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ORIGINAL ARTICLE

Seasonal dynamics of magnesium in rangeland areas of Southeastern region of Rio Grande do Sul State/Brazil: 1. field research

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Abstract – We aimed to evaluate the seasonal dynamics of magnesium (Mg) in the system soil - plant - animal. It was conducted in two natural rangeland areas on two types of undisturbed soils (medium-clayey texture) in the Serra do Sudeste region (Rio Grande do Sul State, Brazil). In each area, 12 heifers were kept under continuous extensive grazing for twelve months without mineral supplementation. Samples of soil and vegetation were collected monthly from 16 fixed points and blood serum from each of the animals in each area monthly for the determination of Mg levels. The data were analyzed by analysis of variance, decomposition of the annual variation of the response variables and regression (harmonic analysis) for adjustment of function to express this variation. The Mg content in the soils of the two areas was high (1.86 ± 0.045 $cmol_c.dm^{-3}$). Mg levels in the vegetation (0.23 ± 0.0025 % DM) are sufficient to meet the needs of all categories of ruminants. The Mg contents in the blood serum (3.05 ± 0.0025) of grazing animals are considered medium to high and in normal levels. Mg supplementation is suggested in the cold season months for the most demanding animal categories (gestating and lactating females).

Keywords: Blood serum. Minerals. Natural grassland. Soil.

Dinâmica sazonal do magnésio em áreas de campo natural na região Sudeste do Estado do Rio Grande do Sul/Brasil: 1. levantamento de campo

Resumo – O objetivo foi avaliar a dinâmica sazonal do magnésio (Mg) na cadeia solo – planta – animal em duas áreas de campo natural com dois tipos de solos não perturbados na Serra do Sudeste (Estado do Rio Grande do Sul, Brasil). Em cada uma dessas áreas foram mantidas 12 novilhas em pastejo extensivo contínuo durante 12 meses. Foram coletadas mensalmente amostras de solo, vegetação, em 16 pontos fixos (raio: 25 m), e soro de sangue dos animais de cada área, para a determinação dos teores de Mg. Os dados foram analisados por análise de variância, decomposição da variação anual das variáveis respostas e regressão (análise harmônica) para o ajustamento de função, a fim de expressar essa variação. Os teores de magnésio nos solos (1,86 ± 0,045 $cmol_c.dm^{-3}$) das duas áreas foram altos. Já na vegetação de campo natural (0,23 ± 0,0025 % DM) são suficientes para suprir as necessidades de todas as categorias de animais ruminantes. Os teores de magnésio no soro de sangue (3,06 ± 0,0025) dos animais em pastejo foram considerados de médios a altos e dentro dos níveis normais. Sugere-se a suplementação de Mg nos meses da estação fria para as categorias mais exigentes (fêmeas gestantes e lactantes).

Palavras–chave: Soro de sangue. Minerais. Pastagem natural. Solo.

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Introduction

In the State of Rio Grande Sul (RS), Brazil, the livestock stands out for its importance. According to Bonetti *et al*. (2020), the state had about 13.9 million cattle in; 7,872,830 million (56.6%) were beef cattle breeds. Sheep farming is also an important activity for the livestock of the state, with 3.2 million animals. It is the second-largest sheep herd in the country, as well as horses, with 528 thousand animals, according to the agricultural census 2017 (IBGE, 2020).

In the RS, most animals are raised in extensive continuous grazing systems on natural grasslands. This fact is mainly due to areas without agricultural fitness, such as steep reliefs, rock outcrops, high stoniness, or even preserved vegetation (subtropical sparse shrubby forest). In this production system, the animals are generally raised on pasture without any supplementation. Under such circumstances, it is essential to know about the potential of these areas for forage production and its nutritional quality.

In addition to the energy-producing nutrients for plants and animals, minerals are also necessary because they take part in biochemical reactions in plant and animal metabolism. They are essential for plant growth and development (MALAVOLTA, 2006). Minerals also play vital functions in the organism of animals, and the deficiency can cause nutritional changes, leading the animal to present productive and reproductive performances below its potential (RODRIGUES; MARQUES; SOUZA, 2016).

Among minerals, magnesium (Mg) is essential for the development of plants since it is part of the central atom of the chlorophyll molecule and activates the enzyme ribulose-1,5-bisphosphate-carboxylase, which acts in the photosynthesis (MARSCHNER, 2011). Mg has important biochemical and physiological functions in grazing animals since it acts as an activator of many enzymes (300 enzymes). The Mg-adenosine triphosphate complex is essential for all biosynthetic processes, including glycolysis, energy-dependent transport in the cell membrane, cyclic adenosine monophosphate formation, and genetic code transmission (NRC, 2016).

