Revista Brasileira de Recursos Hídricos
Brazilian Journal of Water Resources
Versão On-line ISSN 2318-0331
RBRH, Porto Alegre, v. 21, n. 3, p. 636-645, jul./set. 2016
Scientific/Technical Article

http://dx.doi.org/10.1590/2318-0331.011616015

Qualitative characteristics of water resulting from the introduction of Eucalyptus silviculture in Pampa biome, RS

Características qualitativas da água resultante da introdução da silvicultura de eucalipto no bioma Pampa, RS

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Received: January 27, 2016 - Revised: April 24, 2016 - Accepted: May 18, 2016

ABSTRACT

This study aimed to present the effect on surface water quality of the introduction of eucalyptus forestry in areas that were traditionally used for extensive cattle farming in the Pampa biome, by comparing two paired watersheds located in the municipality of Rosário do Sul, one of them used for forestry and the other in an anthropized natural grassland condition in the Pampa biome. For this purpose, every fifteen days the following parameters were collected and analyzed in two watersheds with different land uses (watershed with grassland and extensive livestock farming – GW and watershed with Eucalyptus - EW) between the months of August 2011 and August 2012: pH, EC, temperature, turbidity and concentrations of SO_4^{2-}, K^+, Ca^{2+}, Mg^{2+}, Cl^-, $BOD_{5,20}$, SS, DS, alkalinity, total coliforms and *Escherichia coli*. Water quality and land use parameters averages were compared using the t-Test to account for the land use and seasonality. It was concluded that the introduction of forestry activity together with the areas of environmental protection required by the Brazilian legislation (Permanent Preservation Areas - PPA plus Legal Reserve - LR), contributed to the increased concentrations of conductivity, dissolved solids, alkalinity and calcium, and the decreased concentrations of total coliforms and *Escherichia coli*.

Keywords: *Eucalyptus spp.*; Land use; Water quality; Small watersheds.

RESUMO

Este trabalho objetivou apresentar a influência na qualidade da água superficial resultante da introdução da atividade de silvicultura de eucalipto em áreas com uso tradicional (pecuária extensiva) no bioma Pampa, por meio da comparação de duas em bacias hidrográficas pareadas e localizadas no município de Rosário do Sul, RS, uma sob uso da silvicultura e outra em condição de campo natural antropizado no bioma Pampa. Para tanto, quinzenalmente, realizaram-se coletas de água e a análise dos parâmetros pH, CE, temperatura, turbidez e as concentrações de: SO_4^-, K^+, Ca^{2+}, Mg^{2+}, Cl^-, $DBO_{5,20}$, SS, SD, alcalinidade, coliformes totais e *Escherichia coli* em duas bacias hidrográficas pareadas com diferentes usos do solo (campo com pecuária extensiva e silvicultura de eucalipto) durante os meses de agosto de 2011 a agosto de 2012. Após, avaliou-se a sazonalidade e a influência do uso do solo, por meio de comparação de médias por meio do Teste t entre os parâmetros de qualidade de água e o uso do solo. Por meio dos resultados, conclui-se que a introdução da atividade de silvicultura em conjunto com as áreas de proteção ambiental exigidas pela legislação (APP + RL) contribuiu para a redução das concentrações coliformes totais e *Escherichia coli* e para o aumento das concentrações de condutividade elétrica, sólidos dissolvidos, alcalinidade e cálcio para o período monitorado.

Palavras-chave: *Eucalyptus spp.*; Uso do solo; Qualidade da água; Bacia hidrográfica.

INTRODUCTION

In Brazil, the Pampa biome only exists in the state of Rio Grande do Sul (RS) covering 2.07% of the Brazilian territory (IBGE, 2012). The biome comprises large areas of natural grasslands with a floristic matrix composed by forest formations interspersed along the watercourses (BOLDRINI, 2009).

According to the Ministry of the Environment (BRASIL, 2012b), this ecosystem has presented extensive cattle farming as the main economic activity in the region since the time of the Iberian Colonization, with the introduction of livestock by the Jesuits around 1634, which characterizes the formation of the state and its regional identity.

Besides the traditional use of extensive cattle farming and almost one century of agricultural activity, it was only in 2004 that large areas of the Pampa biome were changed to silviculture, although until that time there had been no significant activity involving forestry. During this period also, a few forestry companies were established and contributed to a mean annual increase of 11% of the area where eucalyptus was planted in the State. In 2011, the planted area in RS, corresponded to 5.7% (280.198 ha) of the total national area planted to genus *Eucalyptus* spp., contributing to keep Brazil in the world ranking of forestry production (ABRAF, 2012).

As eucalyptus silviculture spread in the southern half of the state, many questions arose about the possible changes in soil characteristics and their effects on the water resources in these environments. However the activity of silviculture includes protecting the Permanent Preservation Areas (PPAs) and the Legal Reserve (LR) during the planning phase, and also a number of studies regarding the possible environmental impacts, as determined by law.

