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Incident Precipitation Partitioning: The Canopy Interactions Enrich Water Solution With Nutrients in Throughfall and Stemflow

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Abstract

Atmospheric deposition is responsible for the ions input, which may be due to dust and aerosols and rainfall. During rainfall a portion is intercepted by the tree canopy and returned to the atmosphere by evapotranspiration, another part crosses the forest canopy called throughfall and stemflow. The objective of the present work was to quantify the nutrient input of the incident rainfall, throughfall, stemflow and canopy enrichment in an *Eucalyptus dunnii* plantation, established in soil with low natural fertility. Four plots of 20 m × 21 m were demarcated. The rainfall consists 3 rain collectors in an open área. The throughfall consisted 3 collectors per plot in the line, interlining and diagonal positions of the trees. The stemflow consisted in the installation of three systems per plot formed by a hose in the trunk of the tree that leads the solution to a reservoir. Through rainfall, 29.5 kg ha^{-1} of nutrients were supplied. When we consider the sum of the throughfall and stemflow, the amount of nutrients was 77.6 kg ha^{-1}. After interaction with the tree canopy 48.2 kg ha^{-1} of nutrients were incorporated. Potassium showed the highest enrichment: 607%. The average nutrient enrichment was 163%. The input of N and K via incident rainfall was 1.8 and 3.1 kg ha^{-1}. Considering the fertilization described in the methodology, this contributed amount represents 6.1 and 2.6% of the total. If we consider the rotation of 7 years for *Eucalyptus dunnii*, the contribution at the end of rotation represents 42.4 and 18% of N and K_2O. The interaction with the canopy of *Eucalyptus dunnii* enriches the rainwater with nutrients making the solution with a more basic character.

Keywords: forest nutrition, nutrient cycling, sustainability

1. Introduction

The growth of the world population has generated the search for the increase of raw material, among them the wood and its multiple products. According to FAO 2015, the expansion of the area occupied by forests grew 5 million hectares between 2000 and 2010. In Brazil, between 1990 and 2015 the area occupied grew at an average geometric rate of 1.8%, even thus slightly below the world average of 2.1% (FAO, 2015).

This expansion has occurred in areas often without a silvicultural tradition such as the present study in which it is located in the Pampa Biome. In South America this biome occupies a total area of 751,000 km² (Dixon et al., 2014). About 23.5% of this area is located in Brazil, more specifically in the southern half of the state of Rio Grande do Sul (Brasil, 2016). This region is characterized by predominantly sandy textured soils, low organic matter content and low natural fertility (Suertegaray & Silva, 2009).

To maintain forest productivity in these circumstances, it is essential that atmospheric inputs are computed and considered as a source of nutrients. According to Viera and Schumacher 2010, the movement of the nutrients is dynamic, being continuously transferred between the biotic and abiotic means. This transfer can occur through the geochemical cycle, which is characterized by the inputs that come from dry and wet precipitation (Viera & Schumacher, 2010), which crosses the forest canopy, carries aerosols deposited in the plant tissue and leaches the components of the biomass to the forest floor (Eaton et al., 1973; Schrumpf et al., 2006), representing an important internal flow of nutrients in the forests (Parker, 1983; Bhat et al., 2011; Levia et al., 2011).

The chemical composition of the water from the stemflow and throughfall is a result of the interaction of meteorological factors, distance from the sea, dry depositions and leaching of the canopies (Andre et al., 2008;

Navar et al., 2009), important for the nutrient supply to the roots of the plants and the maintenance of soil water balance (Wang et al., 2011, 2013; Zhang et al., 2013; Jung et al., 2011). According to Neary and Gizyn (1994), the throughfall and stemflow are important sources for the enrichment of cations. Moreover, when treating soils with low cation and sandy exchange capacity, the leaching process has the role of acid neutralization.

Many studies have shown that nutrient levels increase in the following order: incident precipitation < throughfall < stemflow (Balieiro et al., 2007; Perez-Marin & Menezes, 2008). In general, the greater contact of rainfall with vegetation biomass increases the nutrient content, as is the case of stemflow Pereira et al. (2009); Nunes et al. (2003).

The objective of the present work was to quantify the nutrient input of the incident rainfall, throughfall, stemflow and canopy enrichment in an *Eucalyptus dunnii* plantation, established in soil with low natural fertility.

