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Sustainable Intensification of the Montado ecosystem: Evaluation of Sheep Grazing Systems and Soil Amendment

Emanuel Carreira [1,*], João Serrano [1], Shakib Shahidian [1], Paulo Infante [2], Luís L. Paniagua [3], Francisco Moral [4], Luís Paixão [6], Carlos Pinto Gomes [1], José Lopes de Castro [1], Mário de Carvalho [1] and Alfredo F. Pereira [1]

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Abstract: The objective of this study was to determine how application with dolomitic limestone and grazing type (continuous or deferred) affect sheep grazing location and feed preference when the pasture growth rate is maximum. A 4ha field was divided into 4 plots: P1 and P2- without application of dolomitic limestone, continuous (CG) and deferred grazing (DG), respectively; P3 and P4- with application of dolomitic limestone, DG (1AUE), and CG (2.4 AUE), respectively. In DG, animals were placed and removed from the plots depending on the height of the pasture. In each plot, 12 georeferenced sampling points were identified. Throughout the pasture's vegetative cycle (autumn, winter, spring, and early summer) several measurements of pasture height and cut were carried out. From the beginning of March to the beginning of June, animal behavior was observed, by trained observers, through binoculars on six dates. Animals' activity grazing and location was recorded. The results show that: (i) the application of dolomitic limestone combined with CG provided higher values of pasture height; (ii) there were no significant differences in pasture quality between treatments; (iii) Deferred grazing led to 50% more sheep grazing days than continuous grazing; (iv) there were no significant differences in soil compaction between CG and DG; (v) the type of grazing and the treatment with dolomitic limestone did not seem to change the grazing pattern between treatments. This work contributes to understanding the relationships between different types of grazing in dryland pastures, with and without application of dolomitic limestone, and preferred grazing locations for sheep. This work could help agricultural managers make more informed decisions with the aim of promoting the sustainable intensification of livestock production in the Montado ecosystem.

Keywords: deferred grazing; continuous grazing; floristic composition; dolomitic limestone; preferred location; grazing; observations grazing; soil compaction

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1. Introduction

Montado (or Dehesa in Spain) is an agro-silvo-pastoral ecosystem, characteristic of the Alentejo region – Portugal. This ecosystem is associated with various agricultural and leisure activities with

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environmental and social value, thus considered of High Natural Value [1]. Montado is considered as complex ecosystem, due to the interrelations between its fundamental components – climate, soil, pasture, trees, and animals [2]. Montado is influenced by the Mediterranean climate, with rainy and mild winters and, hot and dry summers with great variability and seasonality [3]. During the dry summer, temperatures can reach 40° C and minimum temperatures can drop below 0° C during winter [3]. In this climate, often severe droughts can occur for long periods of time. The soils of this region are classified mainly as Cambisols, derived from granite [4]. These soils usually are degraded, due to erosion and loss of nutrients have fertility limitations and are shallow, stony, acidic, poor in nutrients, with micronutrient imbalances, namely the magnesium (Mg)/manganese (Mn) ratio, which cause Mn toxicity [5]. As a way of mitigating Mn toxicity and the effect of acidity, dolomitic limestone can be applied [6], together with phosphorus fertilization [7]. The typical pastures of the Montado, which tend to be of poor quality associated with low productivity [8], are greatly affected by the amount and the distribution of rain throughout the year and, by the combination of temperatures and rain. Grazing is a key issue for pasture management quality and nature conservation [9,10]. Plants, floristic composition, and biodiversity depends on the animal species, type, and intensity of grazing [10,11]. In the Montado, some farmers practice continuous grazing (CG) system on their farms, while others choose deferred grazing (DG) system, with no common pattern. The DG involves the use of pasture on a given plot, in longer or shorter periods of grazing, depending on the pasture biomass. In this type of grazing, the stocking rate is much higher than that of CG. In large plots, CG tends to prevail [1]. The CG with low stoking rates, enables more selectivity, resulting in higher heterogeneity of pasture consumption, where over- and under-grazed areas can occur simultaneously [12]. Traditionally, pastures are generally managed with relatively low grazing pressures, in both continuous or deferred grazing systems, allowing animals to choose their diet [13]. Selective grazing, stocking rate and grazing seasons influence the range and communities of plant species [14]. Teague et al. [15] reported that DG, provides satisfactory results in productive, ecological, and economic aspects. The DG can contribute to an increase in the coverage percentage of legumes in the pasture, improving the floristic composition and reducing the number of unwanted species of low nutritional value [16]. Heavy grazing can lead to soil degradation (by exaggerated trampling) and loss of biodiversity, while underutilization can lead to a greater preponderance of less palatable species with lower nutritional value and loss of habitat, overlapping a shrub layer [17]. However, Barriga [18], working with cattle, refer that CG has various advantages over DG, such as the return of nutrients to the soil through urine and feces. Also, a decrease in shrubs and increase in grassland species with good nutritional value, and an improvement of animal performances because they can select their diet, are some advantages of CG compared to DG [19,20,21]. The knowledge of the nutritional value of pastures and their availability, throughout the grazing seasons, can lead to improvements in production and management systems for grazing ruminants [22]. In addition to the nutritional value, the height of the pasture also influences the intake, selectivity, and performances of grazing animals [18].

The improvement of feed efficiency, of grazing animals is the major goal of livestock producers [23]. Ecosystems, such as the Montado, where animals have grazed for many centuries, achieve their biological characteristics and balance through interactions between livestock and vegetation [24]. The behavior of ruminants, in grazing, is a function of the characteristics of the plant communities and grazing management decisions [25]. Therefore, the choice of grazing areas is also related to the physical and thermal characteristics of the plot since the animals prioritize their primary physiological needs - water consumption and thermal regulation [26]. Riedel et al. [24] state that the way in which grazing occurs, in each area, depends on the physical environment of that same area, which includes the productivity and quality of pastures, accessibility to certain areas and, the availability of water - very important in the Mediterranean regions mainly in late spring and summer. The season of the year affects the floristic composition of the pasture and its chemical composition, which in turn affect the behavior of grazing animals [14]. In small patches and when the stocking rate is high and, there are plant species of high nutritional value, it can lead to animals always being closer to these areas [27].

Knowledge of animal preferences in pasture and their selectivity is crucial to a better understand of the relationship between animals, grazing and pasture [28]. The use of pastures requires the animals to adapt to their diversity, thus being based on preferences for grazing locations, depending on variety and availability of vegetation [26]. The sheep do not graze continuously, but rather their grazing is interspersed with periods of rumination and rest [23]. The sheep could adjust their behavior on the pasture to maintain group cohesion, if the space provided for each animal is greater than 200 m² [27]. The choice of grazing areas on a plot is related to the animal's ability to select suitable diets, considering the height of the species, the phenological state, their nutritional value, floristic composition, and palatability of the plants [26]. Meteorological conditions also influence the grazing behavior. High temperatures, such as those found in summer in the Alentejo, tend to reduce the amount of daily time spent on grazing and rumination [29]. In sheep, ingestion periods tend to be shorter, and rumination and leisure time are longer and occur during the hottest part of the day. In regions with a hot and dry summer, most grazing periods occur in the early morning, late afternoon, and night [26].

Often, the method for monitoring animal preferences and behavior in the pasture involves direct observation. Observing the behavior of animals during the day, through direct visual observation, is simple, although it time-consuming [23,30], forcing many observations throughout the day at least 10-minute intervals [29,31,32].

The study aims to determine how application dolomitic limestone and continuous or deferred grazing, affect grazing location and preference when pasture presents the highest growth rate.