Although Mg is not needed in large quantities for plants, a deficiency can cause a reduction in plant development and production of forage, resulting in low levels of serum Mg in animals (SOUSA *et al*., 1987)

In this study, we aimed to determine the Mg availability in soil, natural grasslands, and its availability for grazing animals in the Southeastern region – RS, Brazil. Therefore, we investigated the dynamics of magnesium passage in the soil-plant-animal chain.

Material and Methods

The study was carried out in partnership with the Brazilian Agricultural Research Corporation (Embrapa Temperate Agriculture), in the county of Piratini – RS, Brazil, located in the Southeastern Mountain Range. We used two rural areas representing the typical production system of the region, in the 2nd and 4th subdistrict of the county (Area 1: 31°22'14" S and 53°11'08" W, 401.10 meters a.s.l.; Area 2: 31°15'44" S and 52°59'43" W, 321.0 meters a.s.l.). The criteria for choosing the areas and animals for the study were undisturbed (virgin) natural grasslands and the availability of 12 heifers (yearlings, ± 200 kg PV, Ibagé crosses) without any mineral supplementation for one year (Ethics Committee on Animal Experimentation: UFPEL code 5068-2017).

We identified the soils of the two areas according to the Brazilian Soil Classification (STRECK *et al*., 2008). The Area 1 soil (12.6 ha) is Argisol greyish-brown Tb Eutrophic umbric (Soil Taxonomy: Mollic Hapludalf). Area 2 (10.6 ha) is Argisol greyish-brown Aluminic umbric (Soil Taxonomy: Typic Kanhaplohumult).

The vegetation of the two areas consisted of species from the natural grasslands of the region. A flora survey determined that both areas present similar amounts of the main groups of species typical of the natural vegetation, with a predominance of warm-season grasses (79%), predominantly *Paspalum spp.* and *Axonopus spp*., throughout the year (REIS *et al*., 2008).

The climatic data of the municipality of Piratini – RS, Brazil, during the period of execution of the data collection are presented in the table 1.

Table 1. Monthly averages of meteorological variables of the municipality of Piratini – RS, Brazil, during the experimental period.

Month	Temperature (ºC)[1]				Area 1[2]		Area 2[3]	
	max.	min.	aver.	abs. min.	total prec. (mm)	rainy days (nº)	total prec. (mm)	rainy days (nº)
May	22.03	2.68	12.35	-5.0	9.7	2	0.0	0
Jun.	20.70	2.43	11.57	-8.0	96.6	6	81.0	7
Jul.	n.a.	n.a.	n.a.	n.a.	5.7	2	14.0	3
Aug.	21.03	6.06	13.60	-2.0	171.2	9	141.0	8
Sep.	19.03	8.17	13.60	-3.0	80.1	8	75.0	8
Oct.	24.52	12.90	18.71	5.0	171.0	10	171.0	10
Nov.	26.69	12.13	19.41	6.0	79.0	5	79.0	5
Dez.	29.03	16.42	22.73	9.0	67.0	6	67.0	6
Jan.	31.90	17.55	24.73	11.0	61.4	6	67.0	6
Feb.	27.50	16.50	22.00	11.0	304.5	6	301.0	10
Mar.	28.10	13.23	20.66	4.0	31.0	1	29.0	3
Apr.	26.30	10.23	18.27	3.0	35.5	4	61.0	5
May	22.45	9.21	16.14	-3.0	166.1	3	139.0	3
Jun.	15.50	5.73	10.62	-3.0	143.7	9	205.0	9

n.a.: not available; max.: maximum; min.: minimum; aver.: average; abs. min.: absolute minimum; prec.: precipitation.[1]Temperature common to the two areas; [2]Source: Piratini Meteorological Station, located at the Municipal Agricultural School Alaor Tarouco, Latitude: 31°25'49"S; Longitude: 53º06'26"W; Altitude: 401.1 meters a.s.l; [3]Source: Farm São Thomas. Latitude: 31°15'44" S; Longitude: 52°59'43" W; Altitude: 321.0 meters a.s.l.

