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Different Grazing Frequencies Modify the Structure, Production, and Nutritional Value of 'Zuri' Guineagrass in the Brazilian Cerrado

Jéssica Gomes Rodrigues[1] | Gelson dos Santos Difante[1] | Denise Baptaglin Montagner[2] | Valéria Pacheco Batista Euclides[2] | Alexandre Romeiro de Araújo[2] | Marislayne de Gusmão Pereira[1] | Gabriela de Oliveira Aquino Monteiro[3] | Juliana Caroline dos Santos Santana[4] | Alana Amarilha Aparecida Nobre[1]

[1]Faculty of Veterinary Medicine and Animal Science, Federal University of Mato Grosso Do Sul, Campo Grande, Brazil | [2]Brazilian Agricultural Research Corporation, Embrapa Beef Cattle, Campo Grande, Brazil | [3]Department of Animal Science, São Paulo State University "Júlio de Mesquita Filho" – UNESP, São Paulo, Brazil | [4]Graduate Program in Animal Production, Federal University of Rio Grande Do Norte, Macaíba, Brazil

Correspondence: Jéssica Gomes Rodrigues (jessicagr1993@outlook.com)

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ABSTRACT

The increasing climate variability in tropical regions demands management goals that allow for shorter rest periods without compromising pasture persistence. The objective of this study was to evaluate the effects of four pre-grazing light interception (LI) levels on the structural, productive, and nutritional responses of 'Zuri' guinea grass over two growing seasons. The experiment followed a randomized block design with four treatments (80%, 85%, 90%, and 95% LI) and four replications (16 paddocks of 0.045 ha). The pastures were managed using the mob stoking grazing method. LI was measured using a ceptometer and used directly as a management target. The response variables were analysed using mixed models (PROC MIXED, SAS). Significant interactions between LI × year ($p < 0.05$) were observed for canopy height, FM, FA, FAR, and TD. Linear increases in canopy height, FM, and FA with higher LI were more pronounced in the second year. With an LI of 80%, FM, FA, and TD decreased in the second year, indicating lower structural and productive stability. In contrast, pastures managed with LI between 85% and 95% maintained a stable canopy structure between years, with increased production. Morphological composition and nutritional value were affected only by the LI (Low Intake): increasing the LI reduced the percentage of leaves, crude protein, and digestibility, while increasing the stem, dead matter, and fibre content. LI targets of 85% and 90% provide a balance between grazing frequency, forage quality, and structural stability, representing flexible and sustainable management strategies under varying climatic conditions.

1 | Introduction

Management strategies that enable efficient use of forage are essential for animal production systems utilizing pastures. The forage ingested by animals in these systems is the result of the grazing management targets established, such as pre- and post-grazing conditions and criteria used to define grazing intervals. Traditionally, research on tropical forages under intermittent grazing has been conducted using fixed periods of occupation and rest (Crestani et al. 2017). However, in recent decades, grazing management techniques have been developed based on the responses of forage plants to environmental factors, primarily light (Macedo et al. 2021). In systems employing rotational or intermittent grazing methods, factors such as reduced light in the forage canopy during the regrowth process, variations in water and nutrient availability in the soil, and grazing management can alter the canopy composition and compromise both the productivity and the persistence of plants in the system (Braz et al. 2017; Lopes et al. 2017).

Light interception (LI) refers to the fraction of incident solar radiation that is captured by the canopy of forage plants, and is directly influenced by leaf area and plant density (Da Silva and Nascimento Júnior 2007). This variable has been consolidated as an effective physiological parameter for decision-making in grazing management, as it reflects the balance between plant growth and senescence processes (Zubieta et al. 2021). In Brazil, studies with tropical grasses have indicated that the optimum point for interrupting the regrowth process and starting grazing occurs when the canopy intercepts approximately 95% of the incident light, a condition that maximizes the accumulation of good quality forage (Carnevalli et al. 2006; Barbosa et al. 2007; Difante et al. 2009; Zanine et al. 2013).

When climatic conditions limit plant growth, the time required to reach the 95% VD target can be excessively long (Carnevalli et al. 2006; Giacomini et al. 2009), making it difficult to manage animals in the available paddocks and making it an impractical management target for producers under these conditions (Alvarenga et al. 2020). Furthermore, the specific target of 95% LI may be overly restrictive, especially in environments favorable to forage growth, such as fertilized and/or irrigated pastures (Zanine et al. 2011). In such cases, it is common for a larger number of paddocks to reach optimal grazing conditions simultaneously.

Frequent climate variability has significantly altered precipitation patterns, making rainfall distribution increasingly irregular and unpredictable (IPCC 2021; Marengo et al. 2020). This instability is particularly pronounced during seasonal transition periods, such as the shift from the rainy to the dry season and from the dry to the rainy season, when water availability and forage growth conditions fluctuate markedly. During these transitional phases, pasture growth rates become less predictable, complicating grazing management decisions. In this context, understanding the behaviour of cultivars under higher grazing frequencies relative to the conventional management target of 95% LI becomes especially relevant, as it may allow shorter grazing intervals (Zanine et al. 2011) without compromising pasture persistence (Araújo et al. 2020).

It was hypothesized that 'Zuri' Guineagrass [*Megathyrsus maximus* (Jacq.) B.K. Simons & S.W.L. Jacobs, syn. *Panicum maximum* Jacq.] is capable of tolerating grazing frequencies higher than the commonly recommended 95% LI target without compromising its production, structure, or nutritional value. Therefore, the study evaluated the effects of four LI levels (80%, 85%, 90%, and 95%) in pastures managed under stocking grazing over 2 years.

