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Article

Pasture response to continuous and rotational grazing in northern Mexico

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Abstract:

Good management of extensive cattle grazing can be used as a tool to prevent pasture degradation. Grazing systems make it possible to regulate the pressure exerted on the pasture and optimize production. Two grazing systems under similar ecological conditions were evaluated: rotational (RS) and continuous (CS). Both systems have been implemented for more than 20 years in two plots of land of Rancho San Rafael, Canatlán, Durango, Mexico. To determine their impact, the pasture responses in soil, vegetation, and cattle were analyzed. Data were analyzed under a completely randomized design with RStudio and Tukey (P<0.05) for forage production/height, plant cover, and soil minerals. Live weight gain was calculated and compared, stratified by weight ranges, in young stocker heifers (13-15 mo old) for both grazing systems. Significant differences (*P*<0.05) were found for the rotational system, where there was a greater amount of available dry matter (DM), as well as increases in nitrate, sodium, calcium, potassium, and electrical conductivity of the soil. Both forage height and weight gain showed no differences (*P*>0.05); nevertheless, a significant advantage (*P*<0.05) was only found in weight gain for heifers ranging from 121 to 160 kg. The rotational system showed an advantage for forage production due to the periodic rest of the pasture, which allowed greater availability of biomass. Significant improvements (*P*<0.05) were identified for nitrate, sodium, and potassium levels in the soil, which are relevant indicators for pasture productivity.

Keywords: Grazing System, Pasture, Soil, Stocker phase.

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Introduction

Natural pastures occupy approximately 6.1 % of the national territory, while induced pastures occupy 6 % and are mainly concentrated in the north of the country. Nonetheless, about 39 % of these ecosystems show some degree of deterioration due to land-use change and overgrazing(1). In the state of Durango, with a total area of 123,451 km^2 (6.3 % of the national territory), pastures cover about 40 % of the territory (49,272 km^2)(2). According to SEMARNAT's compilation of environmental statistics, Durango has almost seven million hectares of unparcelled ejido land, of which about one million is destined for extensive livestock farming, most of which is not adequately regulated(3,4).

In extensive livestock farming systems, the primary production of natural pasture is the main input for livestock development. Proper management of grazing cattle can enhance pasture productivity and quality(5,6). To optimize rangeland production, it is crucial to maintain a balance between the resources available throughout the year, adjust the stocking rate according to the time of year, and ensure that the animals maintain adequate body condition(7). When implementing cattle grazing system, it is essential to consider the attributes of vegetation and cattle. Although implementation studies can be carried out at different times of the year, during the rainy months, it is advisable to evaluate the response of the pasture to grazing over several years.

The continuous grazing system (CS) allows cattle to have constant and unrestricted access to a specific area, facilitating forage selectivity. This system is simple to implement and requires less labor, in addition to entailing lower handling costs. However, its main disadvantage is the inefficient and irregular use of vegetation, which can lead to pasture degradation(8,9). On the other hand, the rotational grazing system (RS) divides the grazing area into paddocks or smaller plots, between which cattle are rotated at intervals defined by productivity and time of year. This approach allows pastures to recover while cattle feed in other areas. The RS offers advantages such as better control of stocking rate, greater regrowth, and diversity of vegetation; likewise, it also provides greater efficiency in the use of plant resources(10,11,12). In addition, the RS benefits from the experience of the cattle farmer, who can identify areas for improvement and adjust management according to the condition of the vegetation(13). The type of grazing system influences the properties of the soil and the floristic composition of the pasture. Soil characteristics usually determine the distribution and type of vegetation predominant in an area(14-17). This study aimed to analyze and compare the effect of continuous grazing (CS) and rotational grazing (RS), during the stocker phase, on vegetation, livestock, and soil variables, in a medium-size open pasture of a Livestock Production Unit located in the municipality of Canatlán in the State of Durango, in which, this management has been applied for at least 20 yr.