2. Materials and Methods

2.1 Characterization of the Experimental Area

The study was conducted in Alegrete, state of Rio Grande do Sul, southern Brazil, under the central geographic coordinates of 29º47′10″ S and 55º17′30″ W. The experiment is located in a watershed with total area of 340.7 ha. About 31% of the area is for conservation, the remaining 69% is occupied by stands of *Eucalyptus* sp., being 23.4% of the total area covered by the species *Eucalyptus dunnii*. The stand of seminal origin was implanted with spacing 2.5 m × 3.0 m, with an initial density of 1427 trees per hectare. At the time of the study, the trees were between 84 and 96 months old (7 to 8 years respectively).

The planting was carried out in November 2008. Subsoiling and fertilization of 300 kg ha^{-1} of natural phosphate was carried out in the planting line. After 15 days of planting, 140 kg ha^{-1} of N-P_2O_5-K_2O, formulation 06-30-06, + 0.6% of boron were incorporated into the soil. The second fertilizer addition was at 90 days after planting, where 140 kg ha^{-1} of N-P_2O_5-K_2O, formulation 22-05-20, + 0.2% of boron + 0.4% of zinc haul). The third fertilization was at 270 days, using 140 kg ha^{-1} of N-P_2O_5-K_2O, formulation 22-00-18, + 1.0% of sulfur + 0.3% of boron, applied to haul in the line.

2.2 The Weather

The climate of the region is of the wet tempered sub-type Cfa. The variety "Cfa" is characterized by rainfall during all months of the year and has the temperature of the hottest month exceeding 22 °C, and that of the coldest month exceeding 3 °C. The summers can present a period of drought, with average annual temperature of 18.6 °C and average annual rainfall of 1747 mm (Alvares et al., 2014). Figure 1 shows the climatic diagram based on the Alegrete-RS meteorological station. The species *Eucalyptus dunnii*, is still classified with a medium climatic aptitude for the region of Alegrete (Flores et al., 2016).

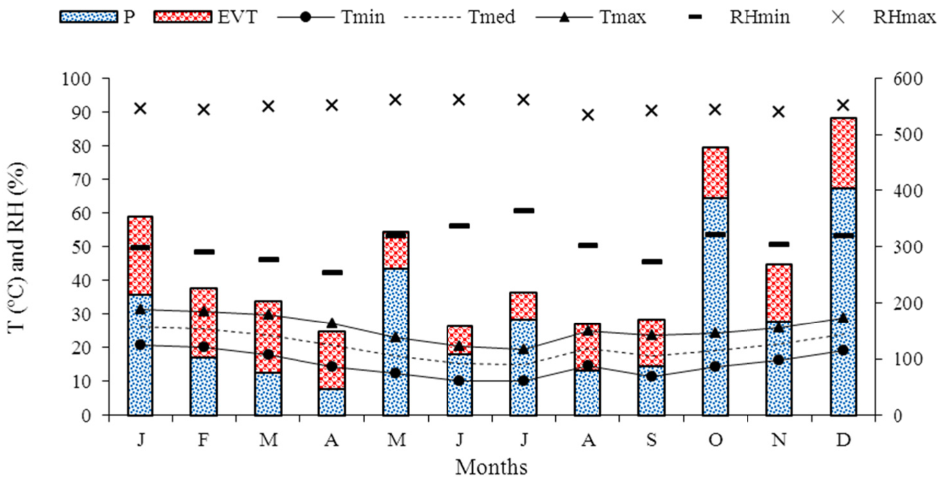

Figure 1. Climatic diagram for the year 2015 in Alegrete-RS

Note. EVT = evapotranspiration.

Source: AGRITEMPO (2019).

2.3 Data Collection

The monitoring of rainfall (P) occurred with the installation of 3 collectors with a diameter of 20 cm at 1.5 m from the ground level. They were allocated in a field area, distant about 50 m from the plots of the eucalyptus stand. *Neoprene* straps with galvanized steel wires were placed in order to avoid that they be used as perches for birds.

For the throughfall (Tf), 4 plots were demarcated inside the stand with dimensions of 20 m × 21 m. Then, 3 collectors with a diameter of 20 cm and height of uptake of 1 m of the soil level were distributed in the positions line, line and diagonal of the trees in each of the plots.