2 | Material and Methods

2.1 | Ethics Statement

This project was approved by the Animal Use Ethics Committee (AUEC) the Embrapa Beef Cattle, under no. 003/2018, in accordance with the ethics of animal experimentation established by the National Council for Animal Experimentation (CONCEA).

2.2 | Location and Experimental Period

The experiment was conducted at Embrapa Beef Cattle, located in Campo Grande, Mato Grosso do Sul, Brazil (20°27′ S latitude and 54°37′ W longitude, at an altitude of 530 m above sea level). The trial period was from October 2020 to May 2022.

2.3 | Climate, Soil, and Fertilization

The region features a tropical rainy savanna climate, subtype Aw (Peel et al. 2007), characterized by seasonal rainfall distribution. Temperature and precipitation data for the experimental period were collected by the meteorological station at Embrapa Beef Cattle. Based on the average monthly temperature and accumulated monthly precipitation data, the water balance for the experimental period was calculated (Figure 1), using a soil water storage capacity of 150 mm (Santos et al. 2018).

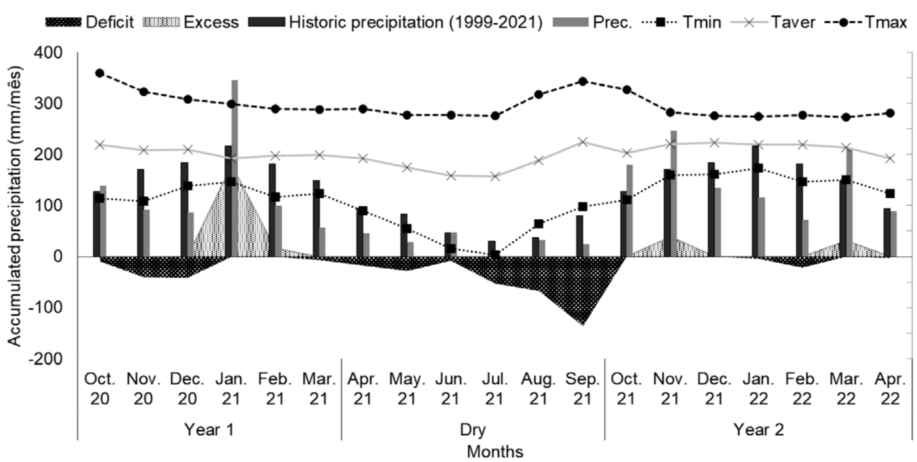

FIGURE 1 | Water balance, monthly precipitation, historical monthly precipitation, and maximum, minimum, and average temperatures during the experimental period. Prec, precipitacion; Tmin, minimum temperature; Taver, average temperature; Tmax, maximum temperature.

TABLE 1 | Results of chemical analysis of soil fertility before the start of the experimental period (March de 2020).

		P	OM	K	Ca	Mg	Al
Depth (cm)	pH $CaCl_2$	mg dm^{-3}	%	cmol^{-3}			
0–10	4.99	6.30	4.02	0.36	2.62	1.91	0.32
0–20	4.87	5.07	3.63	0.19	2.48	1.73	0.48
20–40	4.97	4.52	3.91	0.23	2.72	1.83	0.32

	H + Al	SB	CEC_P	BS	CEC_E	AS
Depth (cm)	dm^3			%		
0–10	5.82	4.89	10.70	45.07	5.21	8.34
0–20	5.34	4.75	9.74	44.09	4.88	13.12
20–40	5.41	4.77	10.18	46.34	5.09	7.52

Note: OM—Modified South Dakota; P and K—Mehlich I; Ca and Mg—Mehlich III; Ca and Mg—Mehlich III; Al—KCl; H + Al—SMP.
Abbreviations: AS%, Al saturation; BS, base saturation; CEC_E, effective cation-exchange capacity; CEC_P, potential cation-exchange capacity; OM, organic matter; SB, sum of bases.

The soil of the experimental area is classified as red Dystric Latosol (Soil Survey Staff 1999). Soil samples were collected on a single date prior to treatment implementation, at depths of 0–10, 0–20, and 20–40 cm for chemical analysis, in order to characterize the initial soil fertility conditions of the area. A 0–10 cm layer was tested separately to evidence nutrient stratification on the soil surface, common in pasture areas under topdressing with few mobile nutrients such as phosphorus. Based on these results (Table 1), fertilization was carried out with 60 kg ha^{-1} of P_2O_5 and 60 kg ha^{-1} of K_2O using a 0-20-20 (N-P-K) formula, and maintenance fertilization included 150 kg ha^{-1}year^{-1} of N divided into three doses of 50 kg ha^{-1}.

Nitrogen fertilization was performed at the end of each grazing cycle, immediately after the animals were removed. Urea was used as the main nitrogen source, except in the final application, in which ammonium sulfate was chosen. This change was due to the decrease in precipitation at the end of the production cycle, since ammonium sulfate presents lower losses through volatilization in drier soil conditions compared to urea.

2.4 | Experimental Area and Design

Zuri guinea grass was sown in 2017 in a total pasture area of 0.96 ha. The experimental area comprised 16 paddocks of 0.045 ha each (totaling 0.72 ha) arranged in four blocks with four paddocks per block and service corridors (totaling 0.24 ha; Figure 2). The experimental design was a randomized complete block design with four treatments, represented by pre-grazing LI levels of 80%, 85%, 90%, and 95%, and four replicates. The post-grazing height was consistently maintained at 50% of the pre-grazing height. The experiment spanned 2 years, from November 2020 to March 2021 and from November 2021 to March 2022.