Material and methods

The study area belongs to a private ranch, with medium-sized open pasture, in the locality of Benjamín Aranda, Canatlán, Durango, Mexico. Semi-dry, temperate climate $BS_1kw(w)$(18). Average annual temperatures range from 12 to 18 °C, with a minimum and maximum of -3°C and 30 °C, respectively. Summer rainfall regime, with 550 mm of annual precipitation(19). The ranch consists of two plots of land where two grazing systems have been used for at least 20 yr: “La Huerta”, with an area of 200 ha, and “La Vía”, with 150 ha. In “La Huerta”, RS has been applied in 16 paddocks, with grazing time in each paddock lasting two to three days. Random sampling was used to evaluate vegetation and soil in both plots. On the other hand, continuous grazing (CS) has been used in “La Vía” since the last century. Stocker cattle grazed each plot for 7 mo (April to October); this included a 3-mo period during the dry season, followed by 4 mo during the rainy season; the above was done in order to gain weight under free grazing. Grazing animals included young crossbred heifers, with an average weight of 166 kg [for weaning weights, less than 0.5 animal units (AU) of 450 kg]. In 2023, 110 heifers were used for each plot or grazing system (55 AU for “La Huerta” and “La Vía”). The stocking rates were 3.64 ha per AU for “La Huerta” and 2.72 ha for “La Vía”.

At the beginning of the experiment, the cattle were randomly assigned in groups of three (experimental unit) to seven replications for each of five groups (3 x 7 x 5 = 105; plus 5 floating individuals); they were analyzed for the different weight ranges; the above became fixed (group) as the animals increased in weight. The first vegetation and soil sampling were carried out in April 2023 (dry season) and consisted of 35 points in each plot, which were randomly generated with ArcGIS Software. The depth of soil sampled was 30 cm, and the height of vegetation was measured from ground level. The variables evaluated in the vegetation included height of pasture plants (grasses), dry matter (g DM m^2), and aerial vegetation cover (%). The variables evaluated in the soil included potential of hydrogen (pH), electrical conductivity, and the following in ppm: nitrates (NO_3), sodium (Na), calcium (Ca), and potassium (K). Of the samples obtained, eight composite samples were formed at representative points of each plot. Ten grams of soil per screened sample were stirred with 10 ml of distilled water for 10 min. For each solution, the elements mentioned above were analyzed with the HORIBA LAQUATWIN kit. Each sensor, and for each nutrient, was calibrated to improve the certainty of results. The second sampling was carried out at the same sampling points as in the dry season, in October 2023, considering the same variables, except for those of the soil, since they reflected a period of at least 20 yr of use under each RS and CS scheme.

Samples to evaluate DM were taken in 1 m^2. The grasses were cut at ground level and dried in the laboratory in a forced-air oven at 60 °C for 48 h to constant weight. The DM data were used to calculate the available DM per hectare. Regarding weight gain, it was obtained based on the weight of each group of heifers at the beginning, during, and at the end of the seven months of grazing, for both systems and established ranges; to this end, the cattle were separated into groups in order to compare the weight gain by weight strata for CS and RS. The data were analyzed under a completely randomized design with RStudio[(20)] and Tukey[(21)], also known as the honestly significant difference (HSD) test, which is used to compare means of treatments and, once the assumptions of normality are met, to determine statistical differences ($P<0.05$).

Results

In soil, nitrates represented the most abundant nutrient in both grazing systems (Figures 1 and 2), reaching concentrations of 500 ppm in CS and 600 ppm in RS, which indicates nitrogen-rich soils, compared to other analyses, where the soil of a medium-sized open pasture did not exceed 30 ppm[(22)]. In general, nitrogen is not a limiting element under high-intensity, low-frequency RS (16:1 paddocks; rest/use, as implemented in this study)[(22)]. The concentration of nutrients in the soil in RS and CS showed significant differences ($P<0.05$).

Although similar concentrations were observed in sodium and calcium levels, nitrates and potassium presented different behaviors. In particular, the highest levels of nitrates were recorded in "La Huerta" (RS). Regarding soil pH, values of 7.0 and 7.3 were obtained for each plot, indicating a neutral pH (Table 1). Statistical analysis using Tukey's test revealed differences ($P<0.05$) in favor of RS for the nutrients evaluated, except for calcium.

