ENFLO
Ecologia e Nutrição Florestal
www.ufsm.br/enflo/
ISSN: 2316-980X
Artigo Científico

Chemical composition of soil solution under eucalyptus plantation in Southern Brazil [1]

Márcio Viera[2]; Mauro Valdir Schumacher [3]

Abstract: This study focuses on changes in the chemical composition of solutions during their transfer in the soil cultivated with hybrid of *Eucalyptus urophylla* x *Eucalyptus globulus* stand in southern Brazil. The chemical composition of soil solution was evaluated from January to December 2010, when the plant was from 8.5 to 9.5 years-old. Ceramic lysimeters were installed in order to measure the chemical composition of the soil solution in two different depths (30 and 80 cm) with six repetitions. The lysimeters were connected to a vacuum pump, where in each four hours, during ten minutes, the solution was suctioned. The soil solutions were collected in glass bottles with 0.5 liters of capacity. Fortnightly the samples were collected and each replicate of soil solution was analyzed separately. The solutions were filtered (0.45 μm) and the nutrients concentrations were measured. The concentration of N – NO_3^-, K^+, Ca^{2+}, Mg^{2+}, Na^+, S – SO_4^{2-} and pH were variable during the year, but without significant difference ($p > 0.05$) in both depth (30 and 80 cm in depth). However, N - NH_4^+ concentration of soil solution was high, for both depths, in the months November and December. The concentrations of soil solution N – NO_3^-, N - NH_4^+, K^+ and Mg^{2+} are not different in the soil profile (30 and 80 cm depth). S – SO_4^{2-} (2.67 and 2.17 mg L^{-1}, respectively in 30 and 80 cm depth) and Ca^{2+} (1.17 and 0.64 mg L^{-1}, respectively in 30 and 80 cm depth) decrease in soil profile ($p < 0.05$), whilst, Na^+ (2.10 and 2.60 mg L^{-1}, respectively in 30 and 80 cm depth) and pH (4.78 and 5.11, respectively in 30 and 80 cm depth) increase in soil profile ($p < 0.05$). Pearson's correlation between cations and anions in the soil solution was significant ($p < 0.01$). In both depths, N – NO_3^- was directly correlated with Ca^{2+} and Mg^{2+}, whilst S – SO_4^{2-} was inversely correlated with Mg^{2+}. This change in chemical composition of soil solution indicated different patterns of nutrients were taken up by roots.

Keywords: Forest nutrition; Water-plant relation; Nutrients available.

Composição química da solução do solo em um plantio de eucalipto, Rio Grande do Sul, Brasil.

Resumo: Objetivou-se com o estudo avaliar as mudanças na composição química da solução, no perfil do solo, sob cultivo do híbrido de *Eucalyptus urophylla* x *Eucalyptus globulus* no extremo sul do Brasil. A composição química da solução do solo foi avaliada quinzenalmente de janeiro a dezembro de 2010, quando as plantas estavam com 8,5 a 9,5 anos de idade. Foram instalados lisímetros para analisar a composição química da solução do solo em duas diferentes profundidades (30 e 80 cm) em seis repetições. Os lisímetros foram conectados a bomba de vácuo, onde em cada quatro horas, durante 10 minutos, a solução foi succionada. A solução do solo foi coletada em garrafas com capacidade de 0,5 litros. Quinzenalmente as amostras foram coletadas e cada repetição da solução do solo foi analisada separadamente. A solução foi filtrada (0,45 μm) e a concentração de nutrientes foi analisada. As concentrações de N – NO_3^-, K^+, Ca^{2+}, Mg^{2+}, Na^+, S – SO_4^{2-} e pH foram variáveis durante o ano, mas sem diferença significativa ($p > 0,05$) em ambas as profundidades (30 e 80 cm). No entanto, a concentração de N - NH_4^+ na solução do solo foi maior, para ambas as profundidades, para os meses de novembro e dezembro. A concentração de N – NO_3^-, N - NH_4^+, K^+ e Mg^{2+} na solução do solo não diferiram no perfil do solo (30 e 80 cm de profundidade). A concentração de S – SO_4^{2-} (2,67 e 2,17 mg L^{-1}, respectivamente para 30 e 80 cm de profundidade) e Ca^{2+} (1,17 e 0,64 mg L^{-1}, respectivamente para 30 e 80 cm de profundidade) diminui com a profundidade ($p < 0,05$). Enquanto que, Na^+ (2,10 e 2,60 mg L^{-1}, respectivamente para 30 e 80 cm de profundidade) e pH (4,78 e 5,11, respectivamente para 30 e 80 cm de profundidade) aumenta com a profundidade ($p < 0,05$). A correlação de Pearson entre cátions e anions foi significativa ($p < 0,01$). Para ambas as profundidades, a concentração de N – NO_3^- esteve correlacionada com Ca^{2+} e Mg^{2+}, enquanto S – SO_4^{2-} esteve inversamente correlacionada com a concentração de Mg^{2+}. Essa mudança na composição química da solução do solo indica que ocorrem diferentes padrões de absorção de nutrientes pelas raízes das plantas.