There was no data collection from April to October because inadequate weather conditions (soil water deficit and temperatures below 15°C) did not allow the pastures to reach pre-grazing targets. The paddocks were established and managed starting in January 2019, with treatments applied from October 2020. They were managed under intermittent grazing using mob stocking, characterized by high grazing pressure for a short period to rapidly remove forage as a management strategy (regime of 1–2 days of occupation) (Allen et al. 2011).

2.5 | Defoliation Agents

Caracu steers, approximately 24 months old, were used as defoliation agents. These animals were kept in a reserve area planted with *Panicum Maximum* cv. Massai until each Zuri grass paddock reached the predetermined pre-grazing targets.

The instantaneous stocking rate was adjusted considering the 1–2-day occupancy period and the post-grazing target height. Animals were allocated to each paddock according to forage availability to achieve the predetermined post-grazing height (50% of the pre-grazing height). Canopy height was monitored frequently during the grazing period, and the number of animals was adjusted when necessary to ensure that the target stubble height was reached within the planned grazing duration.

2.6 | Evaluations

2.6.1 | Light Interception and Canopy Height

LI was estimated using an AccuPAR Linear PAR/LAI ceptometer (Model PAR–80; DECAGON Devices) at 10 representative points within each paddock. Representative points were selected based on the average canopy condition of the paddock at the time of evaluation, considering mean canopy height, tussock size, and spatial distribution of plants. At each point, one reading was taken above the canopy (full sunlight) and another at ground level beneath the canopy. LI was calculated from the difference between the above-canopy and ground-level readings.

Once the paddock reached the target LI, canopy height was measured at 20 points per paddock using a centimetre-graduated

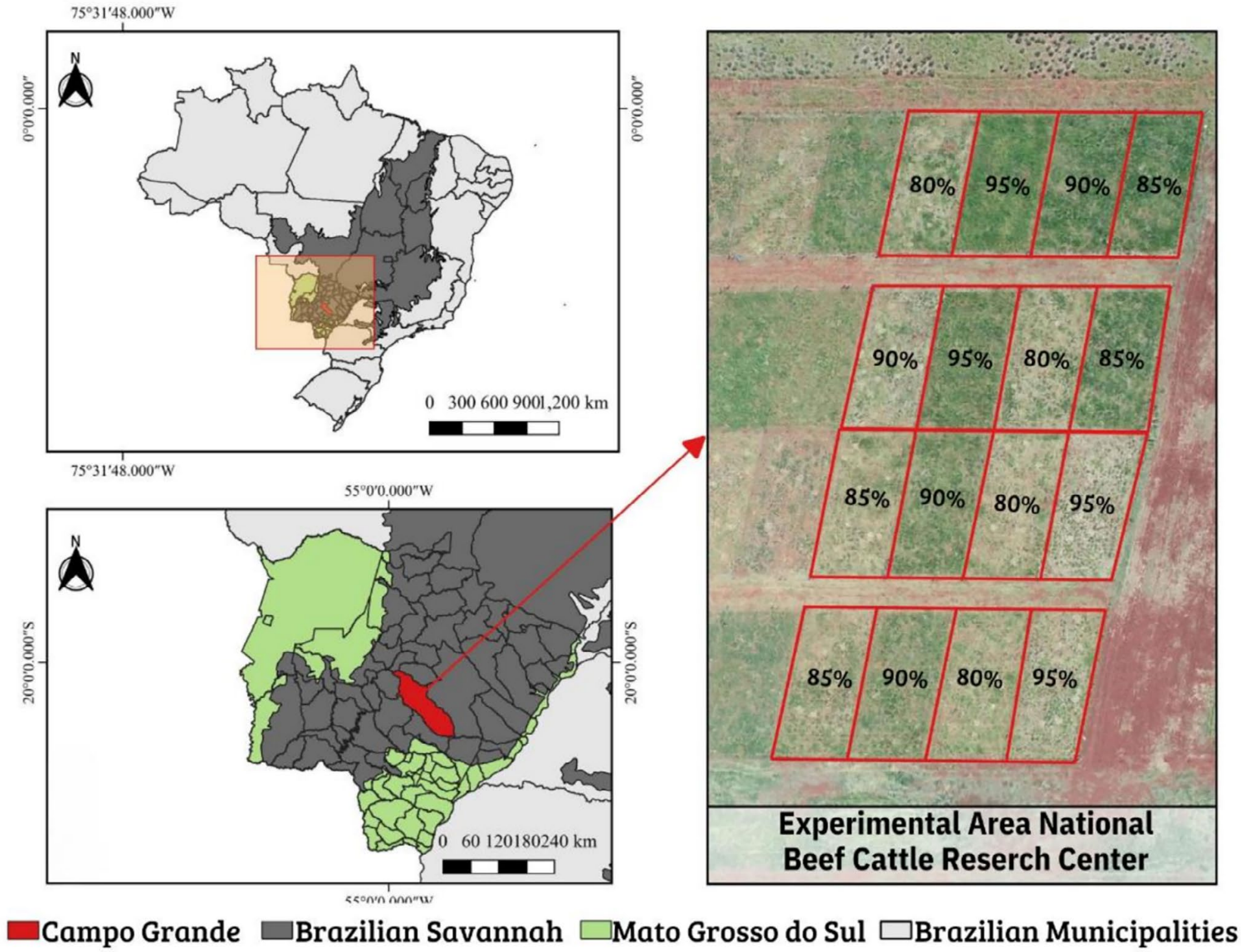

FIGURE 2 | Location of the experimental area in Mato Grosso do Sul, Brazil.

ruler. The mean canopy height corresponding to the target LI was designated as the pre-grazing height and was used to determine the target stubble height for the post-grazing period (50% of the entry height).

