolonged drought causing the plant biomass dry up, allowing greater water retention in the very first rains. However, in the class of the highest amplitude of rain, the interception losses are low when it is compared to the other species, because these

Table 7. Regression equations, determination coefficient (R²) and significance (p) by species in the experimental area.

Species	Equation	R² (%)	*p*
	$T = 0.163*P^{0.8496}$	46.28	0.0105
Aspidosperma pyrifolium	$SF = 0.3067*P^{0.8325}$	78.44	0.0001
	I = -2.0259 + 0.7173P	78.97	< 0.0001
	T = -0.60918 + 0.3685P	38.82	0.0229
Cnidoscolus quercifolius	$SF = 0.1179 \times P^{0.9157}$	68.36	0.0005
	$I = 1.0114 \times P^{0.8503}$	74.20	0.0002
	$T = 0.2789 \times P^{0.7822}$	34.51	0.0347
Croton blanchetianus	SF = -2.9659 + 3.7853*ln(P)	72.11	0.0002
	I = -1.1238 + 0.6189P	59.66	0.0539
	$T = 0.245 \times P^{0.7932}$	40.33	0.0196
Poincianella bracteosa	$SF = 0.3136 \times P^{0.8098}$	86.17	<0.00001
	I = 1.7567 + 0.6249P	59.40	0.002
	T = 1.7562 + 0.2184P	47.36	0.0093
Mimosa tenuiflora	$SF = 0.2159 \times P^{0.7835}$	50.61	0.0064
	$I = 0.516 \times P^{1.0344}$	93.62	<0.00001

precipitations have a higher intensity and occurred in the middle of the rainy season when the parts of the plants were already saturated, favoring the stemflow and the throughfall. When compared with other studies in various forest formations, it is verified that the pattern of loss by interception obtained in this study is not similar, as in most studies the major parts of the water intercepted by vegetation occur in the classes of lower range of rainfall (Thomaz, 2005; Moura et al., 2009; Calux and Thomaz, 2013).

Izidio et al. (2013), studying the rain interception in dense Caatinga, found greater interception losses in the classes with lower range of rainfall, differentiating from the present study. It may be related to numerous factors such as different methodologies, conditions of uneven vegetation, such as the preservation and type of vegetation, the distribution patterns of rainfall in space and time, among others.

The data of gross precipitation and throughfall, of the stemflow and of the loss by interception underwent regression analysis by species, whose results are shown in Table 7. In the species studied, the stemflow showed high relation with the amount of gross precipitation, with the lowest value of the determination coefficient (R^2) of 50.61% in *M. tenuiflora* species.

The throughfall, in turn, showed low relations with the gross precipitation in the study period, with R^2 varying between 34.51 (*C. blanchetianus*) and 47.36% (*M. tenuiflora*). The species *M. tenuiflora, A. pyrifolium* and *C. quercifolius*, in this descending order, obtained the highest relations between the interception losses and gross precipitation with R² equal to 93.62, 78.97 and 74.20%, respectively. While the *P. bracteosa* and *C. blanchetianus* showed determination coefficient below 60%.

Conclusions

The results of this study demonstrate that rainfall distribution differences among the five species evaluated under the same meteorological conditions and rainfall characteristics were not related to the leaf area, CPA, DCL and basal area differences between them. *M. tenuiflora* showed greater throughfall in rain events of greater amplitude. The stemflow was more significant in the dry season, especially in species without bifurcations and smooth bark. *C. blanchetianus* had a higher result for stemflow in the lowest precipitation class, suggesting that this species has a better use of precipitated water during the smaller precipitations, typical of the dry period in the region.

The annual loss by interception was higher in *C. quercifolius*. The water lost by interception represented the largest proportion of gross precipitation in all species. This condition may aggravate the water yield of this dry forest.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

The authors would like to thanks to CNPq for financial support.

REFERENCES

Aboal JR, Jiménez MS, Morales D, Hernández JM (1999). Rainfall interception in laurel forest in the Canary Islands. Agricultural and Forest Meteorology 97:73-86.

Archer NAL, Otten W, Schmidt S, Bengough AG, Shah N, Bonell M (2016). Rainfall infiltration and soil hydrological characteristics below ancient forest, planted forest and grassland in a temperate northern climate. Ecohydrology 9:585-600.

Arcova FCS, Cicco V, Rocha PAB (2003). Net precipitation and interception by Mata Atlântica in an experimental catchment in Cunha, São Paulo, Brazil. Rev. Árvore 27(2):257-262.