Palavras - chave: Nutrição florestal; Relação água-planta; Disponibilidade de nutrientes.

[1] Recebido em 30.08.2014 e aceito para publicação como **artigo científico** em: 02.12.2014.
[2] Engenheiro Florestal, Dr., Professor Adjunto I do Departamento Multidisciplinar da Universidade Federal de Santa Maria – Campus Silveira Martins. E-mail:<vieraflorestal@yahoo.com.br>.
[3] Engenheiro Florestal, Dr. nat. techn., Professor Titular do Departamento de Ciências Florestais, Universidade Federal de Santa Maria. E-mail:<mvschumacher@gmail.com>

Introduction

In Brazil there are at about 5.1 million hectares of eucalyptus plantation, which 284.7 thousand hectares are in the state of Rio Grande do Sul (ABRAF, 2013). The use of eucalyptus in new plantings is being intensified, especially in places without a forest section. In addition, many species of eucalyptus grow relatively well in soils of low fertility (Reis et al., 1989). According to the authors, this may possibly be linked to the low nutritional requirement, the efficiency of the use of nutrients by plants and nutrient cycling. In Brazil, the cultivation of eucalyptus is still strongly criticized by society due to the amount of water used for plantations. Caldato and Schumacher (2013) suggest that, the relationship between the forest plantations and the water depends on the region, species, environmental conditions and management practices on the watershed scale.

The chemical compositions of soil a solution has been extensively studied in forest ecosystems of temperate regions, but on eucalyptus plantation it has been scarce (LACLAU et al., 2003). Studies on quality of soil solution are important for the verification of the effects of forest cultivation on nutrient availability (HOPMANS and BREN, 2007). The chemical composition of soil solution is related to complex processes, such as: the input of nutrients in dry and wet precipitation, organic matter mineralization and weathering, ionic equilibrium, the outputs by roots and microorganisms uptake, and leaching (LACLAU et al., 2003).

In fast-growing plantations the potential uptake rates depends on the functional specialization of roots (SILVA et al., 2011). Mareschal et al. (2013) studied the effect to eucalyptus plantations managed in short rotations after afforestation of an African savanna. They indicated that the limited changes between the nutrient fluxes in ecosystems was the result of fast root growth in the deep soil layers after planting, combined with an intense uptake of the tree roots to satisfy the large nutrient and water requirements. The understanding on the principles of soil nutrient supply and uptake, which link soil and solution culture studies, is likely to provide a unifying approach for diagnosing nutrient-supply limitations to plant growth and a practical tool for nutrient management in forest plantations (SMETHURST, 2000). This study focuses on changes in the chemical composition of solutions during their transfer in the soil cultivated with hybrid of *Eucalyptus urophylla* x *Eucalyptus globulus* stand in southern Brazil.

Material and methods

Study site

This study was conducted in an experimental area in Eldorado do Sul, in the state of Rio Grande do Sul, Brazil. The central geographic coordinate is 30º 10' 31.21" S and 51º 36' 17.85" W. The local climate, according to Köppen classification, is Cfa type, characterized as being subtropical. In the region, the temperature of the coldest month is 9.2 ºC and the average warmest month is 24.6 ºC (FEPAGRO, 2012). The rainfall was about 1,500 mm during the experiment (12 months) which 6.5% of the rainfall intercepted in the canopy.