The determination of the amount of rainfall of the incident precipitation (P) and throughfall (Tf) in (mm) was obtained by the following equation:

$$\text{P or Tf} = x/0.0314 \tag{1}$$

where, the amount of rain P or Tf in (mm) is a function of accumulated x (liters), divided by the catchment area in (m^2).

The quantification of the stemflow occurred with the installation of reservoirs with capacity of 60 liters in 3 trees of average DAP per plot. A 1-inch diameter, longitudinally cut hose, spirally mounted near the tree trunk, allowed the water flowing through the trunk to be stored in the reservoirs.

For the calculation of stemflow, the expression used by Preuhsler et al. (2006) was used:

$$\text{Sf} = (\text{V/g}) \times (\text{G/A}) \tag{2}$$

where, Sf = precipitation (mm), V = volume collected (liters) g = tree basal area (m^2) G = basal area of trees in plot (m^2) A = plot area (m^2).

Volume quantification and chemical samples were collected biweekly alongo one year. At each collection the reservoirs were sterilized with a brush and distilled water.

2.4 Chemical Determination

The samples of incident rainfall, throughfall and stemflow were sent to the Laboratory of Forest Ecology of UFSM, which were determined pH, with pH meter containing glass electrode (Metrohm 827 pH LAB), pre-treatment with simple filtration of pores of 0.45 μm for determination of NO_2^-, NO_3^-, PO_4^{3-}, SO_4^-, Cl^-, K^+, Ca^{2+} and Mg^{2+} ions, by means of ion chromatography (Metrohm 861 Advanced Compac IC), all according to the methodology proposed by APHA (1998).

2.5 Statistical Analysis

The relation between the ions present in the solutions of the incident precipitation, throughfall and stemflow was through the Pearson correlation. For this analysis, the IBM SPSS 20.0. software was used.

The enrichment factor estimates the percentage gains of each nutriente when interacting with the tree canopy. For the calculation are used the amounts (kg ha^{-1}) in each partition of the rain,

$$\text{Nutrient enrichment (\%)} = \frac{(\text{Tf} + \text{Sf}) - \text{P}}{\text{P}} \times 100 \tag{3}$$

where, Tf: throughfall; Sf: stemflow; P: incidente precipitation.

The relation between throughfall and stemflow was calculated by the incident precipitation. The amounts of each nutrient in the different partitions were used (Macinnis-Ng et al., 2012):

$$\text{E} = \text{P/(Tf or Sf)} \tag{4}$$

where, E: enrichment; Tf: throughfall; Sf: stemflow; P: Precipitation.

The balance between the sum of cations and anions is important for understanding the measurements. The relationship between the two groups is expected to be unitary for quality assurance (Al Monami et al., 1995). In the present study, the results showed a unit balance of 0.9. Caggiano et al. (2014) studying the chemical composition of rainwater in western Bulgaria found a value of 1.5 indicating that some cations were excluded from the measurements.

3. Results and Discussion

3.1 Rainfall Partitioning

The total rainfall for the evaluation period was 1903 mm. The average interception by the crown of the trees was 8.9%. The internal precipitation and trunk counts were 90.3% and 0.8%, respectively. Information can be found in Momolli et al. (2019).

3.2 Concentration of Ions

The average pH was 4.57; 4.64 and 5.54 for incidente, throughfall and stemflow (Figure 2). According to Charlson and Rodhe (1982), values below 5.6 may be considered acidic. It is also noted that the extent to which water flows through the leaves, branches, trunk and bark carries basic cations, thereby increasing the pH of the aqueous solution.

The results show that the canopy have the capacity to neutralization the pH of the solution as it interacts with the canopy of the stand. Crockford, Richardson, and Sageman (1996) found pH of 5.66 and 5.30 for throughfall and incident precipitation respectively. According to Miller (1984) these results also suggest the absorption of hydrogen ions by the surface of the vegetation neutralizing the pH of water. Other studies have confirmed the tendency to increase pH as is the case of Shiklomanov and Levia (2014) studying the neutralization capacity of the stemflow in the stand of *Liriodendron tulipifera* at 19 years of age in Maryland USA.