In each area, we chose 16 fixed spots and placed numbered stakes on them. These spots were strategically determined locations, according to the topography, distributed in four levels: high area, half-high slope, half-low slope, and low area. The monthly sampling of soil and vegetation was carried out surrounding each fixed spot (20 - 25 subsamples) within a radius of 25 m, totaling 16 units, i.e., four units per topographic level.

The soil was sampled in a 20 cm depth profile using a stainless auger to avoid contamination. We did not consider plants despised by animals or consumed in small quantities (broadleaf plants), representing the grazing selectivity. We determined the Mg levels and other minerals in soil and vegetation according to Tedesco *et al*. (1995). Organic matter, pH, and clay were also determined in soils. We evaluated soil variables according to CQFRS/SC (2004) since this approach is more appropriate to the region's soil types. We also determined the Mg and other minerals content monthly in the blood serum of grazing animals in both areas according to Fick *et al*. (1980).

The study comprised two factors, area and month, with two and twelve levels, respectively. We analyzed the data using the SAS program (2020). Analysis of variance, trigonometric periodic regression analysis (harmonic analysis), with significance tests at $\alpha = 0.05$ level, and function adjustment to express the variation of magnesium content in soil, plant, and blood serum of animals. This adjustment considered the function with the highest order harmonic component, not higher than that expressed by the trimester trend:

$$Zi = a_0 + a_1x_{1i} + b_1y_{1i} + a_2x_{2i} + b_2y_{2i} + a_3x_{3i} + b_3y_{3i} + a_4x_{4i} + b_4y_{4i} + e_i,$$

where: $x_{1i}=\sin(\pi i/6)$, $y_{1i}=\cos(\pi i/6)$, $x_{2i}=\sin(\pi i/3)$, $y_{2i}=\cos(\pi i/3)$, $x_{3i}=\sin(\pi i/2)$, $y_{3i}=\cos(\pi i/2)$, $x_{4i}=\sin(2\pi i/3)$, $y_{4i}=\cos(2\pi i/3)$, i=1-july, 2-august, 3-september...,12-june.

Results and Discussion

The overall variation in soil magnesium (Mg) over 12 months for Areas 1 and 2 was significant ($P < 0.0001$); the area x month interaction was not significant ($P = 0.1639$). The annual variation was significant in Areas 1 ($P < 0.0017$) and 2 ($P < 0.0001$). The function representing the annual variation of Mg in soil, overall for Areas 1 and 2, is the one with annual/semi-annual/four-monthly components, whose adjustment residue was not significant ($P = 0.1440$); the function that represents each area has both annual/semi-annual components. Therefore, the annual variations revealed similar trends for the two areas, but overall, there is the additional presence of the four-monthly component for these areas. The average monthly levels of Mg in soil and the equation of the periodic trigonometric function overall adjusted for the two areas are presented in Figure 1. This fact is probably due to the effects of individual factors and/or their association in each area, individually. We observed lower soil Mg levels from early winter to early summer. From then on, we observed higher levels until the end of autumn, when vegetation growth is less vigorous (ALFAYA *et* al., 1997; FERNANDES *et* al., 2018). Annual average soil Mg levels were 1.81 $cmol_c.dm^{3-1}$ (1.55 - 2.18 $cmol_c.dm^{-3}$) and 1.90 $cmol_c.dm^{-3}$ (1.55 - 2.2 $cmol_c.dm^{-3}$), for Areas 1 and 2, respectively. The Mg levels in the soil of the two areas are considered high, because according to CQFRS/SC (2004), Mg levels above 1.0 $cmol_c.dm^{-3}$ are high and sufficient for forage production in natural grasslands.

Conversely, to what we found in our study, Alfaya *et al.* (1998) found no significant variation in soil Mg levels throughout the year on three natural grassland areas on three different soil types in Campanha region – RS.

However, according to these authors, there was a significant variation between areas, with average Mg