The hybrid of *Eucalyptus urophylla* x *Eucalyptus globulus* stand was planted in July, 2001 and the spacing was 3.5 m x 2.5 m, after subsoiling at a mean depth of 40 cm, in the planting row. Concomitantly to this operation, the soil received a chemical fertilizer, at the planting row, with the following formulation: 06:30:06 of the formula N – P_2O_5 – K_2O, applied at the rate of 100 g plant^{-1} and 300 kg ha^{-1} of reactive phosphate. More two chemical fertilizations were made: one at three months after the planting seedlings, with addition of 150 g plant^{-1} of NPK 15:05:30, and other at 12 months-old, with the same formulation and the same amount

The leaf area index was 2.55 when the stand was about 10 years old (June, 2010). In this age, the stand was a stocking of 707 trees per hectare, with the mean height of 28.7 m, a mean diameter at breast height of 20.2 cm and a mean over-bark volume of 444.3 m^3 ha^{-1}.

Soil characterization

The type of soil was acrisol (FAO classification) of a low fertility. The soil was acid (pH (H_2O) < 4.8) and with low amount of nutrients (CEC < 7.5 $cmol_c$ dm^{-3}) in the upper layers. The organic matter content ranged from about 2.5% in the first layer (0-25cm) to about 0.5% a depth of 1 m (Table 1).

Table 1: Soil characteristics in the experimental area during the study (n=9).
Tabela 1: Atributos do solo na área experimental durante o estudo (n=9).

Depth (cm)	Particle size distribution (%)			OM*	pH (H_2O)	P	K
	Clay	Silt	Sand	%		mg dm^{-3}	
0 - 25	42.2	11.6	46.2	2.46	4.64	1.86	73.46
25 - 50	62.7	13.8	23.5	1.94	4.73	0.85	71.92
50 - 75	50.8	19.4	29.8	0.90	4.81	0.83	55.27
75 - 100	24.4	25.7	49.9	0.48	4.87	0.75	37.80
Depth (cm)	**OC**	**N**	**Al**	**CEC**	**Ca**	**Mg**	**Na**
	%		$cmol_c$ dm^{-3}				
0 - 25	1.23	0.08	4.13	7.47	0.34	0.41	0.28
25 - 50	0.97	0.07	5.38	6.09	0.25	0.42	0.25
50 - 75	0.45	0.03	4.83	4.72	0.24	0.38	0.22
75 - 100	0.24	0.02	4.45	8.02	0.24	0.30	0.30

* OM = Organic Matter; OC = Organic carbon; CEC = Cation Exchange Capacity.

Collection and analysis of solutions

The chemical composition of soil solution was evaluated fortnightly from January to December in 2010, when the plant was from 8.5 to 9.5 years-old. Ceramic lysimeters were installed in order to measure the chemical composition of the soil solution in two different depths (30 and 80 cm) with six repetitions. The lysimeters were connected to a vacuum pump at a suction of about 0.4 – 0.6 bar, when in each four hours, during ten minutes, the solution was suctioned (the control of the period was made by an electronic timer). The soil solutions were collected in glass bottles with 0.5 liters of capacity. Fortnightly, the samples were collected and each replicate of soil solution was analyzed separately.

The solutions were filtered (0.45 μm) and the nutrient concentrations were measured based in the "Standard methods for the examination of water and wastewater" the best current practice of American water analysts (APHA, 1998). The ammonium, nitrate and sulfate were analyzed by ion chromatography (861 Advanced - Metrohm), calcium and magnesium by atomic absorption spectrometry (AAnalyst 200 Perkin Elmer), potassium and sodium by flame photometry (DM-62 Digimed).

Statistical data processing

The statistical analysis has been performed using the SPSS 13.0 for Windows (1996), at a 5% of error probability, considering a completely randomized design, for evaluated the elements concentration during the year. In order to separate the average contrast, the Tukey test was used. In each depth, paired comparison *t*-tests were performed on the differences between concentrations of soil solutions collected during the year. Pearson's correlation coefficients between cations and anions were calculated at a 1 or 5% of error probability.