2. Materials and Methods

2.1. Study Area

This study is integrated in a long-term project to monitor the Montado ecosystem, which started in 2015 (Figure 1), being the culmination of all interventions in the study area since that date and their influence on the animals' food preferences. Figure 1 shows the chronological scheme, for the whole study, resulting in several publications [3,6,7, 33-38]. These studies have been conducted to monitor the effect of dolomitic limestone application on soil, tree, pasture, and sheep grazing interactions over time.

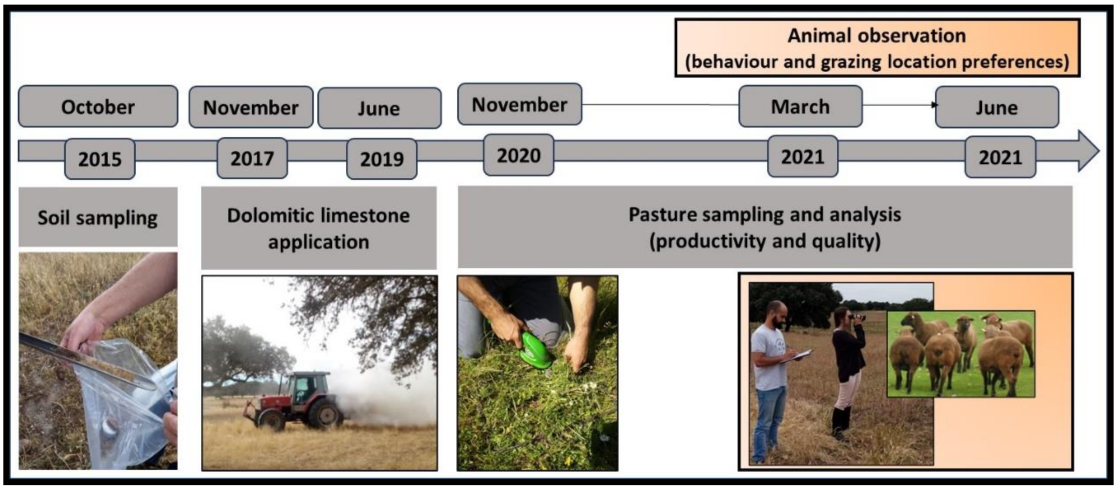

Figure 1. Chronological diagram of the global study, including soil, pasture, and animal monitoring, in the Montado ecosystem.

The predominant soils of this region are classified as Cambisol, derived from granite. The study area is in a large patch of holm oak (*Quercus rotundifolia* Lam.), with dryland pastures in the Montado system, mostly used for extensive animal production, especially to produce beef cattle and sheep.

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The Alentejo is affected by the Mediterranean climate. This climate is characterized by hot and dry summers, and wet and cold winters. The irregular rain distribution and total year precipitation variation are also characteristic of the Mediterranean climate. Most of this precipitation occurring in autumn, winter, and spring. In summer, the precipitation, it will always have residual values.

The study began in November and ended in June, with two phases. In the first phase, from November to February, evaluations were carried out on pastures and measurements of grazing days in the different plots. The second phase began in March with the evaluation of the sheep's grazing behavior, which lasted until late June. The results of height and nutritional value were obtained from November 2020 to June 2021.

This study took place in a 4ha experimental area (38°32.2′ N; 8°1.1′ W), called ECO-SPAA, located at the Mitra experimental farm, University of Évora – Portugal. The 4 ha experimental area was divided into four plots with 1ha each, corresponding following treatments: P1UC - without application of dolomitic limestone and continuous grazing (7 sheep/ha); P2UD - without application of dolomitic limestone and deferred grazing (16 sheep/ha); P3TD - with application of dolomitic limestone and deferred grazing (16 sheep/ha); P4TC - with application of dolomitic limestone and continuous grazing (7 sheep/ha) (Figure 2).

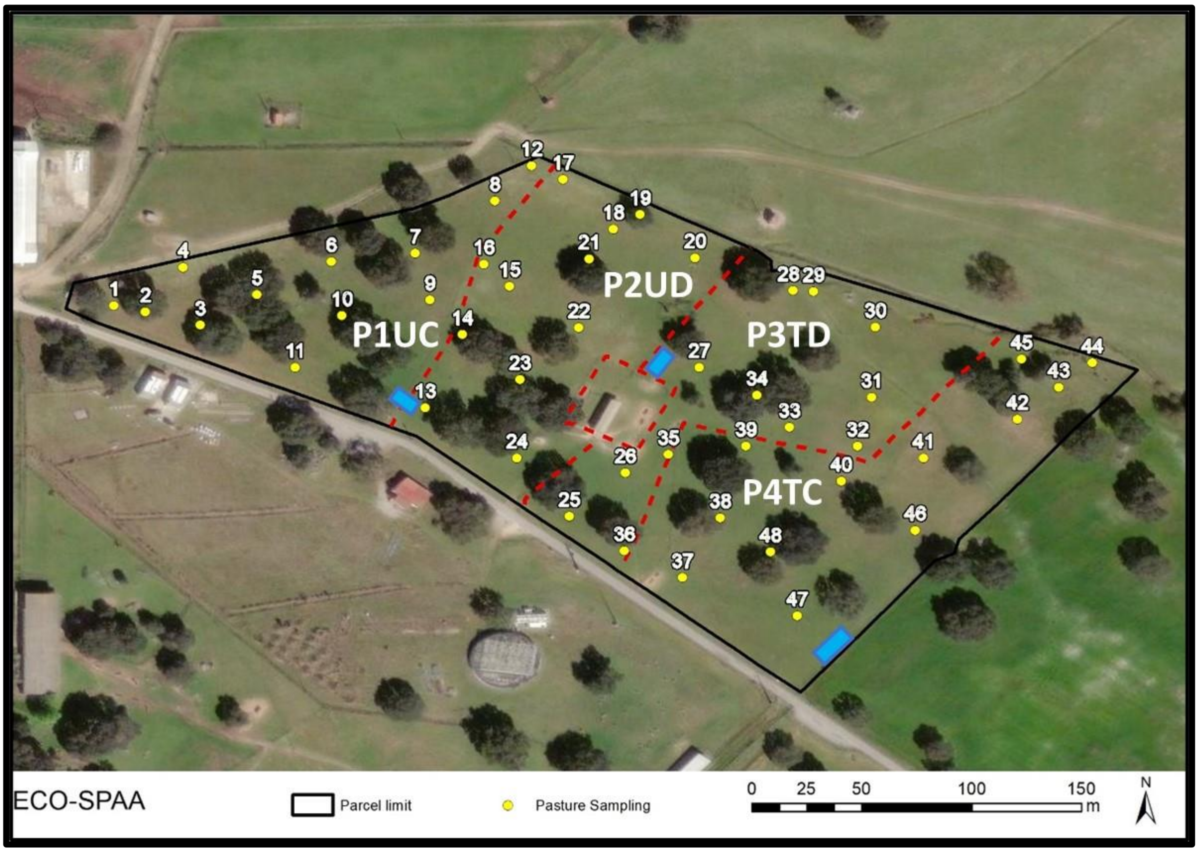

Figure 2. Sampling areas of the experimental field and plots of study. The blue rectangles represent drinking trough.