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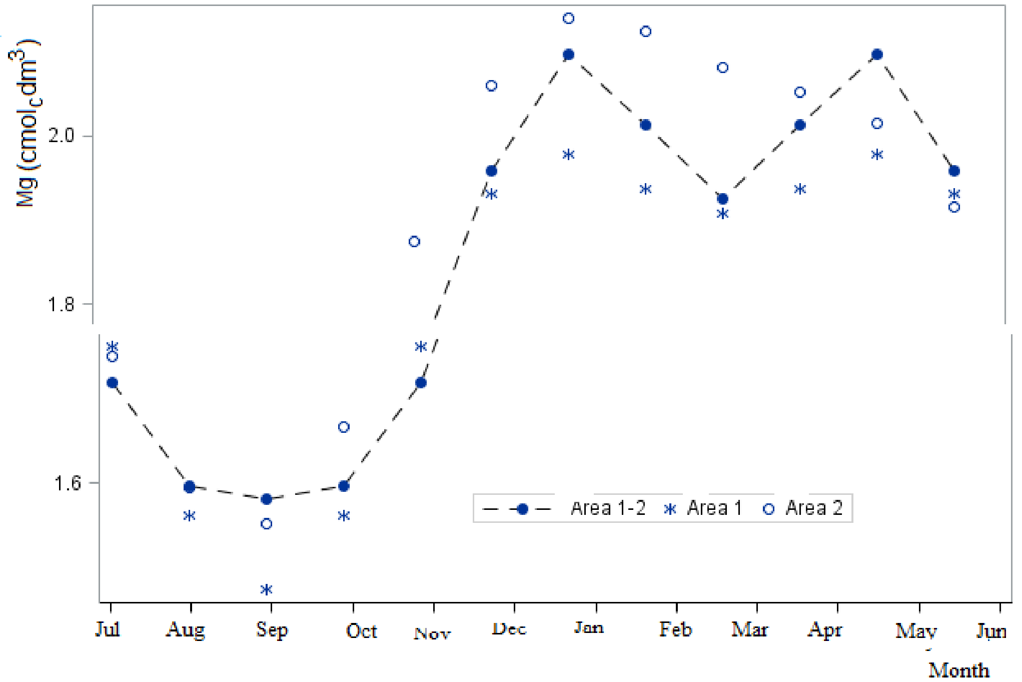
levels of 2.4, 2.1, and 1.0 $cmol_c.dm^{-3}$. These values are similar to those in our study and also considered high (CQFRS/SC, 2004).

Areas 1-2: $z_i = 1.85625 - 0.24095 \sin(\pi i/6) + 0.10313 \cos(\pi i/3) - 0.06875 \sin(\pi i/2)$; $R^2 = 0.847$.



Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Average
Area 1	1.76	1.56	1.47	1.56	1.76	1.93	1.98	1.94	1.91	1.94	1.98	1.93	1.81
Area 2	1.75	1.59	1.55	1.67	1.88	2.06	2.14	2.13	2.08	2.05	2.02	1.92	1.90

Figure 1. Average monthly magnesium content in soils of rangeland areas in the municipality of Piratini – RS, Brazil.

It is possible that factors like weathering (variable) associated with topography influenced the Mg annual variation in the soils of the two areas. Dantas and Negrão (2010) indicate that when an area has a steep slope, there is leaching of nutrients from the soil. Among them, Mg is one of the most susceptible (MCDOWELL; VALLE, 2000).

Velasquez-Pereira *et al.* (1997) compared the levels of exchangeable magnesium in the soil of six cattle production regions in Nicaragua and found higher levels of Mg in the soil for the dry season than for the rainy season. They attribute this fact to the increased leaching of this element during the rainy season.

A survey of the topography of the two areas of our study, determined that the average slope of Area 1 (extremely drained) is 20% and Area 2 (well drained) is 25% (CUNHA *et al.*, 1998). We observed different rainfall volumes and rainy days during the experimental period (Table 1). Therefore, we considered a leaching effect of Mg to lower zones in the two areas and Mg percolation to deeper horizons of the soil, which resulted in the annual variation of Mg contents in the soils of the two areas.

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A study of the mineral contents in 11 soil mapping units (SMU) on natural grasslands in the physiographic regions of Depressão Central and Campanha - RS found a high average of Mg (1.0 $cmol_c.dm^{-3}$) in the spring for SMU. However, there was a high variability of Mg levels in natural grasslands considering the different SMU, from very low (0.35 $cmol_c.dm^{-3}$) to very high (1.72 $cmol_c.dm^{-3}$) (SENGER *et al.*, 1996). These results differ from the present study's results since we detected Mg levels with annual variation between 50% and 100% higher than the levels considered high.

Sousa *et al.* (1987) studied soils of six regions in the northeast of the former Roraima Federal Territory/Brazil (topical zone) in the dry and rainy seasons and detected significant differences between seasons and regions. Unlike our study that found high levels of Mg in both soil types, those authors observed very low levels in soils of five regions and medium in only one region. According to the authors, the average Mg content of the soils was 0.29 $cmol_c.dm^{-3}$, ranging from 0.09 to 0.50 $cmol_c.dm^{-3}$.