Results and discussion

The concentration of N – NO_3^- (1.85 mg L^{-1} ± 1.09 and 1.39 mg L^{-1} ± 0.81), K^+ (1.18 mg L^{-1} ±

0.27 and 0.90 mg L^{-1} ± 0.36), Ca^{2+} (1.36 mg L^{-1} ± 0.62 and 0.57 mg L^{-1} ± 0.27), Mg^{2+} (1.53 mg L^{-1} ± 0.37 and 1,04 mg L^{-1} ± 0.57), Na^{+} (2.03 mg L^{-1} ± 0.36 and 2.82 mg L^{-1} ± 0.75), $S - SO_4^{2-}$ (2.56 mg L^{-1} ± 0.42 and 2.19 mg L^{-1} ± 0.19) and pH (4.74 ± 0.21 and 5.12 ± 0.23) were variable during the year, but they were without significant difference ($p > 0.05$) in both depth (30 and 80 cm, respectively) (Figure 1).

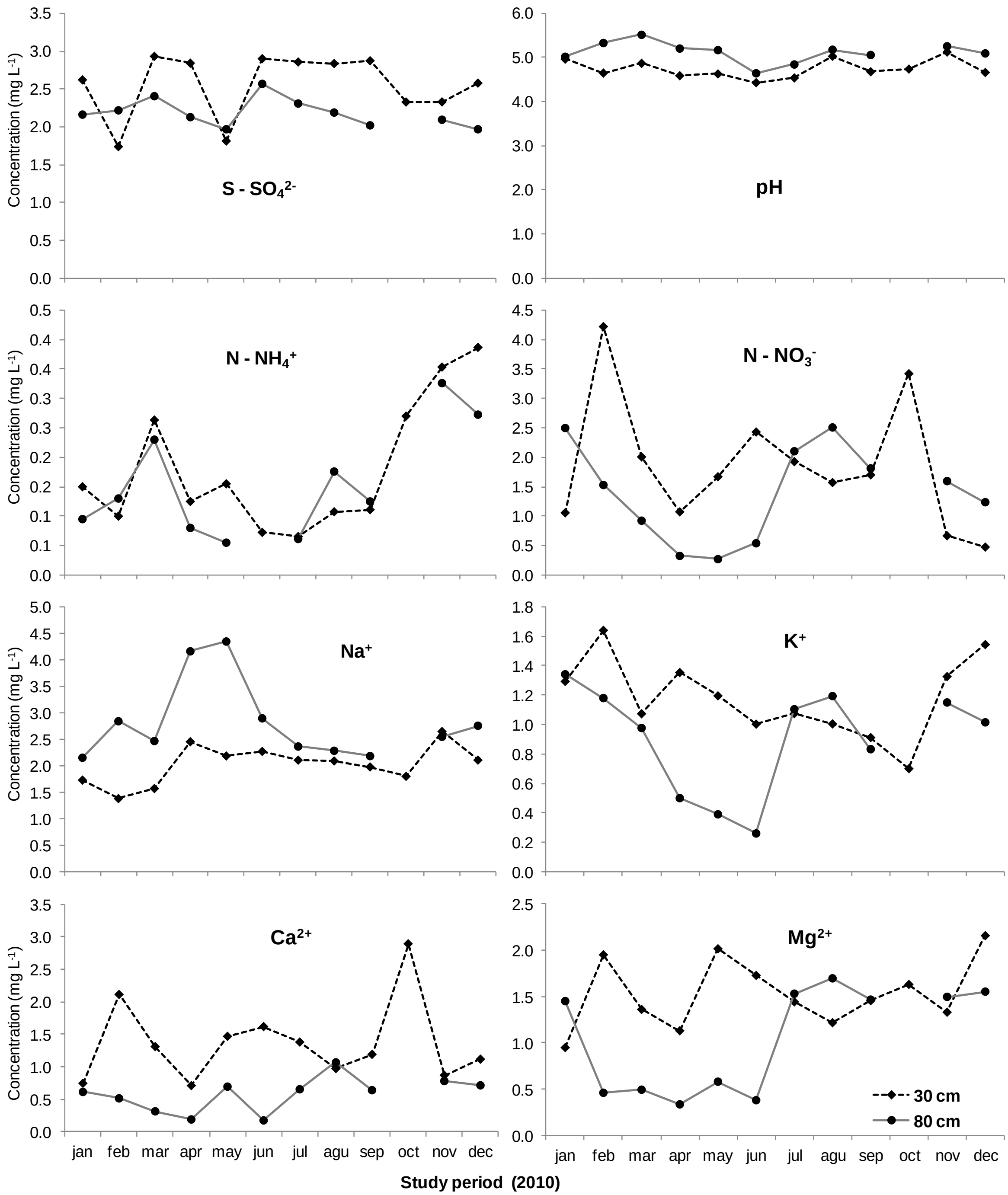

Figure 1: Monthly composition of soil solutions in the eucalyptus stand, during the study period (2010).
Figura 1: Composição mensal da solução do solo em um povoamento de eucalipto, durante o período de estudo (2010).