Balbinot R, Oliveira NK, Vanzetto SC, Pedroso K, Valério AF (2008). The role of the forest in the hydrological cycle in watersheds. Ambience. 2008; 4 (1):131-149

Barua SK, Haque SMS (2013). Soil characteristics and carbon sequestration potentials of vegetation in degraded hills of Chittagong, Bangladesh. Land Degradation and Development 24(1):63-71.

Britez RM (1994). Nnutrient cycling on two forest of quaternary coastal sediments of Ilha do Mel, Paranaguá, Paraná, PR. 240 f. Dissertation.

Bruijnzeel LA (1990). The hydrological cycle in moist tropical forest. In: Bruijnzeel LA Hydrology of moist tropical forests and effects of conversion: a state of knowledge review. Amsterdan: JAHS. pp. 5-38.

Cadaret EM, McGwire K, Nouwakpo SK, Weltz MA, Saito L (2016). Vegetation canopy cover effects on sediment erosion processes in the Upper Colorado River Basin Mancos Shale formation, Price, Utah, USA. Catena 147:334-344.

Calux J, Thomaz EL (2013). Rainfall interception and throughfall: comparision between Mixed Ombrophyla Forest and *Pinus elliotii* var. *elliotti*. Geoambiente On-line 19:01-16.

Cao Y, Ouyang ZY, Zheng H, Huang ZG, Wang XK, Miao H (2008). Effects of forest plantations on rainfall redistribution and erosion in the red soil region of Southern China. Land Degrad. Dev. 19(3):321-330.

Carlyle-Moses DE (2004). Throughfall, stemflow, and canopy interception loss fluxes in a semi-arid Sierra Madre Oriental matorral community. J. Arid Environ. 58:181-202.

Cerdà A, Doerr SH (2005). Influence of vegetation recovery on soil hydrology and erodibility following fire: an 11-year investigation. Int. J. Wildland Fire 14(4):423-437.

Delitti WBC (1995). Studies of nutriente cycling: instruments for the functional analysis of terrestrial ecosystems. Oecol. Austr. 1:469-486.

Fan J, Oestergaard KT, Guyot A, Lockington DA (2014). Measuring and modeling rainfall interception losses by a native Banksia woodland and an exotic pine plantation in subtropical coastal Australia. J. Hydrol. 515:156-165.

Ferreira SJF, Luizão FJ, Dallarosa RLG (2005). Throughfall and rainfall interception by an upland forest submitted to selective logging in Central Amazonia. Acta Amazonica 35(1):55-62.

Franken W, Leopoldo PR, Matsui E, Ribeiro MNG (1982). Study of the interception of rainwater in Amazon forest land cover. Acta Amazônica, Manaus 12(2):327-331.

Freitas JPO, Dias HCT, Barroso THA, Poyares LBQ (2013). Rainfall distribution in the Atlantic Rainforest. Rev. Ambient. Água 8(2):100-108.

Gênova KB, Honda EA, Durigan G (2007). Hydrological processes in different models of restoration planting of ciliary forest in cerrado region. Rev. Inst. Flor. 19(2):189-200.

Germer S, Elsenbeer H, Moraes JM (2006). Throughfall and temporal trends of rainfall redistribution in an open tropical rainforest, south-western Amazonia (Rondônia, Brazil). Hydrol. Earth Syst. Sci. 10:383-393.

Helvey JD, Patric JH (1965). Design criteria for interception studies. In Design of Hydrological Networks; Proceedings of a symposium pp. 131-137.

IBGE (2002) Brazil climate map. Rio de Janeiro: IBGE, 2002. 1 map. Scale 1:5.000.000. Available at:<ftp://geoftp.ibge.gov.br/mapas/tematicos/mapas_murais>. Accessed on: January 21, 2013.

Izidio NSC, Palácio HAQ, Andrade EM, Neto JRA, Batista AA (2013). Rain interception by caatinga vegetation of the microcatchment in semiarid of cearense. Rev. Agro@ mbiente On-line 7(1):44-52.

Jadoski SO, Lopes EC, Maggi MF, Suchoronczek A, Saito LR, Denega S (2012). Method of determination of the leaf area of the potato cultivar Ágata from linear dimensions. Semina: Ciências Agrárias 33(1):2545-2554.