The Mg content varied significantly ($P < 0.0001$) in the natural grassland vegetation for both areas throughout the year (Figure 2). A significant month × area interaction ($P = 0.0063$) indicates that the variation between months should be considered separately for each area. This variation was highly significant for Area 1 ($P < 0.0030$) and Area 2 ($P < 0.0001$). The functions that expressed the Mg annual variation in the vegetation of Areas 1 and 2 have both annual/semi-annual/four-monthly components, whose residues of adjustments were not significant for Area 1 ($P = 0.1905$) and significant for Area 2 ($P = 0.0142$).

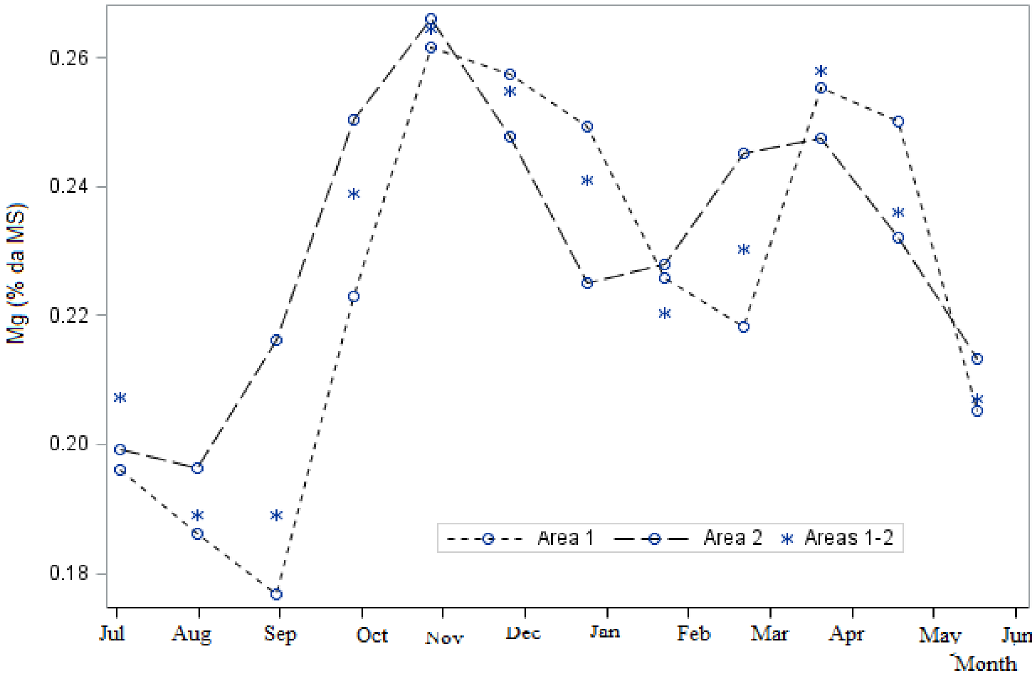
The average Mg content for Area 1 vegetation was 2.3 g Mg/kg DM, ranging from 1.8 g Mg/kg DM in the cold season to 2.6 g Mg/kg DM in the hot season. We observed a similar effect for Area 2. This area also had an average content of 2.3 g Mg/kg DM, ranging from 2.0 g Mg/kg DM in the cold season to 2.7 g Mg/kg DM in the hot season. The annual average levels of Mg in vegetation for both areas are in the range of 1.8 – 3.6 g Mg/ kg DM observed in grasses and legumes (SUTTLE, 2010).

The slightly higher Mg content observed for Area 2 in the cold season than Area 1 is probably due to the different floristic composition, which originated from some factors. Reis (2005) studied the phosphorus dynamics in the same areas and attributed the variation of P levels to the different floristic composition of the two areas, but mainly to the overgrazing, that occurred in Area 2 before the investigation. Probably, it is also due to some interactions in the soil-plant system, climatic factors, and topography of each area individually (ALFAYA *et al.*, 1997).

However, the trend of annual variation was similar for the two areas since the predominant periodic components were annual, semi-annual, and four-monthly. They correspond to seasons of vegetation growth. More exuberant in the hot season, due to milder temperatures (Table 1) from early spring to early summer, and in the cold season, moderate, from early autumn to mid-winter. Another study corroborates this fact (HERINGER; JACQUES, 2002); in their study in the region Campos de Cima da Serra - RS, the authors found a high amount of Mg in undisturbed natural grassland vegetation in the spring-summer, intermediate in autumn, and low in winter. Another study conducted in the same region reached the same results (WUNSCH *et al.*, 2006).