The characterization of the surface layer of the soil (0-0.30 m depth), carried out in October 2015, revealed acidic pH (average value of 5.4±0.3), so two applications with dolomitic limestone were carried out (2 tons/ha of dolomitic limestone) in half the area (P3TD and P4TC) in November 2017 and June 2019. In December 2018, the whole study area (P1UC, P2UD, P3TD and P4TC) received 100 kg/ha of binary fertilizer (18-46-0). The experimental design was based on a factorial, with two plots subjected to application of dolomitic limestone and two other serving as control (U Treatments). Within each treatment with and without amendment with dolomitic limestone, two grazing systems were applied: CG with continuous grazing and moderate stocking rate and DG with a deferred grazing and high stocking rate (2.3 times the applied in the CG).

2.2. Grazing Management, Pasture Measurements and Sampling

The grazing experiment was carried out with non-pregnant and non-lactating adult White Merino and Black Merino ewes. The ewes were always the same in each treatment throughout the experimental trial. All ewes had similar body conditions at the beginning and the end of the trial. Every month, all the animals were evaluated in terms of their body condition score (BCS) to highlight possible weight loss or heterogeneities between the animals' body conditions in the different plots. All animals had a mean BCS of 3.5, with a standard deviation less than 0.5. The scale used is from 1 to 5, where 1 is very thin and 5 is obese [39]. Changes in body conditions score are related to changes in animal weight [40]. The animals always had clean water and mineral supply at their disposal.

Different stocking rates were calculated for the treatments. The stocking rate is the number of animals on a given land over a certain period. The stocking rate is generally expressed as animal units per unit of land area. Carrying capacity is the sustainable stocking rate over time per unit of land area. The stocking density calculation was based on the animal Unit for sheep, which was based on adult animals weighing around 55kg. Thus, the stocking rate was calculated based on the animal unit equivalent (AUE) for sheep. The AUE helps estimate the potential forage demand for different kinds of animals based on the standard animal unit and considers physiological differences. To estimate the stocking rate, the number of animals in the area was considered (AUE/ha), corresponding to 7, 16, 16 and 7 animals in the plots P1UC, P2UC, P3TD and P4TC, respectively. In the case of deferred grazing, a correction factor was introduced corresponding to the percentage of days the animals remained in the respective fences during the grazing season period (AUE/ha*.days). These elements were then used for statistical calculations and corrections.

In plots in the DG system, the presence or absence of animals was linked to pasture height following the "put and take" method [41,42]. Grazing management criterion was a function of the average pasture height in each plot, the animals remained in the whenever the average height of the pasture exceeded 50 mm. Whenever this value was reached, the animals were removed and only returned when the average pasture height was at least 100 mm. Pasture height was measured with an electronic caliper. Pasture above 250mm was measured using a ruler with a scale in mm, to which a horizontal plastic stick was attached to simplify measurements.

Pasture heights were measured in the treatments of the study before and after each grazing period. Pasture samples were also collected to estimate the quality (crude protein CP, and neutral detergent fiber, NDF).

To represent the different existing plant communities, 48 sampling points were georeferenced, 12 in each of the four plots of the study (Figure 2). These 48 representative points were identified, by a botanical specialist, and permanently marked with a numbered flag and identified with a number (1 to 48). These points represent the plant communities identified previously, with species that vary in diversity and occurrence. The characterization of the floristic composition was carried out in January (winter), May (peak of spring) and June (summer). This characterization involved the identification of different plant species on each date in an area of $1m^2$.

The elevation of the experimental field is represented on the altimetric map in Figure 3.

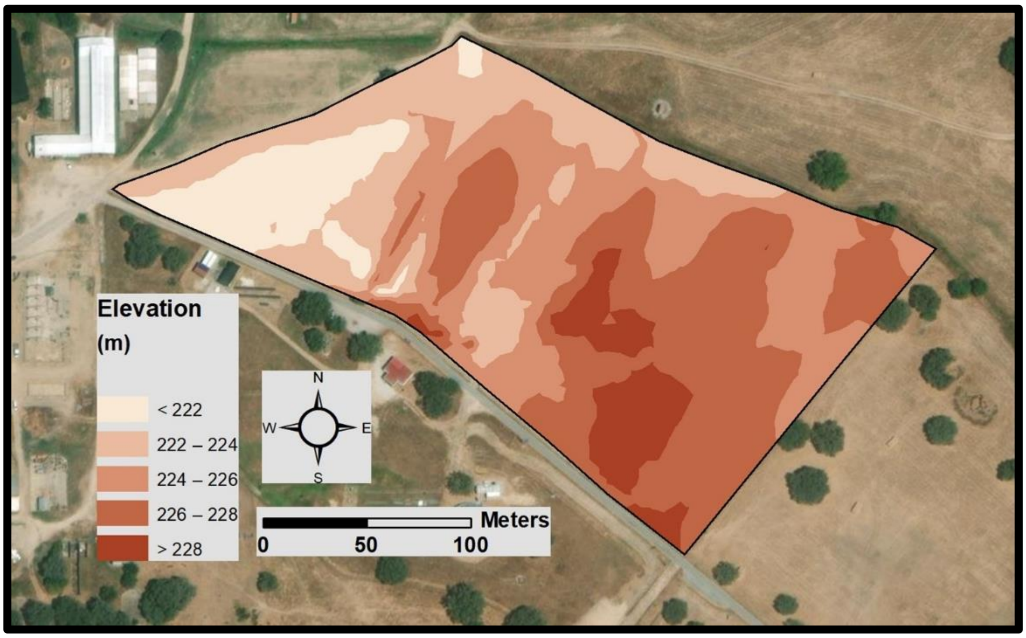

Figure 3. Altimetry map of the experimental field.

The following procedures and respective analyses were carried out to characterize the pastures in the four treatments. Pasture sampling (for pasture quality) was conducted on nine dates grouped into four periods. Period 1 corresponds to autumn (03/nov and 11/dec); period 2 corresponds to winter (10/feb and 12/mar); period 3 corresponds to the beginning and peak of spring (10/apr, 24/apr and 8/may); and period 4 corresponds to late spring and early summer (22/may and 05/jun). In the periods 3 and 4 the samples were taken concomitantly with animal behavior observations. The pasture height was taken at each sample point (**in 3 representative locations of the point, with 3 measurements for each location),** followed by pasture cutting in a known area (frame of "0.40 m × 0.25 m."). All the 12 samples in each treatment were mixed, thus making a total of 4 composite samples (one for each treatment). During the animal behavior observation phase, these pasture procedures were carried out the day before each behavior observation. The pastures samples were conducted to the Animal Nutrition and Metabolism Laboratory - MED Mediterranean Institute for Agriculture, Environment and Development, for they were placed in an oven at 65 °C, for 72 hours, to be dehydrated. Next, the dehydrated samples were weighed and ground in a Perten instrument mill equipped with a 1 mm sieve, for subsequent determination values of CP and NDF, expressed in percentage on a dry weight basis of samples, using conventional wet chemistry methods according to the AOAC [43].

2.3. Cone Index Measurements

To evaluate soil compaction, due to animal trampling, in CG and DG, soil resistance to penetration (Cone Index, CI, in kPa) was measured with an electronic cone penetrometer "FieldScout SC 900" (Spectrum Technologies, Aurora, IL, USA) equipped with an ultrasonic depth sensor. This assessment was carried out in October 2021. Such as Serrano et al. [38], for each sampling point (1m^2 area), 5 measurements were taken (one in the center and one at each of the vertices of the quadrant) with the CI, at a depth of 0 to 30 cm. After, the mean value of the five measurements was calculated for each of the 48 sampling points, at depths of 0-15 and 15-30cm. To avoid variability in soil moisture (which could affect penetration resistance measurements), all measurements at the 48 sampling points, with CI, were carried out on the same day. When measuring resistance to soil penetration, soil samples were taken at the central point of each sampling point. To do this, a gouge auger and a hammer were used. In this way, soil moisture was characterized at a depth of 0 to 30cm. Then the soil samples were weighed and placed in an oven at 70°C for 48 hours. After dehydration, the samples were weighed again to establish the soil moisture content (SMC).