2.6.2 | Forage Mass, Morphological Components, and Nutritional Value

The masses of forage and its morphological components, both pre- and post-grazing, were estimated by cutting the vegetation at ground level in three $1m^2$ squares per paddock, located at points representative of the average canopy height. The harvested samples were divided into two subsamples: one was weighed and oven-dried at 65°C to a constant weight to determine dry matter, and the other was separated into leaf (leaf blade), stem (stem + sheath), and dead material, then dried at 55°C to a constant weight (Details of sample processing were described by Euclides et al. (2016)). Each component was expressed as a percentage of the total weight and used to estimate the leaf: stem ratio and the green: dead material ratio.

The leaf blades from the morphological separation, after drying, were ground to 1 mm and analysed to determine the percentages of crude protein (CP), neutral detergent fibre (NDF), in vitro organic matter digestibility (IVOMD), and acid detergent lignin, using near infrared spectroscopy (NIRS). Details of the samples analysed via wet chemistry for calibration, as well as the calibration equations, are described in Campos et al. (2024).

2.6.3 | Forage Accumulation and Grazing Interval

Forage accumulation (FA) was calculated as the difference in forage mass between the pre-grazing and post-grazing periods of the previous cycle, considering only the green portion (leaf and stem). The rest period (RP; Allen et al. 2011) was defined as the average time (days) required for the pastures to reach the pre-grazing targets after the animals were removed from the paddocks. The forage accumulation rate (FAR) was computed by dividing the FA by the GI.

2.7 | Tiller Density

Tiller density (TD) was assessed by counting tillers in an area of $1\ m^2$ at three points representative of the average pasture height, per paddock. These areas were chosen to reflect the average condition of the pasture, and counts were conducted whenever the pastures achieved the pre-grazing condition.

2.8 | Statistical Analysis

Data were collected in each grazing cycle and the results were grouped into year 1 (October 2020 to March 2021) and year 2 (October 2021 to March 2022). Data were subjected to analysis of variance considering a randomized block design, LI and year and their interactions as fixed effects and blocks as random effects. The model applied was:

The statistical model used was:

$$Yijk = \mu + Bj + IPi + Yk + (IP \times Y)ik + \varepsilon ijk$$

where $Yijk$ is the observed value in the paddock subjected to the i-th LI level, in the j-th block and k-th year; μ is the overall mean; Bj is the random effect of block ($j=1, 2, 3, 4$); IPi is the fixed effect of the in the LI level ($i=80\%$, 85%, 90%, and 95%); Yk is the fixed effect of year ($k=$Year 1 and Year 2); Yk is the fixed effect of the interaction between LI level and year; $(IP\times Y)ik$ is the fixed effect of the interaction between LI level and year; and εijk is the residual error term.

Year was considered a fixed effect because differences between years and their interaction with LI were of interest due to contrasting precipitation patterns (Figure 1). Data were subjected to analysis of variance using the PROC MIXED procedure in SAS OnDemand for Academics, considering LI, Year, and their interaction as fixed effects and blocks as random effects.

When a significant LI × Year interaction was detected ($p \leq 0.05$), the interaction was unfolded, and means were compared using Tukey's test at the 5% probability level to evaluate differences within each LI level across years and within each year across LI levels.

In the absence of significant interaction, the effect of LI was evaluated using regression analysis (PROC REG). Both linear and quadratic models were tested, and the model was selected based on the significance of regression coefficients at the 5% probability level and biological interpretability. Differences between years were interpreted directly based on the ANOVA F-test when no significant interaction was present.

3 | Results

3.1 | Light Interception, Grazing Cycles, and Grazing Interval

LI by the canopy consistently fell within the target ranges of 80% ±0.8, 85% ±0.7, 90% ±0.4, and 95% ±0.2 throughout the experimental period.

There was an LI × year interaction for the grazing cycles (GC) and rest period (RP) (Table 2). For GC there were negative slopes due to the increase in LI of 0.15 in year 1 and 0.35 in year 2. Between the years only the pastures managed with 95% LI did not show changes. For RP there was a positive increase due to LI of 6.55 days (Year 1) and 5.04 days (Year 2). The shortest RP occurred in pastures managed with 80% LI, with a difference of 20 days for 95% LI.

3.2 | Structural and Productive Traits

There was a LI × year interaction for the variables (Table 3) pre and post-grazing height ($p<0.0001$), pre-grazing FM ($p<0.0001$), post-grazing FM ($p=0.0261$), FA ($p=0.0298$), FAR ($p=0.0003$), and TD ($p=0.0169$).

Both pre- and post-grazing heights increased with LI, following an increasing linear equation model. Pre-grazing height increased with LI levels by 8.9 cm in year 1 and 12.4 cm in year 2. For post-grazing, the increase was 0.86 and 1.15 cm in years 1 and 2, respectively (Table 3). A notable reduction of 22.2% in pre-grazing height compared to the previous year was observed only in pastures managed with 80% LI.

Forage mass, both pre- and post-grazing, followed an increasing linear regression model (Table 3). In pre-grazing, forage mass increased by 238.4 kg/ha of DM in year 1 and 353.2 kg/ha of DM in year 2 as LI increased. In relation to post-grazing, the increase in forage mass was 114.94 and 163.42 kg/ha of DM in years 1 and 2, respectively (Table 3). There was an effect of the FM year for treatments with 80%, 90%, and 95% of IL. For pastures managed with 80% of IL, there was a

TABLE 2 | Grazing cycles and grazing interval of Zuri grass managed under pre-grazing light interception levels over 2 years of evaluation.