Evaluating the pH in *Eucalyptus dunnii* stands from 5 to 6 years of age, Dick et al. (2018) showed that the pH was 4.3; 5.0 and 5.3 for incident precipitation, throughfall and stemflow respectively. Correa (2011) also studying a stand of *Eucalyptus dunnii* from 1.4 to 2.4 years of age found the following pH values: 5.0; 5.2 and 5.3 for incident precipitation, throughfall and stemflow respectively.

The order of the contents of the ions in the rainfall precipitation incident was: $SO_4^{2-} > Ca^{2+} > Cl^- > K^+ > Mg^{2+} > NO_3^- > NO_2^- > PO_4^{3-}$. In the throughfall: $Cl^- > K^+ > Ca^{2+} > SO_4^{2-} > Mg^{2+} > NO_3^- > NO_2^- > PO_4^{3-}$. Stemflow: $K^+ > Cl^- > Mg^{2+} > Ca^{2+} > SO_4^{2-} > PO_4^{3-} > NO_2^- > NO_3^-$.

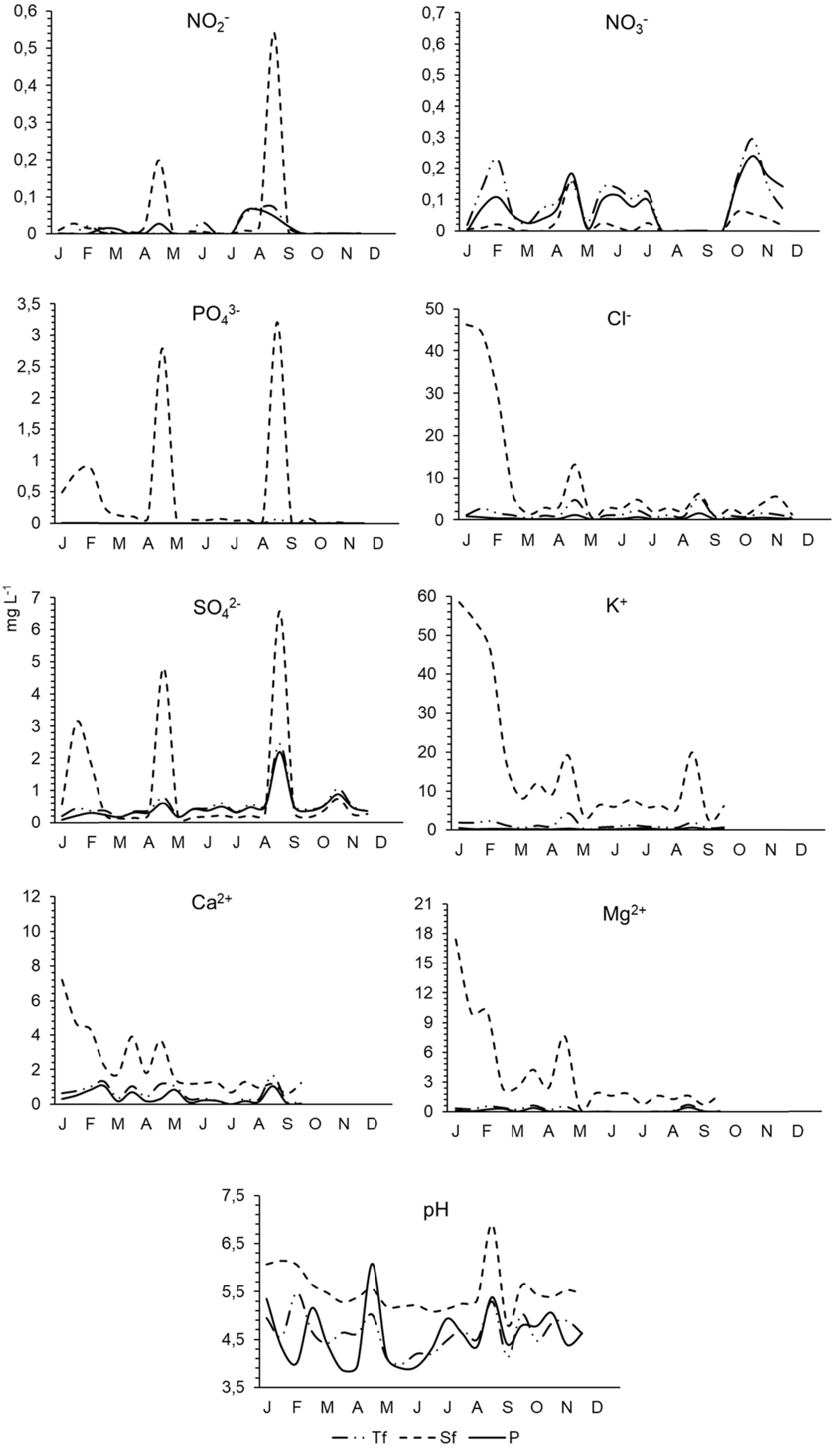

Figure 2. Concentration of the Ions (mg L^{-1}) and pH, for Incident precipitation (P), throughfall (Tf) and stemflow (Sf)

After interaction with the canopy, all the ions presented increase in the contents. In general, the contents of the stemflow solution were more expressive mainly because of the low volume of water. The mean K$^+$ contents were:

0.20; 1.28 and 17.55 mg L^{-1} for P, Tf and Sf. Cl^- also recorded a significant increase: 0.41; 1.5 and 11.14 mg L^{-1} for P, Tf and Sf.

The calcium contents were 0.42; 0.71 and 2.73 for P, Tf and Sf. Although Valente et al. (2016) found higher levels of the element in P than in Tf, Cornu et al. (1998) suggested that the washing of exudates from the decomposition of branches contributed to the increase in Tf.

Mg^{2+} and Ca^{2+} ions had a *Pearson* correlation of: 0.91; 0.89 and 0.57 for incident precipitation, throughfall and stemflow respectively (Table 1). Salve et al. (2008) evaluating the chemical composition of rainwater in Maharashtra in India found r = 0.95. The authors suggest that this high correlation is due to the occurrence of crustal origin.