The use of the watershed as a territorial unit for planning and management purposes was instituted by Federal Law 9,433 of January 8, 1997 (BRASIL, 1997). Thus, the basin can be considered an essential geomorphological unit that comprises the mechanisms triggered in the environment by means of its forms which flow together until a single bed results, called the mouth (CALIJURI; BUBEL, 2006; SILVEIRA, 2001), and water quality is ruled by CONAMA Resolution 357/2005 (BRASIL, 2005).

Brooks, Ffolliott and Magner (1991), Câmara (2004), Gardiman Junior (2012), Likens (1985), Lima and Zakia (2006) and Moster (2007) presented examples of studies that used experimental watersheds as a tool to evaluate the environmental effects of land use. Brown et al. (2005) mention that the "paired basins" method is very effective since it detects the effects of changes in land use, one of the main instruments to support a policy of water resources planning and management being to monitor the water quality parameters (LEMOS; FERREIRA NETO; DIAS, 2010).

Research in the "campanha" region of RS relating eucalyptus silviculture to the characteristics and possible effects on this environment is still very incipient (CALIL, 2008; CORRÊA, 2011), and also as regards possible changes of activity in the water course as demonstrated by Baumhardt (2010), Dambrós (2011) and Consensa (2012), Peláez (2014) which implies lack of information about the possible effects of silviculture on the physical, chemical and biological variables of water.

In the light of the questions about the insertion of silviculture into the Pampa biome, the article considers the hypothesis that silviculture, replacing its traditional use, may help improve the qualitative characteristics of water sampled at the mouth of each basin, a site in which the surface water synthetizes all of the effects of the use of the drained area (IRION et al., 2003).

Based on this assumption, the article evaluates the influence of the introduction of eucalyptus silviculture into areas with a traditional use (extensive cattle farming), in the Pampa biome. The evaluation was done by interpreting the physicochemical and biological characteristics of surface water performed in two paired watersheds, located in a Pampa biome region, one used for eucalyptus silviculture and the other an anthropized natural grasslands.

MATERIALS AND METHODS

Location and characterization of the investigated areas

The study was developed in two watersheds located in the Santa Maria River Basin, which lies between the Santa Maria and Ibicuí da Armada rivers in the southwest of RS. The watershed with grassland and extensive livestock farming (GW) is a private property and the watershed with Eucalyptus (EW) belongs to the Stora Enso S/A company. The areas were selected based on the principle of the methodology of paired watersheds, as regards the similarity of the soil, relief and rainfall regime characteristics, but with different land uses. The two watershed are independent from each other, and 13 km apart in a straight North/South line, under the altitudes of 153 and 133 meters for EW and GW, respectively (Figure 1).

The climate of the region, according to the Köppen climate classification, is Cfa, humid subtropical with a hot summer (ALVARES et al., 2013). Soil is classified as Argissolo Bruno Acinzentado Alítico in the Brazilian Soil Classification System (EMBRAPA, 2006), as originated from siltstone and sandstone in transition with Planosols from the Central Depression (STRECK et al., 2008) and Abruptic Alisols (Alumic, Differentic), respectively in World Reference Base for Soil Resources (IUSS, 2014).

EW comprises an area of about 0.95 km^2, and consists of 0.49 km^2 to be used to plant eucalyptus, with the following species: *Eucalyptus urograndis*, *Eucalyptus grandis* and *Eucalyptus dunnii*, where 91.4% of the plants cultivated belong to species *Eucalyptus urograndis*, with wood for cellulose production. The remainder of the area (0.46 km^2) corresponds to the environmental protection areas using gallery forest and grasslands without the presence of cattle, which corresponds to 48% of the basin area, a percentage higher than that recommended by Brazilian legislation (20%), according to Law nº 12.651, of May 25, 2012 (BRASIL, 2012a). The other watershed (GW) covers a catchment area equal to 0.21 km^2, with the traditional use of the Pampa biome, extensive livestock in an anthropized natural grassland. The drainage network has less riparian protection compared to EW concentrated in the mouth area where the cattle has access to the drainage system.