Considering the recommendations of Mg per kg DM for different categories of beef cattle (NRC, 2016), we can verify that the average Mg levels in the two areas meet the requirements of growing and finishing cattle (1.0 g Mg/kg DM), gestating cows (1.2 g Mg/kg DM), and lactating cows (2.0 g Mg/kg DM). Thus, it is considered that the annual Mg levels determined for the two areas are sufficient to meet the requirements of all categories of cattle grazing on natural grasslands in the county of Piratini – RS, Brazil.

- Area 1: $z_i = 0.2254 - 0.0208\sin(\pi i/6) - 0.0187\cos(\pi i/6) - 0.0191\sin(\pi i/3) + 0.0169\cos(\pi i/3) - 0.0075\cos(\pi i/2) - 0.0110\cos(2\pi i/3)$. $R^2=0.958$.
- Area 2: $z_i = 0.2306 - 0.0083\sin(\pi i/6) - 0.0173\cos(\pi i/6) - 0.0213\sin(\pi i/3) + 0.0063\sin(\pi i/2)$. $R^2=0.858$.



Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Average
Area 1	0.20	0.19	0.18	0.22	0.26	0.26	0.25	0.23	0.22	0.26	0.25	0.21	0.228
Area 2	0.20	0.20	0.22	0.25	0.27	0.25	0.23	0.23	0.25	0.25	0.23	0.21	0.233

Figure 2. Average monthly levels of magnesium in the vegetation of rangeland areas in the municipality of Piratini – RS, Brazil.

Alfaya *et al*. (1998) considered the recommendations of requirements for sheep (NRC, 1985) and cattle (NRC, 1996), and determined Mg sufficiency in the forage of three areas for sheep and insufficiency for cattle only in one area, in the spring-summer period. Those results are very similar to the ones of the present study. Already Wunsh *et al.* (2006), also considering the NRC (1996) indicate that in the region of Campos de Cima da Serra - RS, the Mg content of the vegetation can meet only the requirements of less demanding categories of beef cattle, such as dry cows, growing and finishing animals.

Still in regions of RS, were found in 11 SMU an average of 1.1 g Mg/kg DM in vegetation, ranging from 0.6 g Mg/kg DM to 1.5 g Mg/kg DM over the four seasons (SENGER *et al*., 1996). Considering the NRC (1996), it was concluded that only one unit presented deficiency during the entire year. In three units, they found deficiency only in winter. In the other units (7), there were no deficiencies in forage for grazing animals, as in our study. The authors concluded that only 14.5% of the samples did not present the minimum content required for beef cattle.

In Roraima Federal Territory, Sousa et al. (1987) report that Mg levels in vegetation varied between dry and rainy seasons, and among regions, there was a difference in Mg levels from very low (0.62 g Mg/kg DM) to high (2.42 g Mg/kg DM). However, unlike the present study, these authors determined sufficiency only for the less demanding categories, such as growing and finishing animals in most regions. Only one region there was sufficiency for lactating beef cows.

Mg averages of 1.16 g Mg/kg DM and 1.25 g Mg/kg DM in rainy and dry seasons, respectively, were found in six regions of Nicaragua (VELAZQUES-PEREIRA *et al.*, 1997). The authors determined a variation of Mg levels in the vegetation of different regions, mainly during the rainy season. But they also found a variation in the dry season on a smaller scale. Considering the critical level of ≤ 2.0 g Mg/kg DM they determined Mg insufficiency in the vegetation of all regions in the two seasons.

Mg levels in the vegetation of semi-arid areas in Pakistan on alkaline soils (pH = 7.8-8.4) were studied for four months. The forage was composed of legumes mixed with grasses and there were high Mg levels, an average of 3.3 g Mg/kg DM. This average exceeds more than 40% of those obtained for the two natural grasslands of our study. The high Mg levels in the forage of that study were probably due to a large share of legumes in the vegetation. According to Kirchgessner *et al*. (2014), legumes have Mg levels up to three times higher than grasses.

There was a significant annual variation in Mg content in the blood serum of the animals (Figure 3) for both areas ($P < 0.0001$); the interaction month x area was not significant ($P = 0.0752$).