Pearson's correlation also shows the inverse relation between the pluviometric indexes and the ion concentration. This finding can also be observed in other studies such as Valente et al. (2016) quantifying the nutrient input in *Eucalyptus urophylla* × *Eucalyptus globulus* stands. According to Laclau et al. (2003) this can be explained by the effect of dilution of the ions as precipitation increases.

Table 1. Pearson correlation analysis between ions in the incident precipitation (P), throughfall (Tf) and stemflow (Sf) in *Eucalyptus* stands *dunnii*

	$P_{(mm)}$	pH	NO_2^-	NO_3^-	PO_4^{3-}	Cl^-	SO_4^{2-}	K^+	Mg^{2+}	Ca^{2+}
$P_{(mm)}$	1									
pH	-0.27	1								
NO_2^-	-0.31	0.98^{***}	1							
NO_3^-	-0.36	-0.17	-0.01	1						
PO_4^{3-}	-0.28	-0.11	0.06	0.95^{***}	1					
Cl^-	-0.42	-0.18	-0.03	0.89^{***}	0.91^{***}	1				
SO_4^{2-}	-0.27	-0.08	-0.12	-0.23	-0.21	0.09	1			
K^+	0.00	-0.04	-0.06	0.08	-0.05	-0.07	0.05	1		
Mg^{2+}	-0.28	1.00^{***}	0.99^{***}	-0.11	-0.05	-0.14	-0.11	-0.03	1	
Ca^{2+}	-0.26	0.91^{***}	0.90^{***}	-0.14	-0.05	-0.07	0.03	-0.15	0.91^{***}	1
	$Tf_{(mm)}$	pH	NO_2^-	NO_3^-	PO_4^{3-}	Cl^-	SO_4^{2-}	K^+	Mg^{2+}	Ca^{2+}
$Tf_{(mm)}$	1									
pH	-0.26	1								
NO_2^-	-0.35	0.92^{***}	1							
NO_3^-	-0.36	-0.19	0.19	1						
PO_4^{3-}	-0.27	-0.12	0.27	0.95^{***}	1					
Cl^-	-0.54^{*}	-0.26	-0.06	0.52^{*}	0.50^{*}	1				
SO_4^{2-}	-0.32	0.03	-0.06	-0.28	-0.24	0.52^{*}	1			
K^+	-0.04	-0.05	-0.08	0.05	-0.06	-0.11	0.02	1		
Mg^{2+}	-0.27	1.00^{***}	0.95^{***}	-0.12	-0.05	-0.24	0.01	-0.03	1	
Ca^{2+}	-0.34	0.89^{***}	0.89^{***}	0.01	0.08	0.08	0.18	-0.18	0.89^{***}	1
	$Sf_{(mm)}$	pH	NO_2^-	NO_3^-	PO_4^{3-}	Cl^-	SO_4^{2-}	K^+	Mg^{2+}	Ca^{2+}
$Sf_{(mm)}$	1									
pH	0.15	1								
NO_2^-	-0.30	-0.91^{***}	1							
NO_3^-	-0.32	-0.67^{***}	0.51^{*}	1						
PO_4^{3-}	-0.47^{*}	0.26	-0.01	0.13	1					
Cl^-	-0.34	0.29	-0.15	-0.04	0.26	1				
SO_4^{2-}	-0.48^{*}	0.29	0.03	-0.04	0.95^{***}	0.31	1			
K^+	-0.31	0.44^{*}	-0.25	-0.18	0.34	0.97^{***}	0.39	1		
Mg^{2+}	-0.30	0.35	-0.21	-0.14	0.24	0.91	0.25	0.90^{***}	1	
Ca^{2+}	-0.42	-0.45^{*}	0.60^{**}	0.31	0.14	0.59^{**}	0.15	0.53^{*}	0.57^{**}	1