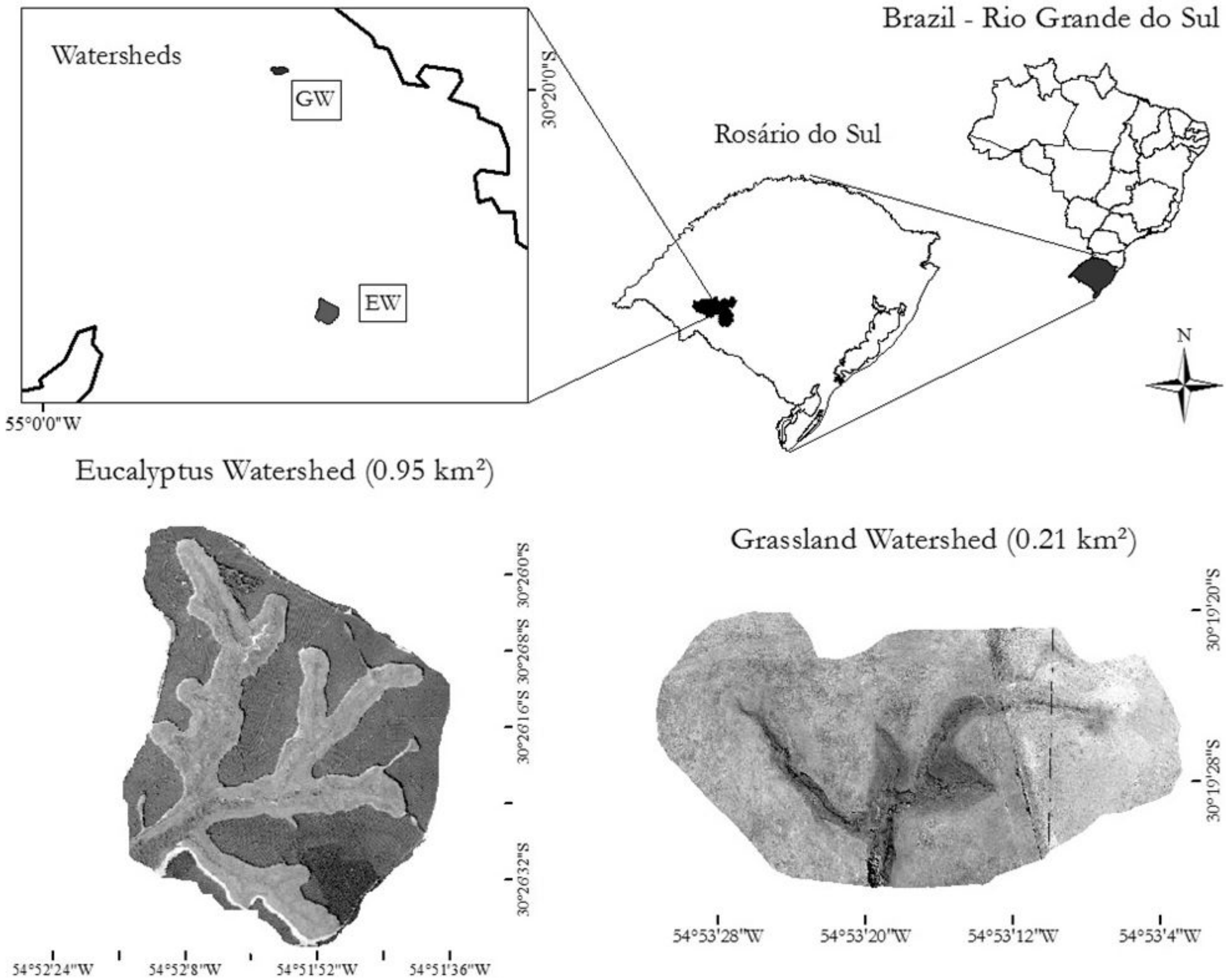

Figure 1. Location of the watersheds investigated, Grassland Watershed (GW) and Eucalyptus Watershed (EW), in the municipality of Rosário do Sul, RS.

Instrumentalization of the areas

Each watershed was instrumentalized with a 90º triangular spillway (built at the mouth) with a thin wall made from a 3 mm galvanized steel sheet, according to the Technical Standard of CPRH N. 2.004; a stilling well 60 × 60 × 80 cm high, where the pressure transducers were installed for the automatic measurement of discharge levels. In an adjacent clearing, 4 rainfall collector funnels were installed. The water quality sampling points in each catchment were located at the respective mouth and upstream from the spillway in order to remain outside the backwater area of influence.

Water collection and physicochemical and biological analyses

Between the months of August 2011 and August 2012, surface water sampling was performed at the mouth to the basins, approximately every 15 days, making up a total of 30 samples, five of the samples in summer, 6 in autumn, 9 in winter and 10 in spring.

The samples were stored in containers with an 0.5 liter capacity and transported to the Forest Ecology Laboratory (LABEFLO) of the Department of Forestry Sciences at UFSM for later analysis of the cations (Mg^{2+}, Ca^{2+}, K^{+}) and anions (SO_4^{2-}, Cl^{-}); the samples contained in the 5-liters containers were sent to the Laboratory of Engineering and the Environment (LEMA) of the UFSM Center of Technology for analysis of the parameters: hydrogenionic potential (pH), electric conductivity (EC), turbidity (Turb.), alkalinity (Alk.), suspended solids (SS) and dissolved solids (DS), biochemical oxygen demand ($BOD_{5;20}$), total coliforms (TC) and *Escherichia coli*. Except for the analysis of water temperature (performed *in situ*), the others followed the analytic procedures recommended by APHA (1995).

Data processing

The data were tabulated and statistically analyzed using the ASSISTAT 7.6 beta software (SILVA, 2012) applying the t test and they were compared between the different areas of study and between the seasons of the year.

RESULTS AND DISCUSSION

In Table 1, below, the t test is applied to the means of the water quality parameters for the different areas of study based on the seasons of the year and the means of GW and EW followed by the same letter mean that they are not significantly different from each other, applying the t test.