	80	85	90	95		p			
Period	**Grazing cycles (n)**				**SEM**	**Linear**	**Quad.**	**Equation**	R^2
					Light interception (%)				
Year 1	6.0b	4.7b	4.0b	3.7a	0.22	0.0138	ns	$Y=17.75-0.15\times$	0.91
Year 2	9.0a	7.0a	5.0a	4.0a	0.22	0.0011	ns	$Y=37.37-0.35\times$	0.97
	Rest period (days)								
Year 1	19.3a	23.3a	27.2a	39.7a	1.62	<0.0001	ns	$Y=10.95+6.55\times$	0.90
Year 2	17.0a	21.5a	25.0a	32.6b	1.41	<0.0001	ns	$Y=11.43+5.04\times$	0.97

Note: Means followed by lowercase letters in the column differ from each other by Tukey's test at 5% significance. Year 1: October 2020 to March 2021; Year 2: October 2021 to March 2022; SEM: standard error of the mean; Linear: p-value for linear regression equation; Quad: p-value for quadratic regression equation. Abbreviations: ns, not significant; R^2, coefficient of determination.

TABLE 3 | Canopy height, forage mass pre- and post-grazing, tiller density, and forage accumulation in Zuri grass pastures managed under interception levels in different seasons of the year, over 2 years.

	80	85	90	95		***p***			
Period	**Pre-grazing height (cm)**				**SEM**	**Linear**	**Quad.**	**Equation**	R^2
	Light interception (%)								
Year 1	48.4a	55.6a	63.4a	74.5a	1.2	< 0.0001	ns	$Y = -94.55 + 1.77\times$	0.97
Year 2	37.6b	54.93a	65.4a	75.6a	1.0	< 0.0011	ns	$Y = -160.91 + 2.50\times$	0.98
	Post-grazing height (cm)								
Year 1	24.7a	27.6a	31.0a	36.4a	0.6	< 0.0001	ns	$Y = -45.80 + 0.86\times$	0.94
Year 2	19.0b	28.0a	32.8a	38.a	0.5	< 0.0001	ns	$Y = -71.89 + 1.15\times$	0.93
	FM_{Pre} (kg/ha DM)								
Year 1	4008.5a	4458.3a	6096.3b	7451.0b	196.7	< 0.0001	ns	$Y = -15337.00 + 238.40\times$	0.95
Year 2	3236.8b	4667.5a	7136.1a	8125.4a	170.8	< 0.0001	ns	$Y = -25051.72 + 353.21\times$	0.92
	FM_{Post} (kg/ha DM)								
Year 1	2560.9a	2919.7a	3595.9b	4158.2b	196.7	< 0.0001	ns	$Y = -6699.84 + 114.94\times$	0.94
Year 2	1980.0b	2697.3a	3808.1a	4350.8a	170.8	< 0.0001	ns	$Y = -11130.40 + 163.42\times$	0.97
	FA (kg/ha DM)								
Year 1	1231.8a	1698.4a	2101.2b	3285.6b	206.4	< 0.0001	ns	$Y = -10137.16 + 136.43\times$	0.91
Year 2	970.7b	1446.2a	3441.6a	3947.9a	179.2	< 0.0001	ns	$Y = -17444.45 + 227.99\times$	0.94
	FAR (kg/ha DM.day)								
Year 1	64.5a	73.9a	78.5b	82.0b	7.8	ns	ns	—	—
Year 2	58.9a	68.26a	141.3a	122.9a	6.8	< 0.0001	0.046	$Y = -2283.27 + 49.36\times\text{-}0.25\times^2$	0.80
	Tiller density (Tillers/m^2)								
Year 1	413.6a	357.9a	320.3a	288.4a	11.9	< 0.0001	ns	$Y = 1064.05 - 8.14\times$	0.98
Year 2	357.9b	364.3a	347.1a	283.3a	10.3	< 0.0001	0.001	$Y = -4389.58 + 112.70\times - 0.66\times^2$	0.99

Note: Means followed by lowercase letters in the column differ from each other by Tukey's test at 5% significance. Year 1: October 2020 to March 2021; Year 2: October 2021 to March 2022; SEM: standard error of the mean; Linear: *p*-value for linear regression equation; Quad: *p*-value for quadratic regression equation.
Abbreviations: FA, forage accumulation; FAR, forage accumulation rate; FM, forage mass; ns, not significant; post, post-grazing; pre, pre-grazing; R^2, coefficient of determination.

reduction from year 1 to year 2 of 19.2% in FM in pre-grazing and 26.5% in post-grazing. In pastures managed with 90% and 95% IL, there was an increase from year 1 to year 2 of 17.0% and 9.0% in pre-grazing FM and 5.9% and 4.6% in post-grazing FM, respectively.

Forage accumulation followed an increasing linear regression model as a function of increasing IL, with an increase of 136.43 kg/ha of DM in year 1 and 227.9 kg/ha of DM in year 2 for each 5% increase in LI (Table 3). In year 2, there was a 21.2% reduction in AF for pastures managed with LI of 80% and an increase of 63.4% and 20.1% for those managed with LI of 90% and LI of 95%, respectively.

FAR in year 1 did not fit any equation model, averaging 74.7 kg/ha DM/day. In year 2, there was an increase in FAR to 61.2 kg/ha DM/day, peaking at 112.7 kg/ha DM per day in pastures managed at 90% LI. Above this level, there was a decline of 6.9 kg/ha DM/day until reaching a LI of 95% (Table 3). A significant year effect was observed in pastures managed at 90% and 95% LI, with increases in year 2 of 44.4% and 33.2%, respectively.