Figure 1: Soil nutrient concentration (parts per million; ppm). Continuous grazing plot "La Vía"

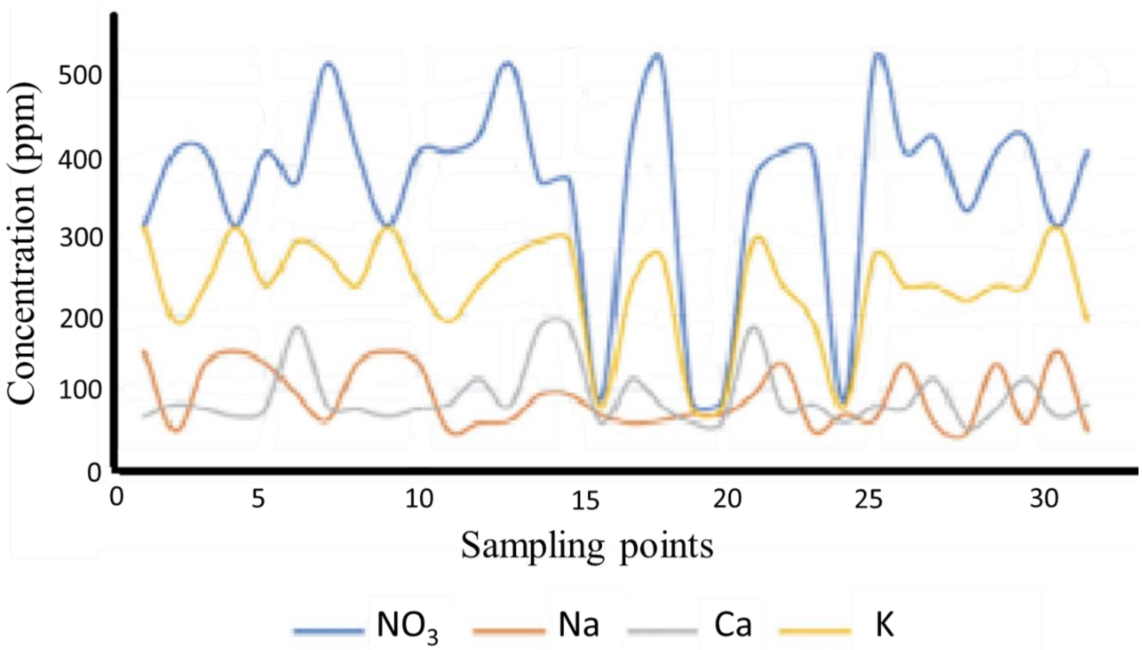
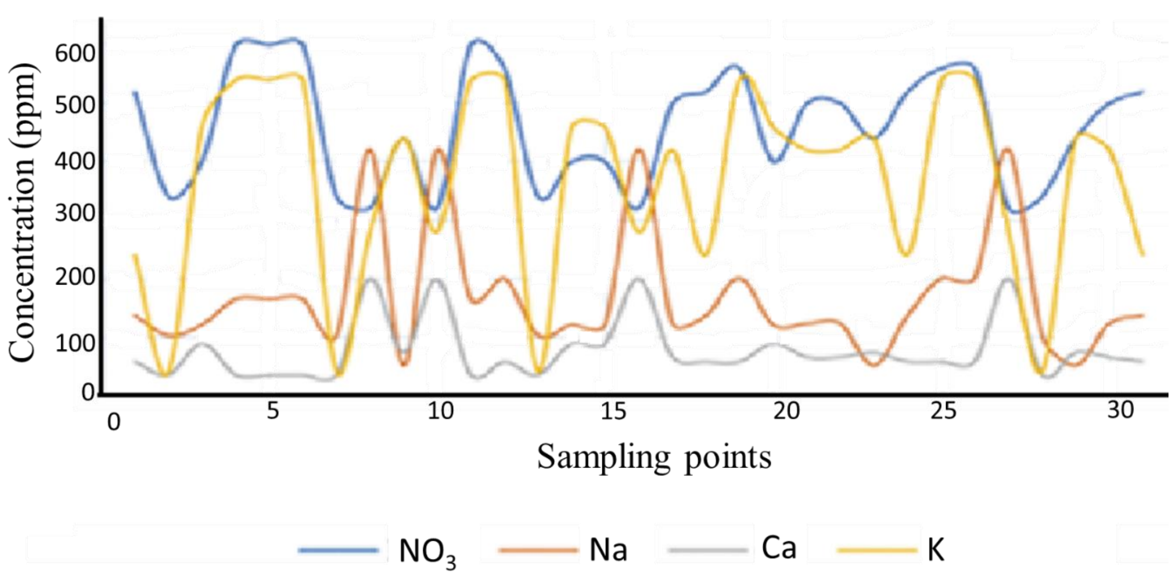