Total precipitation recorded for the months was 583.8 and 721.6 mm, for GW and EW (Figure 2), respectively, while the annual mean of the historical series corresponded to 1444.3 mm. These values corresponded to only 40.42% (in GW) and 49.96% (in EW) of the mean annual precipitation observed in the historical series belonging to one of the farms monitored during the period between 1953 and 2010. Therefore it should be underscored that during the monitoring period, from the months of November 2011 to May 2012, the state of Rio Grande do Sul suffered an intense drought, as a consequence of the *La Niña* phenomenon, in which approximately two hundred days of significantly irregular precipitation caused mean losses of billions in farming and water supply in several communities of the interior, including the Campanha (CEMETRS, 2012). During this drought, Baumhardt (2014) observed that although evapotranspiration is not higher in the EW compared to GW, and the mean flow is superior in GW, during the period of intense drought EW was perennial because of the better recharge provided by silvicultural activity.

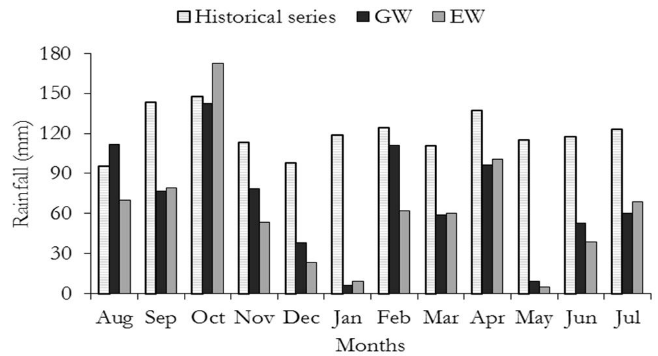

Figure 2. Monthly means of the historical series (1953-2010) and of the period monitored in the watersheds (GW and EW).

The Figure 3 shows the comparative distribution of the values of each variable analyzed for the collections without (s) and with (c) precipitation, in the two areas of study. The turbidity means were equal to 12.47 and 12.42 UNT, respectively for GW and EW, which were not significantly differentiated among the areas and seasons, according to the t test applied (Table 1). The results were similar to those found by Mosca (2003), Câmara (2004), Ribeiro (2009), Queiroz et al. (2010) and Lubenow et al. (2012) for the different uses. According to Figure 3a, in EW the highest turbidity values were observed for collections with a greater volume of pluviosity. This increase due to rainfall, can be accounted for by the entrainment of organic material (leaves and remnants of decomposing vegetation), and possible soil particles (CETESB, 2009).

The increased turbidity partly justifies the higher values of suspended solids (SS), and especially dissolved solids (DS) in EW, as shown by the ratio curve 1:1 (Figure 3j and 3k) and by the t test analysis (Table 1). However, during the period with the greatest drought, higher values were observed in GW, which are due to the presence of cattle in the area and disturbing the soil, since the water source studied is also a watering hole for the animals. It should be emphasized that the two outstanding points on the graphic (Figure 3a) corresponded to low volumes of precipitation (between 1.1 and 7.4 mm), that occurred after a long dry period. In this case, in the forested area, part of this precipitation was lost to interception and evaporation, resulting in less surface runoff and less entrainment of sediment, while in the field the cattle's activity may have influenced the higher turbidity values.

The mean values of pH were 6.23 (GW) and 7.23 (EW) with significant differences among the areas of study to a 1%

Table 1. Mean values of the physical, chemical and biological attributes of surface water in the watersheds with different land uses (GW and EW) for the monitored seasons of the year.

Parameters	Spring		Summer		Autumn		Winter	
	GW	EW	GW	EW	GW	EW	GW	EW
**pH	6.24c	7.07b	6.13c	7.32ab	6.06c	7.40a	6.29c	7.28ab
n.s.Turb	11.26ab	19.95a	18.01ab	6.46b	8.05ab	7.80b	11.43ab	10.03ab
**EC	33.03d	158.42bc	40.83d	335.66a	46.40cd	375.38a	44.13d	265.69ab
*TC	839.01c	540.36c	5907.51ab	3847.85bc	10016.89a	828.55c	2822.45bc	2263.20bc
n.s.*Escherichia Coli*	229.32a	102.30a	2314.83a	1455.83a	4319.22a	97.39a	8644.98a	95.96a
n.s.$BOD_{5,20}$	1.19b	1.70ab	2.04ab	2.49ab	1.47ab	1.98ab	2.06ab	3.31a
n.s.SS	9.49ab	13.9a	11.84ab	5.19b	11.10ab	7.29ab	5.36b	4.4b
**DS	35.56d	137.75c	55.39d	219.72ab	71.50d	234.87a	48.17d	182.43bc
**Alc.	12.46d	77.67c	17.74d	170.49ab	15.63d	194.21a	15.19d	130.86b
**Temp.	19.03b	17.39bc	22.93a	23.60a	17.39bc	14.86cd	13.48d	12.49d
n.s.Cl^-	0.94b	1.44ab	2.65ab	2.24ab	3.40ab	2.24ab	3.796a	3.793a
**SO_4^{2-}	0.17c	1.19b	0.45c	0.47c	0.16c	0.57c	0.22c	1.78a
**K^+	1.05c	1.31bc	2.56ab	2.01bc	3.80a	1.61bc	3.73a	2.07bc
**Mg^{2+}	1.07c	2.01c	1.13c	6.50a	1.44c	6.60a	1.57c	4.91b
**Ca^{2+}	1.44c	12.03c	2.28c	49.42a	2.29c	42.08ab	2.24c	32.22b

The means followed by the same letter are not statistically different from each other applying the t test. ** significant to the level of 1% probability ($p < 0.01$). * significant to the level of 5% probability ($0.01 \leq p < 0.05$). n.s. non significant ($p \geq 0.05$).