Tiller density in year 1 followed a decreasing linear equation model, with a reduction of 8.1 tillers as LI increased (Table 3). In year 2, the data followed a quadratic equation model, peaking at LI 85% and decreasing by 0.66 tillers to LI 95%. There was a significant annual effect for pastures managed at LI 80%, with a reduction of 55.7 tillers (approximately 12%) in year 2.

There was no significant interaction or year effect ($p > 0.05$) on the percentage of leaves (%L), stems (%S), and dead material (%DM) pre- and post-grazing. Regarding the effect of LI, %L followed a decreasing linear equation model, with a decrease of 5.1% pre-grazing and 3.5% post-grazing for each 5% increase in LI (Table 4).

Both %S and %DM adhered to increasing linear regression models, with increases in %S of 2.2% pre-grazing and 1.9%

TABLE 4 | Percentage of morphological components, leaf: Stem ratio (L:S), and green: Dead material ratio (G:D) of Zuri grass managed under pre-grazing light interception levels over 2 years of evaluation.

Variable	80	85	90	95	SEM	*p* Linear	*p* Quad.	Equation	R^2
	Pre-grazing								
					Light interception (%)				
%L	61.2	52.9	50.2	43.1	1.44	< 0.0001	ns	$Y = 149.68 - 1.12\times$	0.94
%S	24.1	27.1	28.7	31.1	0.82	< 0.0001	ns	$Y = -56.4 + 1.03\times$	0.98
%DM	14.7	19.9	21.1	25.8	1.50	< 0.0001	ns	$Y = -41.47 + 0.71\times$	0.82
L:S	2.6	2.0	1.8	1.4	0.11	< 0.0001	ns	$Y = 8.04 - 0.06\times$	0.96
G:D	6.1	4.1	3.9	3.0	0.71	< 0.0011	ns	$Y = 31.06 - 0.30\times$	0.80
	Post-grazing								
%L	32.2	27.9	25.5	21.1	1.66	< 0.0001	ns	$Y = 70.79 - 0.55\times$	0.92
%S	31.9	32.6	35.1	37.6	1.33	< 0.0001	ns	$Y = 28.17 + 0.09\times$	0.78
%DM	35.8	39.5	39.6	42.2	1.13	< 0.0001	ns	$Y = 34.4 + 1.92\times$	0.99
L:S	1.0	0.9	0.7	0.6	0.04	< 0.0001	ns	$Y = 2.47 - 0.02\times$	0.91
G:D	1.8	1.6	1.6	1.4	0.07	< 0.0011	ns	$Y = 4.17 + 0.03\times$	0.89

Abbreviations: %DM, percentage of dead material; %L, percentage of leaves; %S, percentage of stems; G:D, Green: dead material ratio; L:S, leaf:stem; ns, not significant; R^2, coefficient of determination; SEM, standard error of mean.

post-grazing, and in %DM of 3.3% and 1.9%, pre- and post-grazing, respectively (Table 4).

3.3 | Forage Nutritional Value

No significant effects ($p > 0.05$) were observed for the LI × year interaction or the year on any of the leaf blade nutritional value variables. LI significantly influenced the NDF, ADF, CP, IVOMD, and lignin content of the Zuri grass leaf blade (Figure 3).

Both NDF (Figure 3a) and ADF (Figure 3b) followed increasing linear regression equations, with increments of 0.20 and 0.21 respectively, for each interval of LI increase within the range of 80% LI to 95% LI. The NDF and ADF content of Zuri grass, irrespective of LI, consistently exceeded 71% and 37%, respectively. The lignin content exhibited a similar pattern, increasing by only 0.03% for each increment in LI, ranging from a minimum of 3.65 at 80% LI to a maximum of 4.2% at 95% LI (Figure 3e).

Crude protein and IVOMD (Figure 3d) followed decreasing linear regression equations, with declines of 0.24 and 0.58 respectively, as LI in the canopy increased. The lowest observed contents of CP (Figure 3c) and IVOMD at 95% LI were 9.5% and 52.1%, respectively.

4 | Discussion

Zuri grass pastures managed under intermittent grazing with higher LI levels experienced longer rest periods, resulting in a decrease in the number of grazing cycles as the LI target for the canopy increased (Table 2). Alvarenga et al. (2020) noted that consistently halting regrowth when the canopy intercepts 95% of light can be challenging for producers to maintain throughout the year due to adverse weather conditions such as low temperatures and prolonged periods of soil water deficit, which lead to extended regrowth periods.

In this study, during the forage growing season, it took 19 and 39 days for Zuri grass pastures to intercept 80% and 95% LI, respectively. This highlights the necessity to understand the plant's responses to higher grazing frequencies, particularly to optimize use within the production window and during the dry-rainy and rainy-dry transition periods when rainfall becomes even more erratic.

The variation in the number of grazing cycles depending on the year highlights the significant influence of climatic conditions on forage growth, reinforcing the importance of using a physiological parameter, such as the LI (Low Intake Level), to guide the decision of when to interrupt regrowth and start grazing. Furthermore, since the paddocks were grazed for a period of 1–2 days, a greater pre-grazing forage mass under higher LI targets required higher instantaneous stocking rates to achieve post-grazing height, indicating that cattle density responded dynamically to the treatment effects.

Productive and structural variables interact with each other (Table 3) and are influenced by the year and management objectives. The increase in pre- and post-grazing heights as a function of increased LI in intermittent grazing systems is documented in several studies (Emerenciano Neto et al. 2017; Da Silva et al. 2020; Macedo et al. 2021) and can be explained by the morphophysiological patterns of tropical grasses during the regrowth period.