However, $N - NH_4^+$ (0.18 mg L^{-1} ± 0.11 and 0.16 mg L^{-1} ± 0.09, at 30 and 80 cm depth, respectively) concentration of soil solution was high, for both depths, in the months November and December. Laclau et al. (2003) observed that a general trend is the highest concentration during the initial months after the dry season, but with weak and not significant differences.

The concentrations of soil solution $N – NO_3^-$, $N - NH_4^+$, K^+ and Mg^{2+} are not different in the soil profile (30 and 80 cm depth) (Figure 2). $S – SO_4^{2-}$ (2.67 and 2.17 mg L^{-1}, respectively in 30 and 80 cm depth) and Ca^{2+} (1.17 and 0.64 mg L^{-1}, respectively in 30 and 80 cm depth) decrease in soil profile ($p < 0.05$), whilst Na^+ (2.10 and 2.60 mg L^{-1}, respectively in 30 and 80 cm depth) and pH (4.78 and 5.11, respectively in 30 and 80 cm depth) increase in soil profile ($p < 0.05$). For both depths, the pH of the soil solutions was acid. The anion concentrations were greater for $S – SO_4^2$ followed by $N – NO_3^-$. The cation concentrations were upper for Na^+. The same pattern was observed by Mareschal et al. (2013), with eucalyptus plantations in Africa.

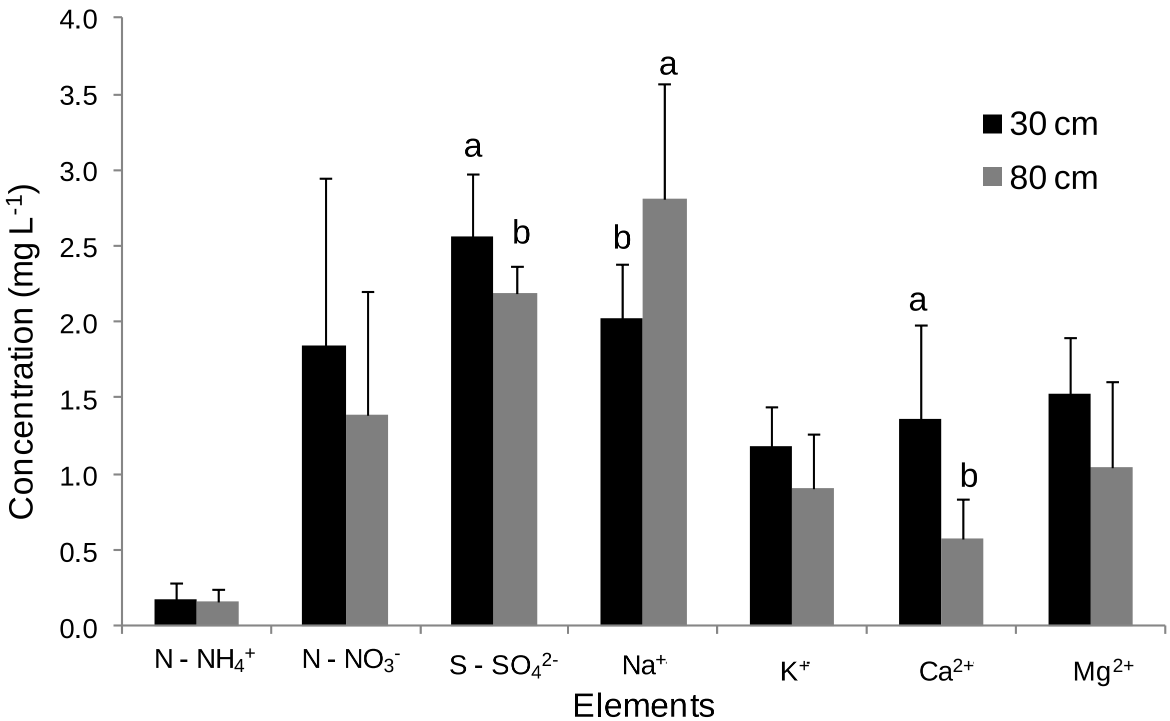

Figure 2: Soil solution concentration in the soil profile, during January and December period, 2010.
Figura 2: Concentração da solução do solo em diferentes profundidades, durante o período de janeiro a dezembro de 2010