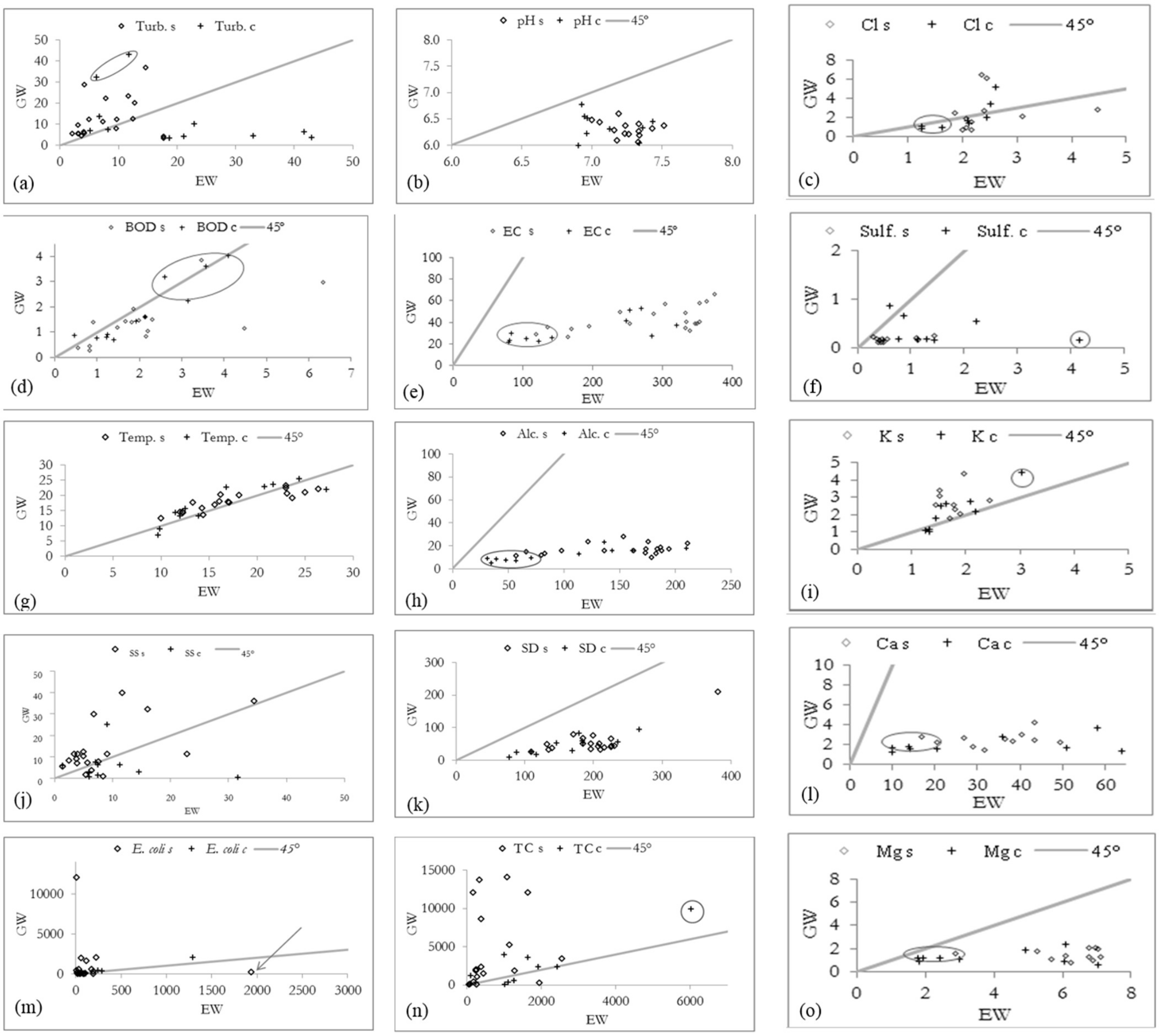

Figure 3. Comparison of the turbidity values (UNT) (a); pH (b); Cl^- (mg L^{-1}) (c); $BOD_{5,20}$ (mg L^{-1}) (d); EC (µS cm^{-1}) (e); SO_4^{2-}(mg L^{-1}) (f); temperature (°C) (g); alkalinity (mg L^{-1} of $CaCO_3$) (h); K^+(mg L^{-1}) (i); SS (mg L^{-1}) (j); DS (mg L^{-1}) (k); Ca^{2+} (mg L^{-1}) (l); *Escherichia coli* (NMP/100 ml) (m); TC (NMP/100 ml) (n); and Mg^{2+} (mg L^{-1}) (o) of water in the different watersheds with eucalyptus and grasslands in collections without (s) and with precipitation (c).