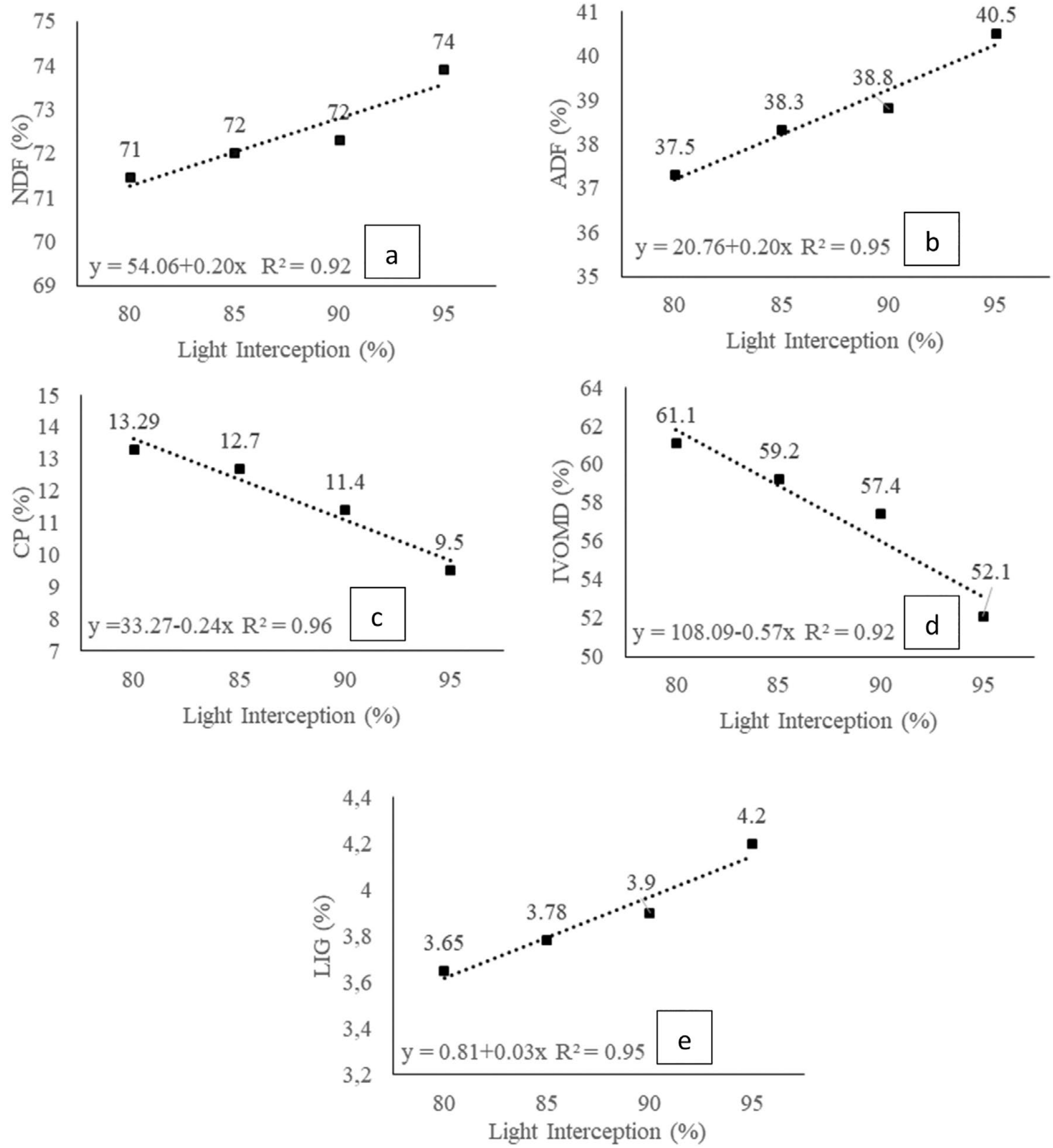

FIGURE 3 | Neutral detergent fibre (NDF, a), acid detergent fibre (ADF, b), crude protein (CP, c), in vitro dry matter digestibility (IVDMD, d), and lignin (LIG, e) of leaves in Zuri grass pastures managed under LI levels over 2 years of evaluation.

Under optimal growth conditions, forage plants rapidly increase their leaf area index (LAI), which subsequently boosts the production of supporting structures (Geremia et al. 2018). This process naturally leads to increases in canopy height, FM, and FA (Table 3).

Canopy height was quantified in conjunction with LI measurements to practically determine the timing for the entry and exit of animals and to verify the correlation between height and LI, as reported in the literature. This approach also facilitates the dissemination of scientific knowledge(Jank et al. 2022). Zuri grass pastures managed with 85%, 90%, and 95% LI maintained constant pre-grazing heights (Table 3). However, pastures managed at 80% LI exhibited a decrease of more than 10 cm in pre-grazing height in the second year and reductions in FM, FA, and TD.

Considering the longevity of the pasture ecosystem, the gradual decline in height, FA and DT observed in pastures managed with 80% LI between the evaluated years demonstrates that even ideal climatic conditions (Figure 1) and nutrient replacement in the second year were insufficient for the pastures to recover their previous tiller density per area, which consequently impacted FM and FA (Table 3). The results suggest that the high frequency of defoliation imposes an excessive demand on the plants, making it difficult to form a stable tiller population. And when it comes to animal production per area, adopting the target of 80% LI in the second year would imply a lower stocking rate due to the lower FA, compared to the same target in the first year.

This behaviour may suggest that Zuri grass employs defence mechanisms against frequent grazing, reducing its growth rate and altering its architecture to evade defoliation. Grazing diminishes plant height, which triggers a range of physiological and plastic responses dependent on the intensity and frequency of grazing (Díaz et al. 2007). With frequent grazing, plants may employ escape and tolerance strategies, such as mobilizing photoassimilates to regenerate leaf area and reducing height to protect growth structures.