Figure 2: Soil nutrient concentration (parts per million; ppm). Rotational grazing plot "La Huerta"



Forage production in April was significantly higher (P<0.05) in RS, with 182 g DM m^2, compared to 75 g in CS. This difference was also reflected in the availability of forage during the dry season, being higher in RS (Table 2). After the grazing period and the rainy season, forage production decreased to 39 g DM m^2 in RS and 27 g m^2 in CS (P>0.05). These figures are attributed to the severe drought recorded in 2023, which significantly limited the production of DM. Despite these conditions, forage availability was higher in the dry season under RS. To evaluate the grazing intensity, the carrying capacity and grazing coefficient of each plot were determined (Table 2; Table 3). In both systems, the equivalent of one animal unit (450 kg) corresponded to 2.5 stocker animals, considering an average weight of 166 kg per heifer. With an estimated feed intake of 3 % of its body weight, each heifer requires approximately 4.98 kg of DM per day. Therefore, the total DM intake in each plot was 600 kg per day. For 7 mo, this is equivalent to a supply of 126 t of available forage in both plots.

Table 1: Values of variables for RS and CS in April 2023 and their significance

Variable	Means		***P*-value**
	Continuous	**Rotational**	
Dry matter, g m^2	75.53 [b]	182.36 [a]	9.499e-06***
Height of pasture plants, cm	16.37	18.77	0.3439[NS]
Electrical conductivity in soil, mS/cm	69.47 [b]	183.81[a]	0.004177***
NO_3 in soil, ppm	375.50 [b]	460.64 [a]	0.004212***
Na in soil, ppm	88.56 [b]	167.93 [a]	0.0003839***
Ca in soil, ppm	89.68	77.35	0.2909 [NS]
K in soil, ppm	235.37 [b]	367.74 [a]	0.0002008***
pH in soil	7.27 [a]	7.04 [b]	0.0328**

Significance: α= 0.05, α= 0.01; ** indicates 95 % confidence; *** indicates 99 % confidence, NS= not significant; mS/cm: microSiemens/centimeter, ppm= parts per million.

Table 2: Carrying capacity and grazing coefficient in April and October 2023

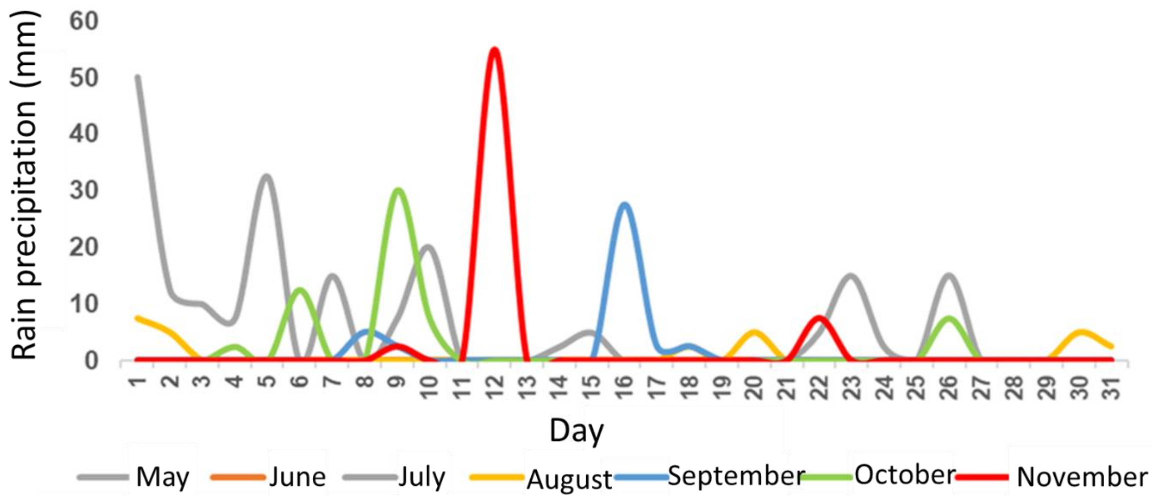
Sampling period in 2023	Grazing system	DM production g m^2 *	DM production kg ha^{-1} **	Total DM production t ***	Actual carrying capacity ****	Grazing coefficient *****
April	Rotational (RS)	185 g	1,850 kg	370 t (200) ha	74 AU $year^{-1}$	2.7 ha AU^{-1}
April	Continuous (CS)	75 g	750 kg	112 t (150) ha	22 AU $year^{-1}$	6.8 ha AU^{-1}
October	Rotational (RS)	39 g	390 kg	78 t (200) ha	15 AU $year^{-1}$	13.3 ha AU^{-1}
October	Continuous (CS)	27 g	270 kg	40.5 t (150) ha	8 AU $year^{-1}$	18.8 ha AU^{-1}