level of probability (Table1) and among the seasons in EW, evidenced by the ratio curve 1:1 (Figure 3b). The values belong to the aquatic life protection intervals in surface waters (6 and9), according to CETESB (2009), 6.0 to 8.5 (LIBÂNIO, 2008) and 4.0 and 9.0 (MOSCA, 2008). The highest values found in EW may be related to the higher concentrations of bicarbonates, especially calcium and magnesium (LIBÂNIO, 2008), which agrees with what was observed in EW for cations Ca^{2+} and Mg^{2+}, as will be better described below, and also the relationship with the geochemical characteristics at the site. These values may also be related to the processes of leaching or release of total bases from the accumulation of leaf litter present in the creek protection area (PPA + LR) because of the low flows that occurred in the watercourse during the monitored period.

Farley et al. (2008) observed, in paired water sources in the Pampa biome in Argentina and Uruguay, mean values of 7.2 and 6.5, respectively, for grassland uses and planting eucalyptus. Mosca (2008) observed pH values between 6 and 7 in a watershed where eucalyptus had been planted in the Cerrado, without much variation during the dry and rainy periods, according to what has been observed in the present study.

The EC means corresponded to 39.08 and 253.49 µS cm^{-1} for GW and EW, respectively. In general, the higher values of EC were observed in EW, as highlighted in the graphic (Figure 3e). Collections in rainy periods with higher EC values corresponded to events with low volumes of precipitation that occurred after a long dry period, and therefore are more closely related to the high concentration of solutes in water in the EW. Esteves (1998) found in tropical regions that the EC of water is more closely related to the geochemical composition and to dry and rainy conditions than to the trophic state of a watercourse. The values are differentiated, statistically, among the investigated areas and were similar between the seasons for the area of study (Table 1).

In EW, a difference is observed among the means for summer and autumn, which corresponds to the dryer period (Figure 3e). It is considered that in continental waters the main ions that contribute to increasing EC are: calcium, magnesium, potassium, sodium, carbonates, sulfates and chlorides (LAUERMANN, 2007), the main sources of these ions being related to the dissolution of rocks and soils (CETESB, 2009; LIMA; ZAKIA, 2006); RIBEIRO, 2009). It can thus be inferred that the significant presence of cations Mg^{2+} and Ca^{2+} (Figure 3l-3o) accounts for part of the EC values found in EW. It is possible that a contribution of these ions is due to the base runoff as regards the high EC values, and not only under the influence of land use, however, this hypothesis requires further evidence. The means of Ca^{2+} were 2.07 and 33.94 mg L^{-1}, for GW and EW, respectively. The values were similar among land uses during the spring (greater pluviosity), however for the other seasons of the year (dry) higher Ca^{2+} contents were observed in EW. The values observed for Mg^{2+}, in EW, are similar to those found by Gardiman Junior (2012). The means of Mg^{2+} were 2.70 and 2.46 mg L^{-1}, for GW and EW. The values can be explained by the accumulation of organic material, but also by their underground origin. According to Câmara, Lima and Zákia (2006), magnesium reaches the outflow mainly via base runoff, which corresponds to the discharge maintained by the groundwater that exists in the aquifers, whose main source is rainwater that infiltrates into the soil and percolates to the deeper strata, and is thus a good indicator of water infiltration into the soil.

The mean contents of K^+ were 2.79 and 1.75 mg L^{-1} in GW and EW, respectively. The highest potassium values were observed in GW, with higher concentrations of the element in the dryer period (Table 1), and the value observed for collection with rainfall (highlighted in Figure 3i) corresponded to an event with low precipitated volumes. The potassium concentrations are within the interval normally observed in natural waters (< 10 mg L^{-1}). These low values may be related to the high solubility of the element in these environments, and it is rapidly incorporated into the mineral structures and accumulated in the aquatic biota, since it is an essential element for their nutrition (CÂMARA; LIMA; ZÁKIA, 2006). Ranzini and Lima (2002) looked at potassium values in water between 1.35 and 1.80 mg L^{-1} in watershed reforested with eucalyptus (LUCAS; FOLEGATTI; DUARTE, 2010). The same authors mention that during dry periods, there is a higher concentration of solutes and mineral elements such as potassium because of the lower discharge. This finding is consistent with what was found in the grasslands that presented higher potassium values for collections without precipitation.