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2.4. Observation of Sheep's Grazing Behavior and Spots Preferences

Between March 13th and June 7th, sheep grazing behavior was monitored for twelve days to identify their favorite spots. Considering that the grazing systems were different among treatments during autumn and winter, with potentially different levels of selectivity, it is essential to understand whether the disposition of the animals' favorite spots in the pasture differs in the spring when the maximum growth rate occurs. Sheep behavior was observed approximately every 15 days. Each date observation corresponds to two repetitions on two consecutive days:

Date 1- March 13th (Start – 8 a.m.; End – 7 p.m.).
Date 2- March 28th (Start – 7 a.m.; End – 7 p.m.).
Date 3- April 25th (Start – 7 a.m.; End – 8 p.m.).
Date 4- May 9th (Start – 7 a.m.; End – 8 p.m.).
Date 5- May 23rd (Start – 7 a.m.; End – 8:30 p.m.).
Date 6- June 6th (Start – 7 a.m.; End – 8:30 p.m.).

2.4.1. Animal Observations

Four trained observers carried out behavioral observations simultaneously. Observations using binoculars were carried out every 10 minutes, from sunrise to sunset, which, represents about 12 hours per day. The observers were placed far enough from the animals so as not to interfere with their natural behavior [14,29]. At each moment of observation, for each of the 4 plots (P1UC, P2UD, P3TD, P4TC), the location of the animals was referenced to the 12 sampling points. Combining with the local site, individual grazing activity was registered.

2.5. Meteorological Conditions

Meteorological conditions are presented in **Figure 4**, which shows the temperature and rain graph for Mitra meteorological station (Évora) between September 2020 and June 2021. The greatest amount of precipitation occurred in September and February (537 mm), while only 91 mm of precipitation was recorded during spring and early summer (when temperatures were more favorable for pasture growth and extension of its vegetative cycle).

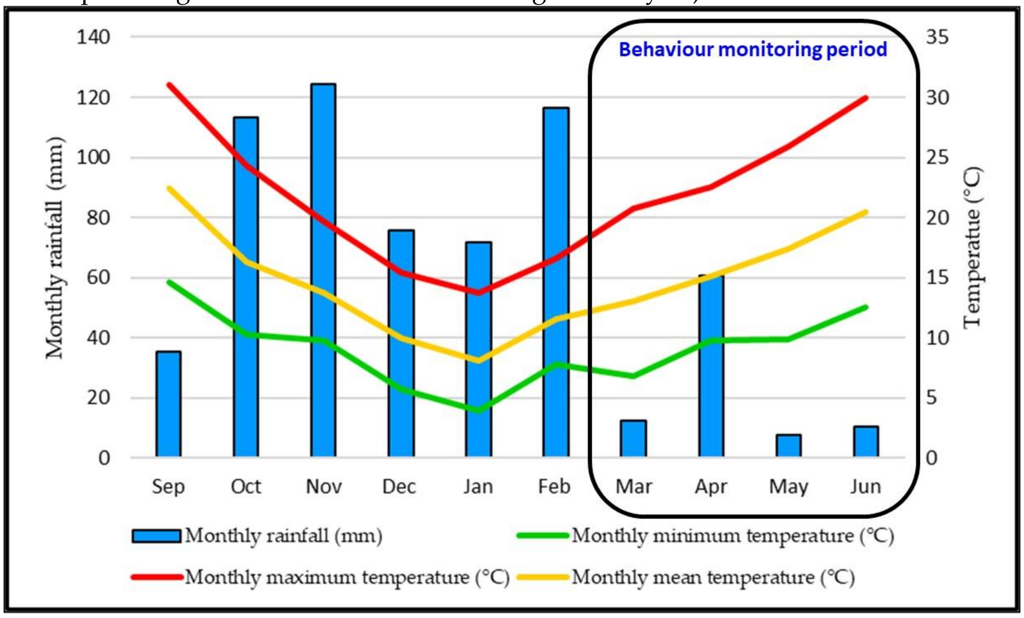

Figure 4. Thermopluviometric graph for the Mitra meteorological station (Évora), between September 2020 and June 2021.

2.6. Statistical Analysis of Data

2.6.1. Pasture Height and Quality

Considering that in P3TD, in December, the animals remained grazing for 7 more days than in P2UD, height measurement in P3TD was carried out once more than in the other plots. On the day the sheep left P3TD (December), height measurements were taken only in this plot, which meant that the number of measurements between P3TD and the remaining plots was different. For the statistical analysis of pasture height and quality, two different approaches were used. One for pasture height, and different approach for CP and NDF.

1) For pasture height a "Generalized Mixed Additive Model" (GMAM) was used with a Gamma response. A logarithmic link function was adjusted for pasture height. Treatments were entered into the model as fixed parametric factors and their effect was controlled for mean temperature (as smooth variable modelled with thin plate regression spline), cumulative precipitation (as smooth variable modelled with thin plate regression spline) and for the number of animals per grazing days (animals/(grazing days+1)) - as smooth variable modelled with thin plate regression spline). Plot/spot pairs were entered as a random factor, as this is where repeated measurements occur.

This model was better than the corresponding Generalized Linear Mixed Model (GLMM), also with gamma response and logarithmic link function, as it presented lower AIC and BIC values, a better fit to the data and a better explanatory capacity (it can explain 65.1% of total deviance).

The assumptions of independence, homoscedasticity and normality of the residuals were verified, as well as the normality of random effects. Through the "Estimated Marginal Means" (Emmeans R) package it was possible to perform multiple comparison tests adjusting for "Tukey" test.

2) For CP and NDF it was not possible to use a GLM model as the residuals are correlated. The best approach was the use of a GLMM (Generalized Linear Mixed Model) if the random effect was the treatment itself, which made the main objective, of comparing the 4 treatment levels as a fixed effect, unfeasible. Therefore, a comparison was made between the levels of treatments 2 by 2, using the t-test for paired samples (normality was verified for the samples of differences by combining the observation of the "qq-Plot" and the "Shapiro-Wilk" test), adjusting the p-values by "Holm" correction. To evaluate the effect of the Period, we consider mixed linear models (GLMM), adjusted by restricted maximum likelihood (REML) with the plot as a random effect, adjusting for the mean temperature (in the logarithmic transformation), animals per grazing day (logarithmic transformation of the quotient between the number of animals and the number of grazing days plus 0.5, this because there are cases in which there were no animals) and the accumulated precipitation (also in the logarithmic transformation corrected plus 0.5, as there are cases in which there was no precipitation). All models fitted the data well and satisfied the assumptions of homoscedasticity and normality of the residuals, as well as the normality of the random effects.

2.6.2. Cone Index

An analysis of variance (ANOVA) was carried out between the types of grazing (CG and DG) and between CI depths (0-15 and 15-30cm). These analyzes were performed using the IBM SPSS Statistics package for Windows (version 28.0, IBM Corp., Armonk, NY, USA). The Tukey's HSD test was also performed to compare the means.

The maps of soil variables (SMC and CI) and the altimetric map were carried out through geostatistical analyzes with the Geostatistical Analyst" extension of ArcGIS software (version 10.5, ESRI, Inc., Redlands, CA, USA).