*DM g m^2= dry matter in grams per square meter; ** DM kg ha^{-1}= dry matter in kilograms per hectare; *** DM t ha^{-1}= dry matter in tonnes per hectare;
**** AU $year^{-1}$= animal units per year; ***** ha UA^{-1}= hectares per animal unit.

According to the analysis carried out in April, the CS can sustain up to 34 AU, considering a utilization of 100 % and daily consumption equivalent to 3 % of the DM of the animals' body weight; the above is for the eight months that the stocker period lasts. Based on the DM production in April (Table 2), having 112 t DM available to the 8-mo grazing period that the stocker stage lasts, one AU would require consuming 3,240 kg of dry matter to sustain itself. These 34 AU, multiplied by the annual consumption of forage in the stocker period, translate into a total of 85 heifers (assuming 2.5 heifers per UA). Nevertheless, during the dry period, the CS supported a stocking rate of 110 stocker heifers, which represents a surplus of 25 heifers over the estimated capacity. This imbalance indicates that the stocking rate in the CS was excessive during the dry season, compromising the sustainability of the pasture and the body condition of the cattle.

Typically, there is more forage production during the rainy season; however, this was not the case due to the reduced rainfall in 2023 (Figure 3). The vegetation, adapted to aridity conditions, managed to provide the required DM through compensatory growth, provided by nocturnal atmospheric humidity (dew) and despite the grazing exercised[23]. RS demonstrated the ability to sustain up to 114 AU, considering a 100 % utilization for 8 mo of grazing and a DM intake equivalent to 3 % of the animals' live weight. Nonetheless, the scarce precipitation limited the normal development of forage in both plots, which resulted in an increase in the grazing coefficient. In RS, the coefficient showed a four-fold increase (has AU^{-1} yr^{-1}; Table 2); in contrast, in the CS, the increase was almost three-fold. Forage production in RS decreased by 79 %, from 1,850 to 390 kg ha^{-1}, between the two seasons evaluated. In CS, the reduction was 64 %, from 750 to 270 kg ha^{-1}. At the end of the grazing period, the feed intake of the forage produced was 79 % in RS and 65 % in CS (Table 2). Based on this analysis, a remainder of 20 % of the annual growth was left, since the cattle did not exceed a feed intake of 80 % of the forage available in the plots. During the warmer grazing months, there was a rainfall of 360 mm, significantly lower than the historical average of 540 mm for the same period over the past 10 yr, representing a 35 % reduction (Figure 3). This low rainfall negatively affected forage production, particularly during the prolonged dry season.

Figure 3: Precipitation (mm) in Rancho San Rafael, Canatlán, Durango, Mexico, in the stocker period and for the year 2023



During the dry season, differences (P<0.05) were observed between RS and CS in several variables, except for the height of pasture plants (P>0.05; Table 3). In contrast, in the rainy season, there were highly significant differences (P<0.01) for pasture plant height and pasture cover, with the highest values observed in RS. Regarding animal weight gain, the individuals managed in RS obtained an average gain of 89.6 kg (0.427 g d^{-1}) during the stocker period; on the contrary, those in CS reached 90.4 kg (0.430 g d^{-1}) (P>0.05; Table 4); nevertheless, a decrease in weight gain was detected as the weight of the animals increased (due to natural growth), which is attributed to higher nutritional needs in the advanced stages of the stocker phase.

The weight ranges between 121 and 160 kg stood out as the most efficient in terms of gain during the 7 mo of the stocker phase, a period traditionally used at Rancho San Rafael. Weight gain was 66.3 kg ha^{-1} in CS, compared to 49.3 kg ha^{-1} in RS. Tukey's test showed no significance (P>0.05) concerning average weight gain between both systems, and a similar performance was identified in the gain patterns by weight ranges (Table 4).