The decrease in TD in Zuri grass pastures due to increased LI by the canopy (Table 3) may reflect the plant's response to competition for light (Machado et al. 2020). Since tillering is stimulated by the quantity and quality of light that reaches the base of the canopy (Difante et al. 2011), canopies that are maintained at higher levels receive less light at their base, resulting in less activation of axillary buds to produce new tillers. This leads to a size/density compensation, where pastures maintained at higher levels have larger but fewer tillers (Gastal and Lemaire 2015).

In contrast, pastures managed with 85%, 90%, and 95% LI managed to maintain constant TD between years. Despite lower TD, pastures maintained at higher levels have larger tillers (Gastal and Lemaire 2015). The size vs. density compensation mentioned previously highlights the plasticity of Zuri grass in adapting its growth pattern under adverse scenarios. In conditions of low light incidence, the plant prefers to prioritize the conservation of resources in more stable tillers.

Thus, an increase in LI intensifies competition for light at the base of the canopy, prompting the plant to modify its growth to maximize light utilization (Da Silva et al. 2020). This adaptation significantly influences the morphological composition of the FM (Pereira et al. 2014).

Zuri grass pastures managed with 95% LI exhibited significant changes during the pre-grazing period compared to the target of 80% LI, with a decrease of 30% in %L, and increases of 31.26% in %S and 49.61% in %DM (Table 4). It is important to note that these adjustments may occur not only to utilize photosynthetically active radiation efficiently but also to maintain the physical structure of the canopy by producing more fibrous structures to support leaf production (Valente et al. 2010).

All pastures displayed a pre-grazing L:S above one, indicating a higher %L relative to %S. This is a desirable trait, as leaves have a higher nutritional value than stems (Emerenciano Neto et al. 2017) and contribute to greater photosynthetic capacity in the forage canopy.

The higher pre-grazing L:S at higher grazing frequencies indicates that these pastures have a better structure for grazing animals (Table 4). However, the favourable L:S in pastures managed with 80% LI, while reflective of the percentage of these components, does not consider the amount in kilograms of DM available for animal consumption, which is a critical factor in production systems. Considering that a ruminant consumes approximately 2.5% of its live weight, the decrease in height, FM, FA, and TD in year 2 suggests a reduction in the carrying capacity of these pastures. Moreover, without sufficient forage mass, there is no animal production in pastures, and management practices that compromise TD can accelerate the degradation process, undermining the perennial nature of these plants in the system.

The impact of LI targets on leaf nutritional value variables (Figure 3) and the absence of a year effect suggest that the chemical composition of Zuri grass is more influenced by the stage of development than by environmental variations, provided nutritional requirements are met. Supporting these findings, Tesk et al. (2018) identify the maturity stage as the primary factor affecting nutritional value components, with environmental factors such as soil moisture and fertility playing secondary roles. Thus, the influence of LI targets on the maturity stage of plants significantly alters their nutritional value.

Several studies have assessed tropical grasses, comparing the use of the 95% LI target with maximum LI (Echeverria et al. 2016; Nave et al. 2014; Pedreira et al. 2017) and have reported improved nutritional value, better forage mass composition, and leaf accumulation in pastures managed with 95% LI. Other studies (Alvarenga et al. 2020; Zanine et al. 2013) comparing the 95% LI target with 90% LI found improvements in nutritional value and forage composition at 90% LI, without compromising forage accumulation.

The decrease in CP and IVOMD alongside increases in NDF, ADF, and LIG as LI by Zuri grass pastures increases demonstrates a dilution effect of CP with the rise in pasture maturity and fibrous components (Zubieta et al. 2021). This suggests that halting the regrowth process at higher frequencies, compared to 95% LI, offers animals a diet of better quality, higher nutritional value, and improved structure. However, this aspect must be cautiously evaluated and not considered in isolation, as while improved nutritional value may enhance individual gain, the lower mass and accumulation of forage at pastures managed under 80% LI could lead to a reduced stocking rate and diminished pasture carrying capacity.

In addition, reduced TD and canopy height in Zuri grass pastures are conditions that, together, decrease ground cover. This structural opening creates ecological niches that can be occupied by opportunistic grasses or unwanted native plant species, which compete for light, water and nutrients with the forage of interest. The establishment and persistence of these species alter the botanical composition of the pasture, reducing the stability of the forage ecosystem, and characterizing a degradation process. In this context, the management of zurigrass with 80% LI shows signs of long-term unsustainability, since it compromises both the productivity and the functional composition of the pasture in perennial systems.

Associating the results of yield and nutritional value with assessments of tiller dynamics and the morphogenetic flow of Zuri grass allows for a more detailed understanding of the behaviour of these pastures managed under higher grazing frequencies relative to the maximum target of 95% LI. This approach will provide greater insight into new possibilities for specific, flexible management or extended use periods for more precise forage planning.

5 | Conclusion

LI targets modify the morphological composition, productive capacity, and nutritional value of Zuri grass. Pastures managed under higher defoliation frequencies (80%, 85%, and 90% LI) showed improved nutritional value and morphological composition compared with 95% LI. However, the reductions in forage mass, forage accumulation, and tiller density observed under 80% LI indicate potential limitations to productivity and long-term persistence.

During seasonal transitions (wet–dry and dry–wet), when climatic conditions are unstable and plant growth is less predictable, flexible management is essential to ensure efficient forage utilization. Under these conditions, LI targets of 85% and 90% allow earlier grazing while maintaining adequate forage quality and pasture stability, and are therefore recommended.

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The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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