2.6.3. Animal's Location Preferences

The behavior analysis was carried out by observation date, based on animal presence or absence near each sampling point and in each plot. For this purpose, cross-tabulations of the animals' permanence at the sampled points in each plot were created based on the observations every 10

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minutes on each observed day. Statistical analyses of data on animal locations on the pasture, were carried out using the IBM SPSS 25.

With the aim of visualizing the animal distributions throughout the experimental field and during different dates, animal presence was estimated at any un-sampled location. As a continuous variable was necessary, an area of 1 m^2 was associated with any location and, in consequence, animal density was mapped. Kriged maps showing the spatial distributions of animals in each date were generated.

Using geostatistical techniques, in this case ordinary kriging, estimated values were obtained for all unsampled locations based on the point measurements distributed throughout the experimental field. This allowed visualization of the spatial patterns of the variables considered, and finally, raster maps were obtained with a spatial resolution of 1 m^2.

That resolution was logically selected and introduced as an input parameter in ArcGIS when converting from vector (point) to raster format.

The ArcGIS software (version 10.5, ESRI Inc., Redlands, CA, USA) was used to model the spatial variation of grazing. Interpolation analyses were performed with the ordinary kriging algorithm utilizing the Geostatistical Analyst extension in ArcGIS.

3. Results

3.1. Grazing Days, Stocking Rate and Pasture Height

Regarding grazing days, Figure 5 compares the number of days per month that the sheep stayed in DG plots P2UD and P3TD with the total number of days that sheep stayed in CG plots (P1UC and P4TC), and **Figure 6** displays the total grazing days per treatment. In the plots subject to DG, there were approximately 80 fewer days of grazing (pasture recovery days) than those subject to CG. However, in these plots the stocking rate was much higher. The application of dolomitic limestone provided 7 more days of grazing than non-application in plots subject to DG (Figure 6). Figure 7 shows the sheep grazing days for each treatment. Although the grazing days in the P2UD and P3TD plots were lower than in the remaining plots, when we multiply these days by the number of animals on each day and in each plot, we find that the sheep grazing days in the plots subject to DG are much higher (around 50%).

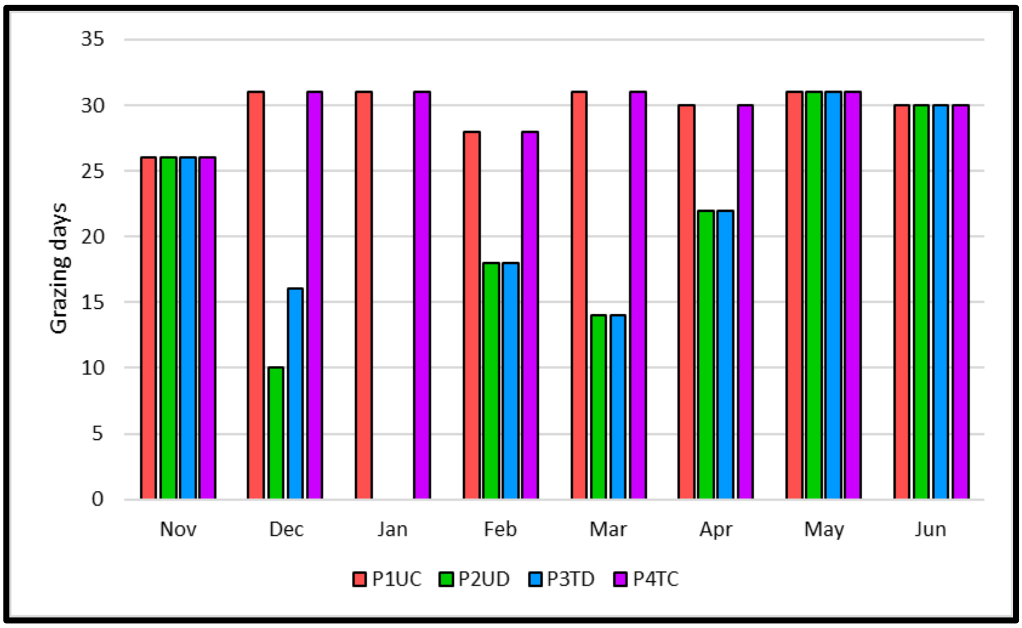

Figure 5. Number of grazing days in each treatment, per month.

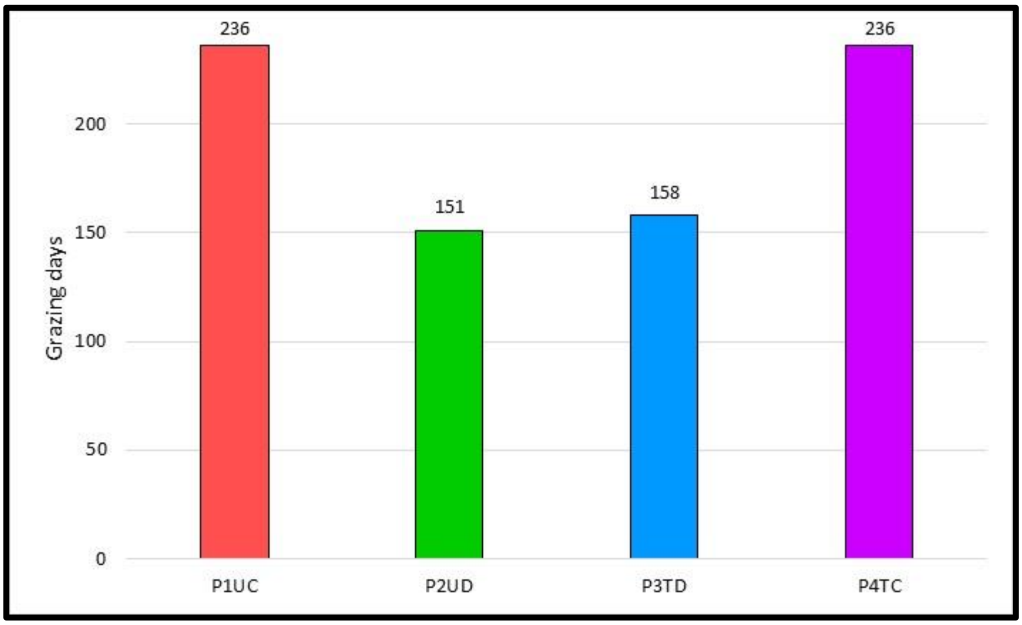

Figure 6. Total grazing days in each treatment.