Table 3: Attributes of the vegetation under rotational (RS) and continuous (CS) grazing, October 2023

Variable	Means		*P*-value
	Continuous	Rotational	
Dry matter, g m^{-2}	19.00	32.08	0.2172
Height of pasture plants, cm	7.59 [b]	10.08 [a]	0.0009301***
Aerial vegetation cover, %	72.65 [b]	79.63 [a]	0.0068230***

** indicate 95 % confidence and *** indicate 99 % confidence.

Table 4: Weight gain in kg, by strata from initial to final weight, in stocker heifers from RS and CS, for seven months

Initial weight range (kg)	Weight group	Continuous	Rotational
		Gain (kg)	Gain (kg)
100-120	1	113	75
121-140	2	103.6	102.6
141-160	3	97	104.9
161-180	4	83.6	93
181-200	5	82.6	68.8
201-220	6	87.6	65.3
221-240	7	74.6	54.5
	Mean	90.4	89.6
P-value			0.83

RS showed differences ($P<0.05$) compared to CS ($P<0.01$), with 20 % more NO_3 in soil. This higher concentration of nitrates in RS translated into higher primary productivity, especially when combined with adequate rainfall during the summer. These results are comparable to those reported under holistic and continuous management in natural pastures[23]. The efficiency in the use of NO_3 in the soil showed a direct response to the type of grazing management implemented, favoring RS, especially when regulated stocking rates were applied[24]. This advantage aligns with previous studies, where the availability of NO_3 in CS tends to be lower due to a more extended period or greater pressure of grazing during the study periods[14,25]; however, although the increase in nitrates may be beneficial for vegetation cover, it may also represent a disadvantage. Areas with high availability of NO_3 in the soil are more susceptible to invasion of unwanted species[26]; therefore, it is recommended to analyze the flora present in each grazing system. Hence, it is essential to analyze the flora present and monitor its changes. The difference in floristic composition lies in the selectivity of cattle in RS and CS, as well as in the number of paddocks and behavior of cattle when grazing[27].

Discussion

The length of grazing by area is shorter in RS; given the above, nutrients in the soil are affected by the duration of grazing at the site: the higher the grazing intensity, the lower the availability of total nitrogen, total phosphorus, and total organic carbon; on the other hand, pH did not show a direct relationship with the type of grazing(23). In this case, as only 80 % of the forage production was used, even in an abnormal year of drought, the levels of NO_3 were adequate in the soil. As a result of greater resilience of vegetation and soil nutrients, due to historical grazing management, DM production was significantly higher (P<0.05) for RS in the drought period. This was not observed in the comparative analysis of RS and CS in the rainy season (P>0.05), due to the intensity of the drought and the lack of regrowth during 2023. Abnormally low rainfall, as was the case in this year of study, caused the natural recovery of the pasture to be slow, a response confirmed by the second DM analysis performed at the end of the study period (Table 2). CS presented lower forage production, but this DM production did not show a significant difference (P=0.2172). With a normal average rainfall level, higher forage production (DM) and pasture recovery would have been observed in both plots, although with a significant advantage to RS due to the resting period of the pasture(28,29).

The stocking rate used for the year 2023, both in the CS and RS plots, would exceed the forage production capacity available for 2024 and, therefore, would be limiting to re-enter the same number of animals from 2023, for the stocker period in 2024, which is shown as a disadvantage in abnormal years of low rainfall, as 2023. In this regard, the drought compromised the plant's regrowth response to the onslaught of grazing. Jakoby *et al*(30) mention that adjusting the stocking rate to the grazing capacity should be sufficient to guarantee the regeneration of the pasture, which suggests that the appropriate grazing system is one that respects the forage production capacity of the pasture(30). This contrasts with other authors who point to continuous grazing as the leading cause of degradation, since it promotes selectivity and irregular patches by generating pressure on certain landscapes, communities, and species(31). Selectivity provides cattle with the best forage quality, making the weight gain greater in CS, and also causes irregular patches with highly variable and differential regrowth for primary productivity. Dry forage needs for cattle are consistent throughout the year; nevertheless, productivity fluctuations are limited to the periods of abundance/scarcity of growing conditions (rainy/dry; summer:winter), factors that determine the response of vegetation in pasture under grazing.