Keesstra SD (2007). Impact of natural reforestation on floodplain sedimentation in the Dragonja basin, SW Slovenia. Earth Surface Process. Landforms 32(1):49-65.

Keesstra SD, Bruijnzeel LA, van Huissteden J (2009). Meso-scale catchment sediment budgets: combining field surveys and modeling in the Dragonja catchment, southwest Slovenia. Earth Surface Process. Landforms 34(11):1547-1561.

Leopoldo PR, Conte ML (1985). Rainfall distribution in vegetation cover with cerradão characteristics. In Brazilian Symposium on Hydrology and Water Resources and International Symposium on Water Resources in metropolitan areas, São Paulo. Annals São Paulo: ABRH. pp. 212-220.

Lima WP, Nicolielo N (1983). Precipitacao efetiva e interceptacao em florestas de pinheiros tropicais e em reserva de cerradao. Effective precipitation and interception in tropical pinus forests and in a cerradao (Cerrado) reserve 24:43-46. http://www.ipef.br/publicacoes/scientia/nr24/cap04.pdf

Lima WP (1986). Entry of nutrients by rain and leaching from the canopies of the homogeneous forests of tropical pines and in natural vegetation of Cerradão. Acta Limnologica Brasiliensia 1:503-525.

Macinnis-Ng CMO, Flores EE, Müller H, Schwendenmann L (2014). Throughfall and stemflow vary seasonally in different land-use types in a lower montane tropical region of Panama. Hydrological Processes 28(4):2174-2184.

Medeiros PHA, Araújo JC, Bronstert A (2009). Interception measurements and assessment of Gash model performance for a tropical semi-arid region. Revista Ciência Agronômica 40(2):165-174.

Moura AES, Correa MM, Silva ER, Ferreira RLC, Figueiredo AC, Possas JMC (2009). Rainfall interception in an Atlantic Forest fragment in the Prata Basin, Recife, PE. Rev. Árvore 33(3):461-469.

Novara A, Gristina L, Saladino SS, Santoro A, Cerdà A (2011). Soil erosion assessment on tillage and alternative soil managements in a Sicilian vineyard. Soil and Tillage Research 117:140-147.

Oki VK (2002). Impacts of the harvesting of *Pinus taeda* plantation on the water balance, water quality and nutriente cycling of a catchment. Dissertation.

Oliveira Júnior JC, Dias HCT (2005). Net precipitation in a forest fragment of Mata Atlantica. Revista Árvore 29(1):9-15.

Oliveira LL, Costa RF, Sousa FAZ, Costa ACL, Braga AP (2008). Net precipitation and interception in Caxiuanã, in the Eastern Amazonia. Acta Amazonica 38(4):723-732.

Olson JS (1963). Energy storage and the balance of producers and decomposers in ecological systems. Ecology 44(2):322-331.

Oyarzun CE, Godoy R, Staelens J, Donoso PJ, Verhoest NEC (2011). Seasonal and annual throughfall and stemflow in Andean temperate rainforests. Hydrological Processes 25(4):623-633.

Parker GG (1983). Throughfall and stemflow in the forest nutrient cycle. Advances in Ecological Research 13:57-133.

Reddy SJ (1983). Climatic classification: the semiarid tropics and its environment – a review. Pesqui. Agropecu. Bras. 18(7):823-847.

Regalado CM, Ritter A (2010). Synthetic roving: a numerical technique to estimate fog water dripping below the canopy. 5th International Conference on Fog, Fog Collection and Dew.

Santana JAS (2005). Phytossociologic structure, litter production and nutrients cycling in an Caatinga area in the Seridó of the Rio Grande do Norte. Thesis.

Sousa JS (2011). Phytosociology, floristics, and litter formation in Caatinga areas. Dissertation.

Sousa RC, Rizzi NE, Ranzini M, Arcova FCS, Cicco V, Silva LR (2016). Rainfall interception by the canopy of the Alto-Montana Mixed

Ombrophylous Forest in the Campos do Jordão State Park, SP, Brazil. Floresta 46(2):243-250.
Thomaz EL (2005). Assessment of rainfall interception and throughfall in brushes and Secondary Forest in Guarapuava–PR. Geografia (Londrina) 14(1):47-60.
Wink C, Monteiro JS, Reinert DJ, Liberalesso E (2012). Crown parameters and their relationshio with diameter and height of Eucalyptus trees at different ages. Scientia Forestalis 40(93):57-67.