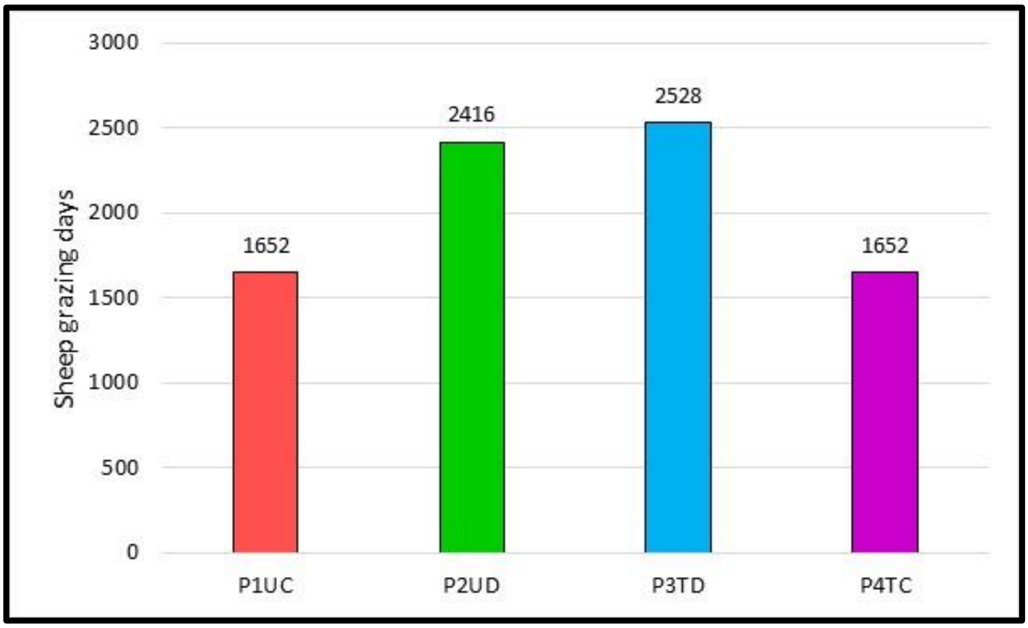

Figure 7. Sheep grazing days in each treatment.

Figure 8 shows the dispersion of pasture height values (minimum, median, maximum and quartiles) by date and plot, throughout the pasture's vegetative cycle (autumn, winter, spring, and early summer). Despite the different number of grazing days in DG treatments, there was no significant interaction between treatments and dates for pasture height. Generally, as expected, the treatments associated with CG had higher pasture heights; on some dates, pasture heights were significantly higher. Within the CG treatments (P1UC and P4TC), the average heights were significantly higher in the P4TC treatment on most dates. However, when the model is inserted with the correction for the number of grazing days and the number of animals, the differences between the treatments are not significant, mainly due to the dispersion of the pasture height within plots, as can be seen in Figure 8.

At the beginning of April, the pasture's growth rate exceeded the sheep's intake rate in all plots, which was reflected in a significant increase in pasture height in both treatments with a moderate animal load (P1UC and P4TC) as well as the treatment with a higher animal load (P2UD and P3TD).

All plots reached maximum pasture height in May and June, with some values exceeding 550 mm. It should be noted that, in all plots, many pasture areas reached heights of over 500 mm, while other areas remained close to 70 mm, indicating a reduced growth rate or greater preference by the animals.

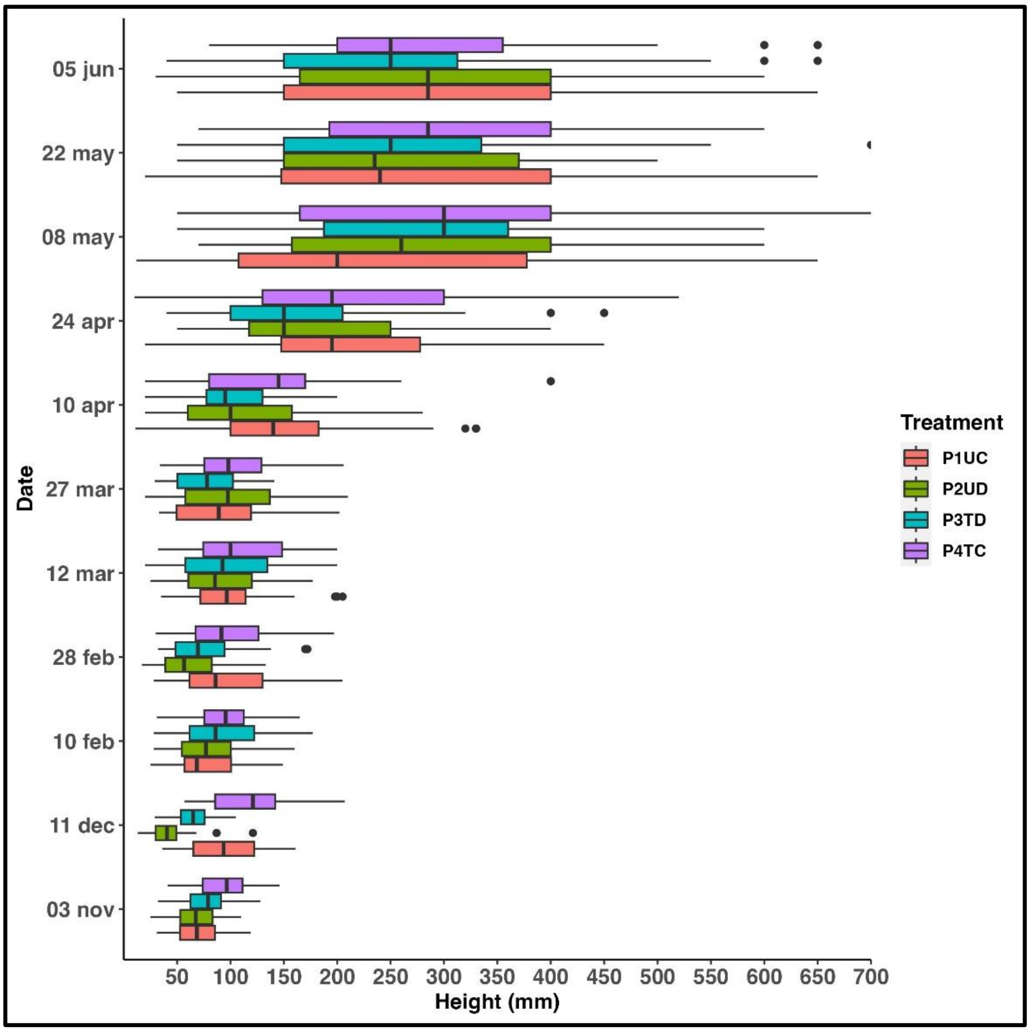

Figure 8. Dispersion of pasture height values (minimum, median, maximum and quartiles) by date and by plot, throughout the pasture's vegetative cycle (autumn, winter, spring, and early summer). The black points correspond to outliers.

3.2. Characterization of the Nutritional Value

Figure 9a shows the average percentage of CP of the pasture in each treatment, throughout the animal observation period. At the end of winter and spring, the highest percentage of CP occurred in the P3TD plot (20.1%, 13.4%, respectively). The highest percentage of CP occurred at the end of winter, with 15.9%, 18.8%, 20% and 18.9%, for the plots P1UC, P2UD, P3TD and P4TC, respectively. On the other hand, the lowest values were observed at the beginning of summer, with values of 7.3%, 7.2%, 6.2% and 6.1%, for the plot P1UC, P2UD, P3TD and P4TC, respectively. Figure 9b shows the percentage of NDF in each treatment, throughout the animal observation period. As it can be seen, at the beginning of summer occurred to higher NDF values (62.2%, 63.4%, 66.0% and 65.9%, for P1UC, P2UD, P3TD and P4TC, respectively), while at the end of winter had the lowest values (46.7%, 47.4%, 42.4% e 44.7%, for P1UC, P2UD, P3TD and P4TC, respectively). at the beginning of summer, the P1UC treatment showed the lowest value (62.2%).

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Figure 10a shows the CP dispersion of pastures (minimum, median, maximum and quartiles) for each treatment. No significant interactions in CP were observed between treatments and periods. Figure 10b shows the dispersion of pasture NDF values (minimum, median, maximum and quartiles) for each treatment. No significant interactions in NDF were observed between the factor's treatments and periods. There were also no significant differences between the treatments for CP and NDF (P>0,05).