The annual averages for the two areas of 3.05 and 3.06 mg of Mg/100 ml of blood serum are high for beef cattle. Although McDowell and Valle (2000) indicate ≤ 2.0 mg of Mg/100 ml as a critical level, levels above 2.0 mg of Mg/100 ml are considered normal (NRC, 2016). Moreover, values between 2.0 and 4.0 mg of Mg/100 ml were considered as normal for beef cattle (KANEKO; HARVEY; BRUSS, 2008; GONZÁLEZ; SILVA, 2019).

The adjusted curves of the two areas are similar, with high coefficients of determination. Both have linear components and annual, semi-annual, and four-monthly periodicals; the curve adjusted for Area 1 includes the trimester component. The residues of these adjustments were not significant ($P = 0.2571$ and $P = 0.4846$, respectively, for the Areas 1 and 2).

We observed a continuous increase in Mg levels in the blood serum of animals from the beginning to the end of the study, expressed by the significance ($P < 0.0001$) of the linear component. This trend suggests the result of young growing animals (heifers), which are more efficient in homeostatic control than adult animals. Consequently, there is a better absorption, utilization, and excretion of Mg from the body (mechanism: intestine - bones – kidneys). As the animals grew, the Mg content in blood serum increased, reaching almost 4.0 mg of Mg/100 ml, which is the upper limit of normality proposed (GONZÁLES; SILVA, 2019).

The adjusted curves for the two areas have annual, semi-annual, and quarterly components; the curve adjusted for Area 1 includes the trimester component. The residues of these adjustments were not significant P = 0.2571 and P = 0.4846, respectively, for Areas 1 and 2.

In the Federal Territory of Roraima, it was concluded, as in our study, that the Mg levels in the blood serum of animals were within the normality standards (SOUSA *et al.*, 1987). The values ranged from 2.1 to 3.2 mg/100 ml in lactating cows and 2.5 to 3.0 mg/100 ml in young cattle during dry and rainy seasons. Therefore, similar Mg levels for growing and adult animals.

In Nicaragua Mg levels were evaluated in blood serum of lactating cows, heifers, and calves (VELASQUEZ-PEREIRA *et al*, 1997). The authors reported that lactating cows presented higher levels of Mg in blood serum than heifers and heifers more than calves. Those results were not expected since young animals are more efficient in controlling metabolic balance than adult animals. Considering this assumption, we observed the evolution of the Mg levels in the blood serum of the animals of our study (Figure 3). The levels are in accordance with the animals' growth, from calves to heifers, corroborating the results observed in that study.

The research in Nicaragua also reports that except for calves in the dry season (1.9 mg of Mg/100 ml), the averages for all categories were ≥ 2.0 mg Mg/100 ml; however, it is reported that the variability was 0.04 and 0.07 mg Mg/100 ml. Thus, the averages below the critical level varied among the six regions studied, both for the rainy (15 – 63 %) and for dry seasons (17-55 %).

In Pakistan, in areas grazed by lactating cows (± 315 kg; 2nd lactation), it was concluded that the average Mg levels in animal plasma (1.36 mg/100 ml) were marginally deficient, although the average Mg levels in vegetation (0.33 % kg DM) were relatively high (KHAN *et al.*, 2010). The authors suggest the need for Mg supplementation to improve plasma levels and prevent growth and metabolic disorders in animals. Those results are in disagreement with ours. Although we found average levels close to critical (MCDOWELL; VALLE, 2000) in the natural grassland vegetation, there were high Mg levels in the blood serum of grazing animals.

The comparison of results from this and other studies suggests a very complex interaction in the soil–plant–animal chain. Thus, there is a need for more studies to elucidate unknowns that arise in studying the dynamics of Mg in this chain.

Considering the average levels of Mg in the vegetation (2.3 g Mg/kg DM) of both areas and the recommendations for small ruminants (NRC, 2007), we infer that the Mg content in the natural grassland vegetation of the region meets the needs of the sheep's categories: growing lambs (1.2 g Mg/kg DM), ewes at the end of gestation (1.5 g Mg/kg DM) and ewes at the beginning of lactation (1.8 g Mg/kg DM).

The average Mg content in vegetation (2,3 g Mg/kg DM) of both areas is sufficient to meet requirements of Mg content per kg of DM for growing horses of 200 -250 kg (1.8 g Mg/kg DM); horses of 400 kg with average work (2.1 g Mg/kg DM); mares in the tenth gestation month (2.0 g Mg/kg DM), and lactating mares (2.2 g Mg/kg DM) (MEYER; COENEN, 2002; NRC, 2006).