Note. Level of significance: *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

The pH had a correlation of 1.00 and 0.89 with the Mg^{2+} and Ca^{2+} ions in the throughfall. These findings suggest that the leaching of plant tissues, when carrying basic cations, becomes responsible for neutralizing the pH from the incident precipitation.

3.3 Nutrients Input

The total amount of ions was 29.5; 67.6 and 10.0 kg ha^{-1} for incident precipitation, throughfall and stemflow respectively. The difference between the net precipitation by the incident precipitation ((Tf + Sf) – P) was 42.8 kg ha^{-1}, which in turn represented an enrichment of 163.5% of the total amount of ions contributed after interaction with the stands.

The total amount contributed by the net precipitation was 77.6 kg ha^{-1}, of which, 64.7% were Cl^- + K^+ (Figure 3). The difference of K^+ d the net precipitation by the incident precipitation shows an increase of 18.8 kg ha^{-1}, that is, 607% enrichment. The same behavior was observed for Mg^{2+} and Cl^-, in which the interaction with the canopy was responsible for the enrichment in 155 and 276% respectively.

The input of 7.5 kg ha^{-1} of chlorine in the incident precipitation is similar to that found by Dick et al. (2018) who quantified an average of 6.5 kg ha^{-1} for two years of evaluation. However, Valente et al. (2016) quantified a contribution of 49.4 kg ha^{-1}, and the experiment was 170 km away from the ocean. For Loss et al. (2010) as it moves away from the ocean towards the interior of the continent, the proportion of Cl^- decreases. Sodium chloride has its source from the evaporation of ocean water and enters the continent by means of marine spray. The present study is 400 km away straight from the ocean.

In relation to the expressive increase of chlorine in the internal precipitation, Prado (2008) points out that the element has high mobility in the plant, being constituent of the photosynthesis and therefore easily leached from the plant structures.