Câmara (2004) also found higher concentrations of magnesium, calcium and conductivity related to the reduction of the creek discharge in water sources where there was eucalyptus. Considering that, according to Likens et al. (1967), the loss of cations Ca^{+2}, Mg^{+2} and K^+ in the surface waters of watercourses is due mainly to the geological weathering process, it can be inferred that the hydrologic regime of the watershed may be influencing the exit of ions Ca^{+2}, Mg^{+2} e K^+ in the outflow, since the time of permanence of groundwater, together with the low pluviometric indices, promotes interaction between this and the deeper strata of the soil, and especially with the rock alteration zones, consequently releasing a larger amount of solutes into the watercourse (ARCOVA; CICCO; LIMA, 1985). The means of these cations were the contrary of those observed by Farley et al. (2008) in areas used for grasslands and eucalyptus. The concentrations observed in EW were higher than the confidence interval estimated by Câmara, Lima and Zákia (2006) for Ca^{2+}, Mg^{2+} and below for K^+. However, the same authors mention that Ca^{2+} is rapidly dissolved from rocks rich in calcium minerals, such as carbonates and sulfates, and usually presents concentrations below 15 mg L^{-1}, in natural waters. In general, lower values were observed during the periods with greater pluviosity (highlighted in the graphic of Figure 3l), except for the four collections with rainfall, that occurred during the dry period (low precipitated volume and less runoff formation) in which higher values were observed, as previously discussed.

The means for Cl^- were 2.70 and 2.46 mg L^{-1} for GW and EW, respectively, and higher chloride values were observed during the collections without pluviosity in both areas of study (Figure 3c). According to CETESB (2009), this anion is found in the groundwaters, from the percolation of water through soils and rocks, emphasizing as a possible source of contribution the base runoff in EW, as previously mentioned.. On the other hand, in surface waters, major sources of chloride are cattle farming wastes, partially explaining the values observed in GW. For the sulfate anion, the means were 1.10 (EW) and 0.25 mg L^{-1} (GW), evidenced in the comparative graphic (Figure 3f). These concentrations were lower than those observed in a study that covered various watersheds with forests and agriculture in Slovakia (PEKÁROVÁ; PEKÁR, 1996). The same authors correlated the high concentrations with the substrate of the areas of study, in agreement with what was found by Fernandes et al. (2012), who mention the dissolution of soils and rocks as a source of sulfate in natural waters. According to CETESB (2009), sulfate (SO_4^{2-}) is one of the most abundant ions in nature, and in natural waters the main source of sulfate occurs due to the dissolution of soils and rocks, and by sulfide oxidation. The means were the same, significantly, for summer and autumn (dry periods), according to Table 1.

The means of TC were 3616.83 (GW) and 987.25 NMP/100 ml (EW), with significant differences between the areas during autumn (Table 1), at a 1% level of probability. The highest values observed in GW occurred for the period with the greatest drought, except for a collection that took place after the rainfall event (low volume precipitated after a long dry period, probably with low surface runoff and consequently, with a small capacity for dilution, highlighted (Figure 3n). In general, eucalyptus silviculture, as this activity was implemented, with 48% of the area for PPA and a legal reserve, without the presence of cattle, helps lower the values of this variable at the monitored site (EW), compared to those of the GW watershed, whose traditional activity is cattle farming. This result was expected, and confirmed by the tests. It should also be observed that these bacteria are not exclusively of fecal origin, according to the considerations of OMS (1995) and Von Sperling (2005).

As to *Escherichia coli*, the means corresponded to 366.0 (ranging from 5.0 to 5231.0) and 2656.98 (14.35 and 48392.0) NMP/100 ml for GW and EW, respectively. The relationship beweeen cattle farming and high values observed is seen in GW, since part of the animal waste tends to run off towards the creek when flash floods occur, raising the number of bacteria. The graphic (Figure 3m) shows that the highest concentrations of *Escherichia coli* occurred during the dryest periods, wich can be explained by the cattle farming at GW, and also by the accumulation of these wastes because of the low level of water in the creek. Contamination by the *Escherichia coli* bacteria in EW is explained by the presence of wastes of wild animals, such as hares, deer and pampas foxes that are sometimes seen in the area of study. However, the high amount of *Escherichia coli* (highlighted in Figure 3m) in EW, an exceptional value, is believed to have been due to the occasional invasion of cattle in the area of study, because during one of the field trips, a few heads of cattle were observed close to the watershed that was being studied. Since the planted areas planted are extense (5,600 ha) with fragile fences, the cattle from neighboring areas may get in, and it takes up to two months to find livestock that strays into the forest.

The mean values of $BOD_{5,20}$ corresponded to 1.59 and 2.14 mg L^{-1} for GW and EW, respectively, and there are no differences between the areas and the seasons (Table 1). These values are lower than those observed by Campello et al. (2005) in the National Forest of São Francisco de Paula in RS, which showed values between 2.83 and 3.34 mg L^{-1}, superior to those observed by Ribeiro (2009) in rural watersheds used for native forest, reforestation and agriculture, whose values ranged from 0.65 to 1.31 mg L^{-1} and similar to those of Lubenow et al. (2012) where a value of 1.52 mg L^{-1} was found in an area preserved around the source, in the municipality of Irati (PR). The highest values of $BOD_{5,20,}$ in EW, during the dry period (winter), are supposedly related to the greater presence of organic matter accumulated in the watercouse because of the long dry period that occurred during the study. Lower values were found during the collections with greater pluviosity (Figure 3d), which may be due to the dilution factor of the $BOD_{5,20}$. concentration. However, events were observed with high values (points highlighted on the graphic), which occur for periods with less precipitation, and these are found after a dry period of 2 and even 3 months, which is related to the greater accumulation of organic matter in the watercourses.