The differences in nutrients concentrations in the soil profile can be related to the uptake rates and the trees growth. Silva et al. (2011) evaluating *Eucalyptus grandis* plantations observed that the fine roots exhibit contrasting potential uptake rates with depth depending on the nutrient. These authors suggest that, the roots specialization might contribute to the high growth rates of the trees and efficiently providing the nutrients required in their development.

Pearson's correlation between cations and anions in the soil solution was significant ($p < 0.01$). In both depths, $N – NO_3^-$ was directly correlated with Ca^{2+} and Mg^{2+}, whilst $S – SO_4^{2-}$ was inversely correlated with Mg^{2+} (Table 2). Correlation significant also was identified for Calil el al. (2010), analyzed ion input via rainwater in the southwestern region of Rio Grande do Sul, Brazil.

Table 2: Pearson's correlation coefficients between cations and anions in the soil solution.
Tabela 2: Coeficientes de correlação de Pearson entre cátions e anions da solução do solo.

Anions	Depth	Cations				
		NH_4^+	Na^+	K^+	Ca^{2+}	Mg^{2+}
NO_3^-	30cm	ns	-0.345*	ns	0.800**	0.656**
	80cm	ns	ns	0.615**	0.424*	0.493**
SO_4^{2-}	30cm	ns	ns	ns	ns	-0.322*
	80cm	ns	ns	0.361*	ns	-0.533*

ns = not significant. * ** significant at the 5% and 1% of error probability, respectively.

Conclusion

The concentration of elements in soil solution were variable during the year, but without significant difference, except for N - NH_4^+. The concentrations of soil solution S and Ca decrease, whilst Na and pH increase in soil profile. In both depths, N – NO_3^- was directly correlated with Ca and Mg, whilst S was inversely correlated with Mg. This change in chemical composition of soil solution indicated that different patterns of nutrients were taken up by roots.

References

ABRAF - Associação Brasileira de Produtores de Florestas Plantadas. *Anuário brasileiro da ABRAF*: ano base 2012. Brasília; 2013.

APHA. Standard methods for the examination of water and wastewater. 19 ed. Washington, D.C.: APHA/AWWA/WPCF.1998.

CALDATO, S.L.; SCHUMACHER, M.V. O uso de água pelas plantações florestais – uma revisão. **Ciência Florestal**, v.23, p.507-516, 2013.

CALIL, F.N. et al. Ion input via rainwater in the southwestern region of Rio Grande do Sul, Brazil. **Cerne**, v.16, n.3, p.373-380, 2010.

FEPAGRO – Fundação Estadual de Pesquisa Agropecuária do Rio Grande do Sul. **Atlas climático: Rio Grande do Sul**. Fepagro: Porto Alegre, 2012.

HOPMANS, P.; BREN, L.J. Long-term changes in water quality and solute exports in headwater streams of intensively managed radiata pine and natural eucalypt forest catchments in south-eastern Australia. **Forest Ecology and Management**, v.253, p.244–261, 2007.

MARESCHAL, L. et al. Nutrient leaching and deep drainage under Eucalyptus plantations managed in short rotations after afforestation of an African savanna: Two 7-year time series. **Forest Ecology and Management**, v.307, p. 242–254, 2013.

REIS, G.G. et al. Crescimento de *Eucalyptus camaldulensis, E. grandis* e *E. cloeziana* sob diferentes níveis de restrição radicular. **Revista Árvore**, v.13, p.1-18, 1989.

SILVA, E.V. et al. Functional specialization of Eucalyptus fine roots: contrasting potential uptake rates for nitrogen, potassium and calcium tracers at varying soil depths. **Functional Ecology**, v.25, p.996–1006, 2011.

SMETHUST, P.J. Soil solution and other soil analyses as indicators of nutrient supply: a review. **Forest Ecology and Management**, v.138, p.397 - 411, 2000.

SPSS. Statistical package for the social sciences: programa de computador, ambiente windows. Chicago, 1996; Versão 7.5.1.