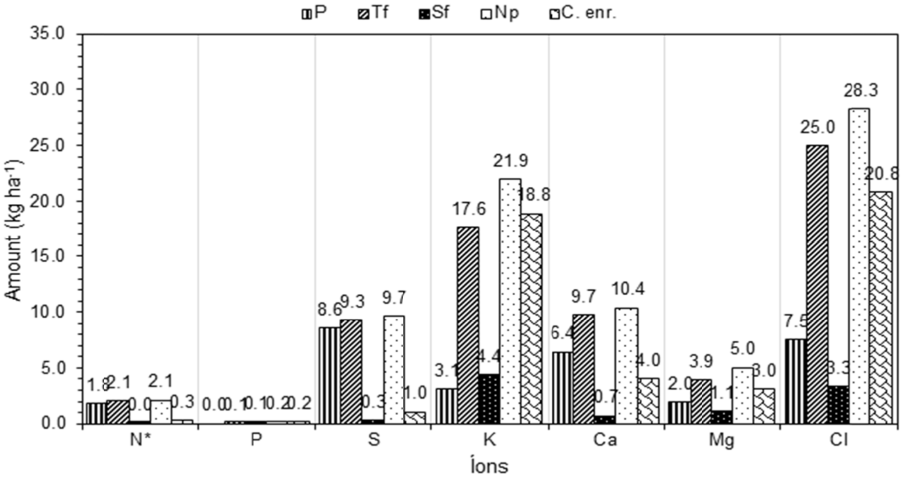

Figure 3. Nutrients input (kg ha^{-1}) for incident rainfall (P), throughfall (Tf), stemflow (Sf) and net precipitation (Pl)

Note. N* = NO_2^- + NO_3^-.

On average, 46.2 % of the nutrients come from the incident precipitation and 53.8% from the interaction with the biomass (Table 2). It is also observed that 61.7 and 89.2% of $Ca^{2+}$and SO_4^{2-}, are derived from the incident precipitation. The Sf represents only 0.8% of the solution volume, however, when we consider the concentration of ions becomes more representative, reaching 12.8%. According Gay and Murphy (1985) approximately 30-70% of the total dry deposited SO_4^{2-} may be retained in the canopy.

Calil et al. (2010) found an entry for nutrients incident rainfall 102.1 kg ha^{-1}, of these, about 40% of SO_4^{2-}. In the present study, the total was only 29.5 kg ha^{-1}, of these, 29.2% SO_4^{2-}. The higher amount of SO_4^{2-} by Calil et al. (2010) whether the existence of pollutant emissions by burning coal in thermoelectric Candiota. According to Rótulo (2003), the plant did not have a suitable filter system, which caused the high emission of SO_4^{2-}.

Table 2. Percentage of chemical elements in incident precipitation (P), throughfall (Tf), stemflow (Sf) and nutriente enrichment after canopy interaction

Partition	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	Average
	--			% --		
P	14.1	61.7	39.1	89.2	26.6	46.2
Tf	68.8	35.8	47.3	10.3	64.7	45.4
Sf	17.1	2.5	13.6	0.5	8.7	8.45
Total	**100**					
Tf + Sf	85.9	38.3	60.9	10.8	73.4	53.8
	--			Np --		
Tf	80.1	93.5	77.6	96.7	88.2	87.2
Sf	19.9	6.5	22.4	3.3	11.8	12.8
Total	**100**					
Nutrient enrichment	607.1	62.0	155.5	12.1	275.8	222.5

Migliavacca et al. (2005) in a study developed in the region of Candiota found slightly acid pH indexes 4.0-5.6. The factorial analysis also showed a possible contribution of marine salts influencing the contents of Cl^- and Mg^{2+}. The analysis also indicated anthropogenic influences mainly for SO_4^{2-} and K^+ ions. In our study, the mean pH was 4.5; 4.7 and 5.6 for incident, throughfall and stemflow, indicating mild acidity.

A prediction model was presented during CLRTAP, the Gothenburg Protocol (Fagerli et al., 2006), showed that in 1990 several areas of Europe had S deposition higher than 30 kg ha^{-1}. In 2004, only part of Europe had deposition higher than 10 kg ha^{-1}. These results are relevant to the reduction of particulate emissions by the best efficiency of the filters, therefore, for the study developed by Calil et al. (2010), the quantities were above average.

Rainwater when interacting with the canopy is enriched mainly with K^+, Mg^{2+} and Cl^-. In Table 3 the Tf/P (throughfall/precipitation) and Sf/P ratio (stemflow/precipitation) is compared for the ion concentrations found in the present study with those of other works. Relationships > 1, indicate that there is an increase in contents after passage through the canopy. Cl^- and Ca^{2+} presented the lowest relationships for throughfall. Sulfate (SO_4^{2-}) is formed after the absorption of SO_4^{2-} by clouds or raindrops, followed by oxidation in aqueous phase (Vujović & Milić-Petrović, 2016), which explains the lower levels. For Laclau et al. (2003) and Laclau et al. (2010) values < 1 were observed for Ca^{2+} in the throughfall.