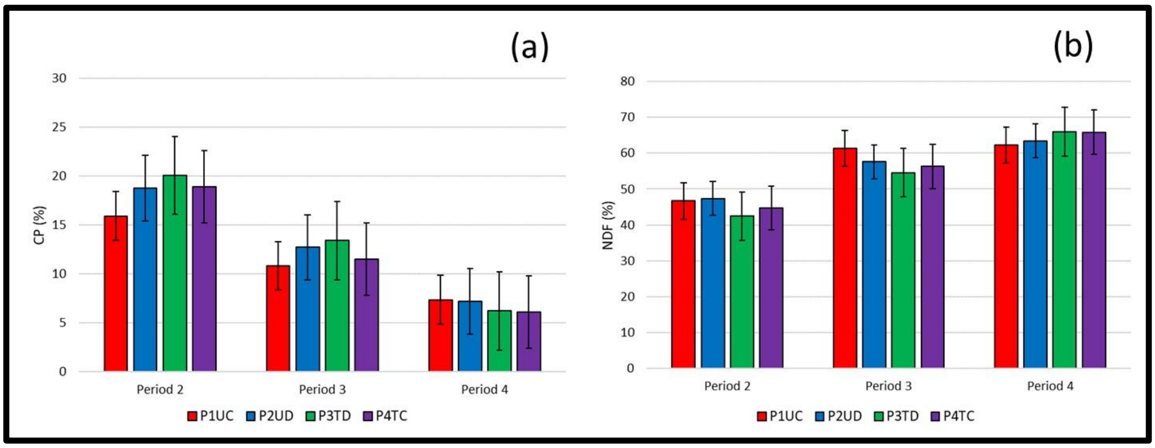

Figure 9. Average percentage in each treatment throughout the animal observation period, for CP (a) and NDF (b).

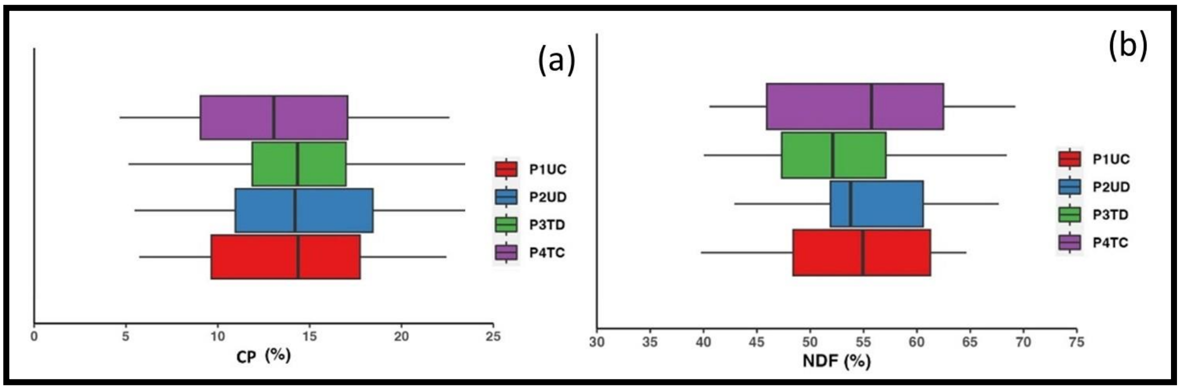

Figure 10. Comparison between median values and respective quartiles in each treatment for CP (a) and NDF (b).

3.3. Preferred Grazing Locations versus Average Height of Pasture

Figures 11, 12 and 13 are composite figures representing the preferred grazing areas on the twelve days of observation, based on the 12 georeferenced points in each plot (according to Figure 2). In these figures it is possible to observe the evolution of height of pasture per point and preferred grazing areas throughout the observation period (end of winter, spring and beginning of summer). The maps have up to 4 graduations, from lightest to darkest, which correspond to the following: no or low preference, medium preference, high preference, and very high preference, respectively.

In the P1UC plot, sheep stayed mainly in the lower part of the field, where the pasture was not always the highest. The spots most preferred by sheep were 8 and 12, extending to spots 5, 7, 9, and 10. After the third observation date, the space became more evenly frequented, regardless of the height of the pasture, with spots 5 and 11 being the most grazed on the fourth observation date. Points 1 and 2 were the least sough after throughout the observation period.

In the P2UD plot, sheep grazing pattern was similar throughout the observation dates. The sheep preferred spots 17, 18, 19 and 20 throughout most observations. After the fourth observation date, the animals showed more dispersed grazing behavior throughout the available area, except for spot

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23, which was less preferred on all observation dates. The animals did not choose spots according to the height of the pasture; other variables, possibly the species and its nutritional value, may have driven the different preferences for the various spots. Spots 13, 14 (except on the last observation date and in warmer weather), 15, 23 and 24 were the least grazed throughout all observations.

In the P3TD plot, a more restricted grazing area is visible. The most preferred spots during the first observation dates were 30, 31 and 32, with a lower frequency for spots 33 and 34. After the 3rd and fourth observation dates, a more extensive range of grazed areas was observed. Sheep did not show a particular preference for areas where the height of the pasture was higher; in many cases, their preference was for lower pastures. Finally, on the last two observation dates, there was a return to the areas that were initially most grazed. The observations showed a clear tendency for spots 25, 26 and 35 to be grazed less.

In the P4TC plot, the sheep's preferences were somewhat more heterogeneous. On the first observation dates, there was a clear preference for spots 40, 41, 45, 46, and 47. The pattern changed on the third and fourth observation dates, restricting preferences to spots 41 and 42 adding spot 45 on date 5. Like what was observed in the other treatments, the motivations for choosing the spots were not just related to the height of the pasture. On observation date six, there was more dispersion across the available area, with spots 37, 38, 39, 47 and 48 remaining negligibly preferred.

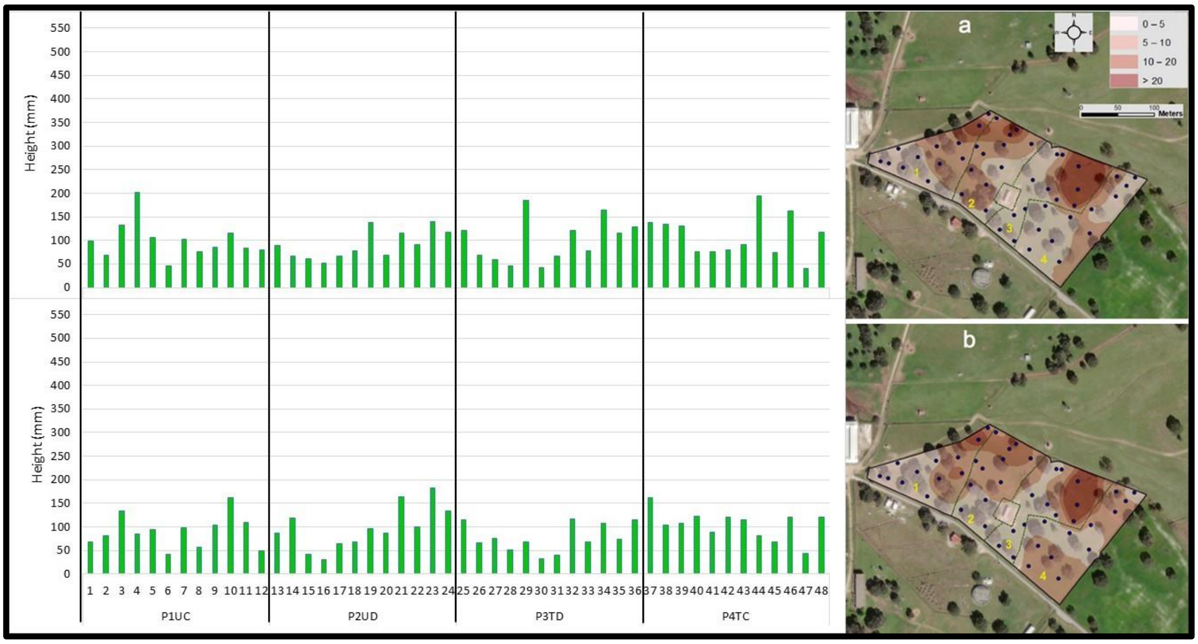

Figure 11. Average pasture height on each observation date by plot and by sampling point and respective maps with preferred grazing areas (a- date 1; b- date 2). The numbers, on the graphs, correspond to the 12 georeferenced points in each plot (1 - P1UC; 2- P2UD; 3- P3TD; 4- P4TC).