The SS means were 11.42 and 9.03 mg L^{-1}, for GW and EW, respectively, which did not present significant differences between the areas. These values are below the confidence interval (CI) estimated by Câmara, Lima and Zákia (2006), in an area with eucalyptus and within the the CI for what was observed in a secondary forest. The highest values found in GW occurred during the period with the most severe drought (Figure 3j). Moreover, the increase may be due to the soil that was disturbed by cattle.

The DS means were 50.97 and 184.32 mg L^{-1} for GW and EW, respectively. The values observed in EW are different from those found in GW, and are also superior to the DS concentrations observed by Lubenow et al. (2012), who found 15.5 (SS) and 20 mg L^{-1} (DS) in a water source area protected by gallery forest, 16.5 (SS) and 60.5 (DS) in areas with access to animals and without the protection of vegetation, and in an area under crops they found 13.5 (SS) and 70 mg L^{-1} (DS). The lowest values of DS in both areas were recorded during the period with the greatest pluviosity (spring). As to DS, in EW higher concentrations are found during the dryest period (Figure 3k), again emphasizing the possibility of a greater accumulation of organic matter (decomposition, leaching and ion dissolution), or as a result of very biogeochemical characteristics in the area of study, as mentioned previously.

As to alkalinity, the mean concentrations were 15.15 and 128.30 mg L^{-1} of $CaCO_3$, respectively, for GW and EW, which are statistically differentiated (Table 1), as evidenced in the graphic (Figure 3h). Outstanding are the collections with greater precipitated volumes in which there are the lowest concentrations of alkalinity. On the other hand, the highest values observed during the other collections with rainfall (low volumes of incident precipitation) were preceded by long dry periods. The elevated mean found in EW explains the increased pH found in the area of study. According to Mosca (2008) the capacity to neutralize acids in an aqueous system depends on some compounds such as bicarbonates, carbonates and hydroxides.

The mean values for temperature were 17 °C (ranging from 9.7 to 27.2 °C) for EW, and 18 °C (7.0 to 25.5 °C) for GW. The means were similar to those observed by Arcova and Cicco (1999), Sabara (1999) and Bueno et al. (2005), in areas where eucalyptus is planted. Câmara (2004) observed higher temperatures in microbasins with grasslands than in afforested areas. According to the t test, both areas presented similar means at each season of the year (Table 1), as evidenced by the comparative curve of 45° (Figure 3g).

According to Lima (1996), the characteristics that consider the outflow water quality parameters in areas with forest species show that the final quality of water, under natural conditions, depends more on the geology, watershed soil and rainfall regime in the region, through the interaction of hydrological processes involved in outflow generation by the body of water.

The results show that for this case study, the considerations of Gardiman Junior (2012) were valid, for whom the highest averages of water quality variables observed in the forested basin may be associated: with the characteristics of the physical environment of the watershed investigated itself; the reduction of water velocity found in the water body and, consequently the low flow that contributed to increasing the concentration of some variables; the greater input of organic matter from the riparian vegetation that exists there and the chemical characteristics of the soil.

CONCLUSIONS

The results of the analyses of the following variables: total solids, dissolved solids, turbidity, pH, Ca^{2+}, Mg^{2+} and EC, indicate a significant influence of the activity on the Pampa biome, and the highest values in the watershed are from eucalyptus silviculture (EW) compared to the watershed with extensive livestock in an anthropized natural grassland (GW) and these results can be ascribed to the leaching of leaf litter. On the other hand, the great influence of cattle farming is observed in GW, when the total coliform and *Escherichia coli* parameters are analyzed, with significantly higher values than those observed in EW. It also became evident that the influence of the variation of concentrations was a result of drought or of the presence of antecedent rainfall. In periods of rainfall there are signs of the influence of entrainment on the values of the quality variables, such as suspended and dissolved solids, and turbidity which in EW are greater in the presence of rain, probably due to the entrainment of organic matter present in the litter. On the other hand, during dry periods the highest values occur in GW, showing the influence of the presence of cattle near the water body.

It is thus concluded that the silviculture monitored in this study reduced the concentrations of total coliforms and *Escherichia coli* and increased the concentrations of electric conductivity, dissolved solids, alkalinity and acid.

ACKNOWLEDGEMENTS

We thank all those who collaborated to peform this study: CAPES, CNPQ, FINEP, FAPERGS, CT-HIDRO, LABEFLO, UFSM, Group GERHI, STORA ENSO and Mr. Ildo José Spanevello, owner of Fazenda São Carlos, the farm where part of this research was performed.

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Authors contributions

Jussara Cabral Cruz: Development of main idea, organization of research methodology, contributed to the analysis and discussion of the results and writing of the article, guiding the research.

Mirian Lago Valente: Development of main idea, responsible for developing the work, literature, performing the sampling and laboratory analysis, statistical analysis, analysis of results and writing of the article.

Carine Baggiotto: Contributed in carrying out the collection and laboratory analysis, and writing the article.

Edner Baumhardt: Contributed in the analysis of results and review of the text.