Table 3. Relation of the concentrations of the precipitation incident with the throughfall (Tf) and stemflow (Sf) with other studies

	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Cl^-	Author	Specie
Tf	3.70	1.21	6.33	2.21	1.69	Present study	*Eucalyptus dunnii*
Sf	27.40	2.30	86.56	35.24	6.49		
Tf	2.80	0.99	3.30	1.24	1.38	Laclau et al. (2003)	*Eucalyptus* (Rainy season)
Sf	10.48	2.09	21.31	3.29	6.28		
Tf	1.46	1.14	1.85	1.48	1.04		*Eucalyptus* (Dry season)
Sf	1.64	1.05	6.84	1.11	1.95		
Tf	4.21	1.50	2.46	-	-	Balieiro et al. (2007)	*Eucalyptus grandis*
Sf	25.71	18.75	18.21	-	-		
Tf	6.89	1.43	2.38	1.09	3.96	Corrêa (2011)	*Eucalyptus dunnii*
Sf	39.11	5.09	8.50	1.00	14.17		
Tf	24.36	11.25	5.83	-	-	Dezzeo and Chacón (2006)	Primary Forest
Sf	42.36	17.00	5.33	-	-		
Tf	6.38	1.30	1.57	1.43	1.19	Caggiano et al. (2014)	*Fagus sylvatica*
Sf	8.12	2.70	2.83	3.33	1.87		
Tf	4.42	2.11	2.34	2.55	1.47	Caggiano et al. (2014)	*Picea abies*
Sf	8.89	5.65	5.34	8.29	2.33		
Tf	5.22	1.46	3.28	1.51	1.84	Dick et al. (2018)	*Eucalyptus dunnii*
Sf	38.43	1.74	19.00	0.92	7.79		
Tf	12.85	2.15	1.65	1.98	1.44	Heartsill-Scalley et al. (2007)	Subtropical Forest
Tf	3.58	-	-	-	-	Perez-Marin and Menezes (2008)	*Gliricidia sepium*
Sf	6.46	-	-	-	-		

Laclau et al. (2010) evaluating chlorine + potassium in the throughfall and stemflow found 7.0 and 5.8 kg ha^{-1} in Itatinga-Brazil and Kondi-Congo respectively. In the present study the quantities were much higher than 31.5 kg $ha^{-1}$for Tf + Sf. Salehi et al. (2016) found more approximate values, 36.3 kg ha^{-1}.

The chemical alteration of the throughfall is due to leaching of the plant structures (leaves, bark, etc.), together with the dissolution of aerosols and particles deposited on the forest canopy (Lindberg & Lovett, 1985; Laclau et al., 2003). Salehi et al. (2016) also showed that the canopy composition in stands of eastern Phage had great influence on the nutrient flow of Tf. Caggiano et al. (2014) found an increase in K^+ levels in the Tf: 572 and 486% for *Fagus sylvatica* L. and *Spruce abies* L., relative to the incident precipitation.

Calil et al. (2010) studied the precipitation via nutrient inputs in the southeast of Rio Grande do Sul. The average rainfall of the two years evaluated was 1588 mm, about 12% higher than the historical average for the region. *Pearson's* correlation to the authors showed that when the rainfall volumes are higher, the average concentrations of ions decrease considerably (negative correlation). This behavior was observed in our study and is related to the dilution effect of deposited and suspended particles.

4. Conclusions

Although it represents 0.8% of the volume of solution of the precipitation incidente, the stemflow represents an important source of nutrients to soil 12.8%. The pH of the incident precipitation and throughfall is influenced by Ca^{2+} and Mg^{2+} cations and by NO_2^-. The forest canopy is able to neutralize the pH of the incident precipitation through the absorption of H ions and leaching of basic cations present in the cellular structures.

The total nutrient input by the precipitation after interaction with the canopy was 2.6 times higher when compared to the open area entrances.

The input of N and K via incident rainfall was 1.8 and 3.1 kg ha^{-1}. Considering the fertilization described in the methodology, this contributed amount represents 6.1 and 2.6% of the total. If we consider the rotation of 7 years for *Eucalyptus dunnii*, the contribution at the end of rotation represents 42.4 and 18% of N and K_2O. Through these results we can infer about the management of fertilization allowing the reduction of the applied amounts of fertilizers. With this, there is a reduction of the costs of fertilization, labor, and benefits to the environment with the reduction of the risks of contamination of the water table.

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