In any case, supplementation should be considered for the most demanding categories, such as gestating and lactating females of all species, from late autumn to mid-spring, due to the fact that the apparent absorption coefficient (20-40%) of magnesium of forages is very low (GONZÁLES; SILVA, 2019; HENRY;

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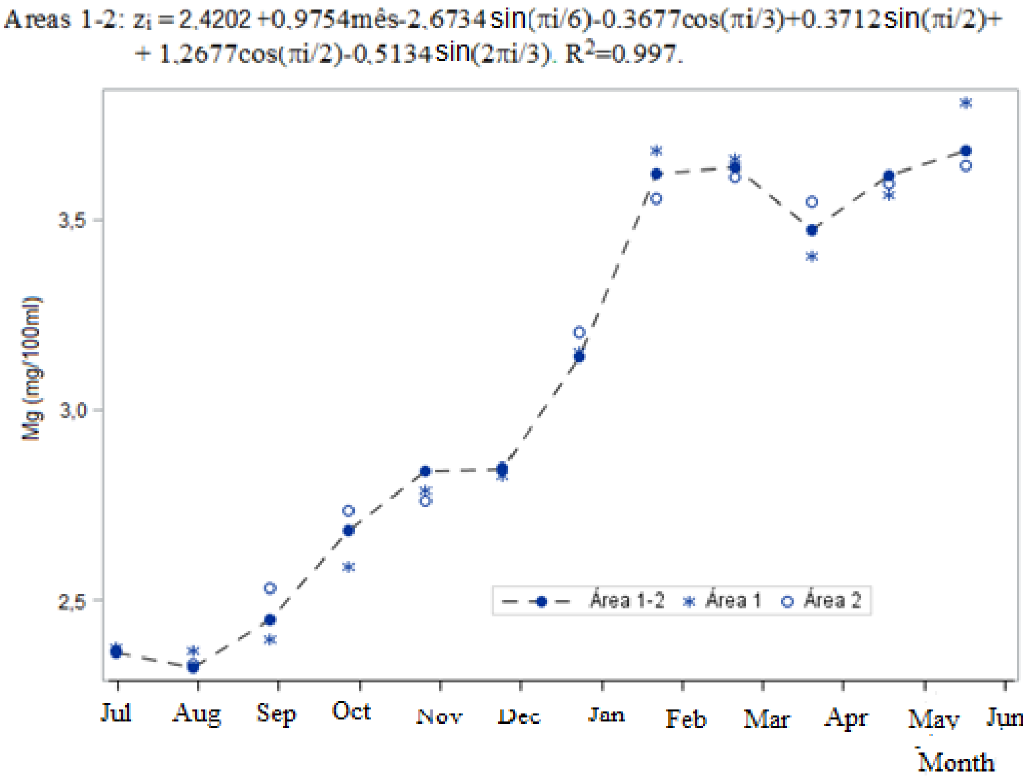
BENZ, 1995; NRC, 2016; SUTLLE, 2010; VELASQUEZ-PEREIRA *et al*., 1997).



Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Average
Area 1	2.37	2.36	2.39	2.59	2.79	2.82	3.15	3.68	3.66	3.40	3.56	3.81	3.05
Area 2	2.36	2.33	2.53	2.73	2.76	2.85	3.20	3.55	3.61	3.54	3.60	3.64	3.06

Figure 3. Average monthly levels of Mg in blood serum of grazing animals in rangeland areas in the municipality of Piratini – RS, Brazil.

Thus, considering the results obtained in this study, it is inferable that there is an annual variation of magnesium contents in soil, vegetation and blood serum of growing animals kept under continuous extensive grazing in natural grasslands areas at the region. The magnesium contents in these soils are considered high. Magnesium contents in the vegetation is sufficient to meet the needs of all categories of beef cattle, small ruminants and horses. Magnesium levels in the blood serum of growing animals (heifers) are considered medium to high and are within normal levels. Magnesium supplementation should be considered for the most demanding categories in the cold season of the year.

Conflict of interest

The authors declare that the research was conducted in the absence of any potential conflicts of interest.

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Ethical statements

The authors confirm that the ethical guidelines adopted by the journal were followed by this work, and all authors agree with the submission, content and transfer of the publication rights of the article to the journal. They also declare that the work has not been previously published nor is it being considered for publication in another journal.

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