A comparative study conducted in Canada between these two grazing systems considered 32 ranches with similar conditions; the information was based on the total area grazed, the number and size of the sub-paddocks, the beginning and end of each grazing season, as well as the grazing period within these paddocks in the pasture growing season. The number of cattle grazing was used to determine the carrying capacity of each ranch. The ranches were considered to be randomized complete blocks. The rest period for pastures in rotational ranches was two months on average, whereas in continuous grazing ranches, it was minimal or almost non-existent[9]. In this case, the rest period of the rotational pasture ranged between 30 and 40 d in each paddock, plus the winter period (4 mo); in contrast, in CS, the rest period for the pasture only corresponded to the 4 mo of the winter period. The height of the pasture was higher for the rotational system (P<0.05). According to an analysis in 40 ranches under continuous and rotational grazing in Uruguay, the difference in pasture height was 3.7 cm on average in favor of the rotational grazing system[32]; in this study, the difference was 2.4 cm in the dry season and 2.49 cm in the rainy season, greater for RS.

Weight gain has been described as less efficient in RS. Studies show a 12 to 14 % reduction in annual weight gain in cattle. Nonetheless, given the low stocking rate in both systems, this drawback can be controlled[33]. In this experiment, a non-significant difference (P>0.05) was observed in the percentage of gain in live weight in RS compared to CS, probably due to the control of the stocking rate in rotational grazing, where there is no high selectivity among cattle for forage resources or over-/under-grazed areas in the paddock. It has been justified that there is an advantage in live weight gain in animals under continuous grazing and that it is lower under a rotational system. However, other studies in tropical areas, in monoculture pastures and better forage production conditions, suggest a greater gain in rational rotational grazing, described as a 14-paddock cattle rotation system. In this case, there were 16 paddocks under rotation with grazing times according to the producer's criterion of choosing the best paddock at the time for grazing[28]. A higher efficiency in live weight gain per hectare has been reported for the rotational system, which outperformed the continuous system; in this case, the live weight gain in RS and CS did not show significant differences[34]. The climatic or precipitation effect is not the same in all plots, so its influence is direct in terms of obtaining protein in grazing animals[35]. Nevertheless, applying a system that adapts to the observation and use of the best paddock allows, in rainy weather, to choose the pasture with the highest grass growth, which, by nature, will give a higher DM and quality of forage in the grass available for cattle.

One of the necessary factors to evaluate in pastures is access to and distance to water sources, which is influenced by factors such as storage infrastructure, type of cattle, and annual rainfall, which could cover around 70 % of the amount of water extracted annually in cattle wells[35]. In this case, in the two plots, there was water availability all year round, allowing the heifers to be adequately supplied, so it was not considered a stress factor for the cattle. On the other hand, concerning aerial soil cover, RS presented 10 % greater cover compared to that observed in CS, indicating potential soil losses due to erosion (water or wind) when grazed under a CS. This cover was lower in CS compared to RS and under the vegetation conditions studied (P<0.05), this responds, indirectly, to a greater capacity to take advantage of moisture and reduce sediment loss in rotational systems, given the (theoretical) reduction in the kinetic energy of water runoff and the effect of exposure to the sun and wind; this is as shown by research that considers variables such as aerial biomass and soil depth[36]. The effects on the evaluated parameters are associated with increases in the capacity to capture moisture, which translates into greater production of vegetative material, which in turn results in greater soil sustainability in the pastures[37] and is reflected in the productivity and ecological functionality of the pasture.

Conclusions and implications

Grazing management in San Rafael, with more than 20 yr of application, showed better results in pasture condition in the rotational system (RS) compared to the continuous system (CS). Implementing a grazing control strategy that allows the pasture to rest during its growth period (as in RS) resulted in a better condition of the pastoral ecosystem. Despite the benefits observed in RS, the total weight gain of stocker cattle throughout the grazing season did not show significant differences (P>0.05) between the two systems. However, when analyzing specific stages of the stocker phase, it was observed that the continuous movement of cattle in RS, under the evaluated scheme, was not sufficient to induce significant increases in weight gain. These results highlight the importance of adjusting grazing schemes to maximize pasture and cattle productivity, especially under conditions of climatic variability. The better condition of pasture fertility in RS implies a better productive response capacity of the latter when there are years of abundant rainfall. It is recommended to continue evaluating and optimizing RS management over several years to document and, where appropriate, fully exploit its advantages and ensure the sustainability of the tangible and non-tangible benefits of the pasture.

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