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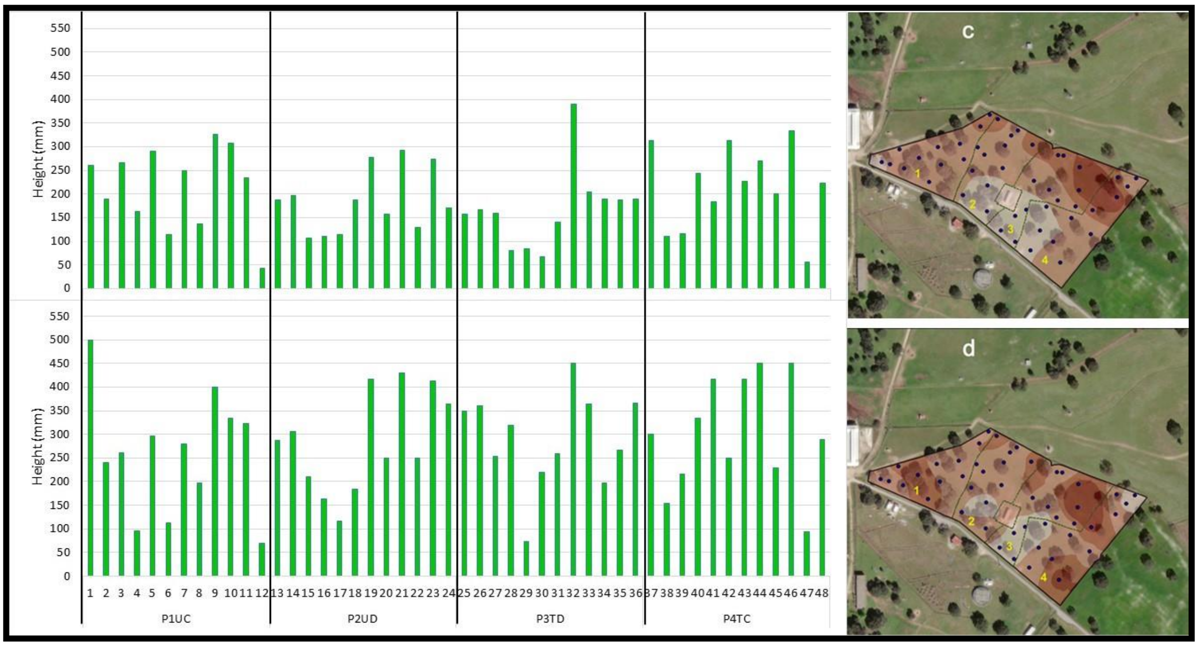

Figure 12. Average pasture height on each observation date by plot and by sampling point and respective maps with preferred grazing areas (c- date 3; d- date 4). The numbers, on the graphs, correspond to the 12 georeferenced points in each plot (1 - P1UC; 2- P2UD; 3- P3TD; 4- P4TC).

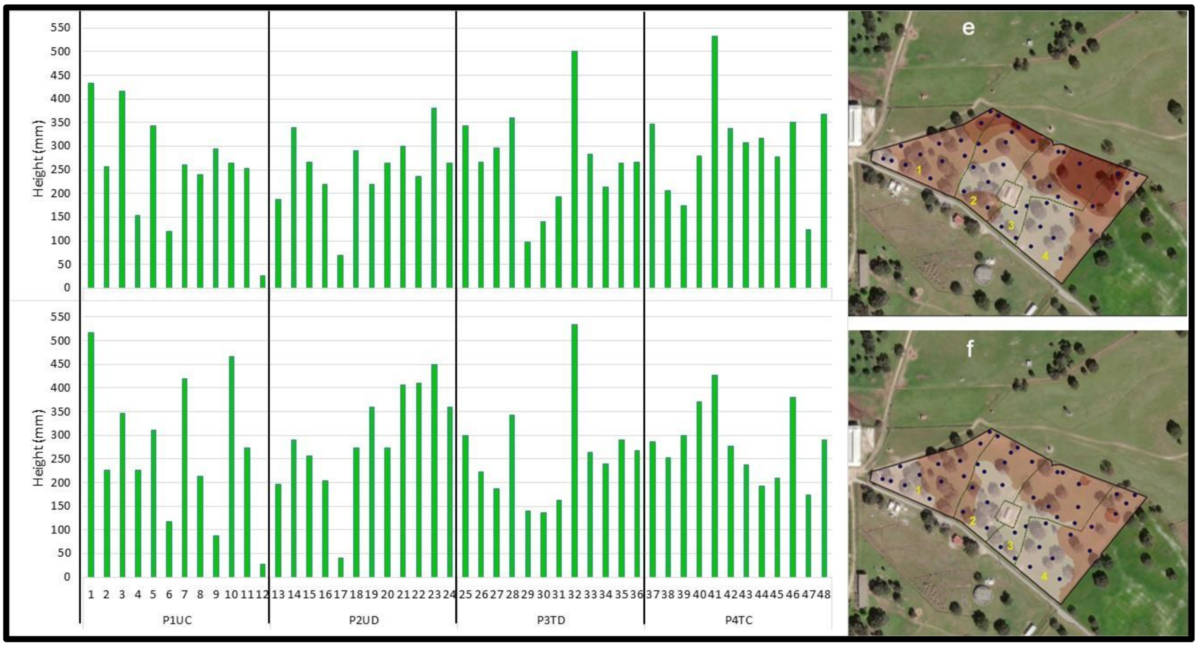

Figure 13. Average pasture height on each observation date by plot and by sampling point and respective maps with preferred grazing areas (e- date 5; f- date 6). The numbers, on the graphs, correspond to the 12 georeferenced points in each plot (1 - P1UC; 2- P2UD; 3- P3TD; 4- P4TC).

3.4. Relationship between Preferred Grazing Locations and Floristic Composition

Figure 14 shows the information accumulated over all the observation dates. In P1UC, spots 1, 2 and 3 are very poorly grazed, unlike spot 8, which is the most preferred. In the other plots, it is important to highlight an extensive area with very little daily grazing time, especially spots 13, 23, 25, 26, 35 and 37 - It should also be noted that the spots most consistently preferred by the animals were 30, 31 and 42, and, with some relevance, spots 41 and 45.

Table A1 (Appendix A) shows the botanical species identified, in January, in the sheep's favorite grazing spots, during the month of March. Table A2 (Appendix A) shows the botanical species identified, at the beginning of May, in the sheep's favorite grazing spots, in the May observations. As we can see in these tables, floristic diversity was high in all treatments, and in May, a greater number of botanical species were identified.

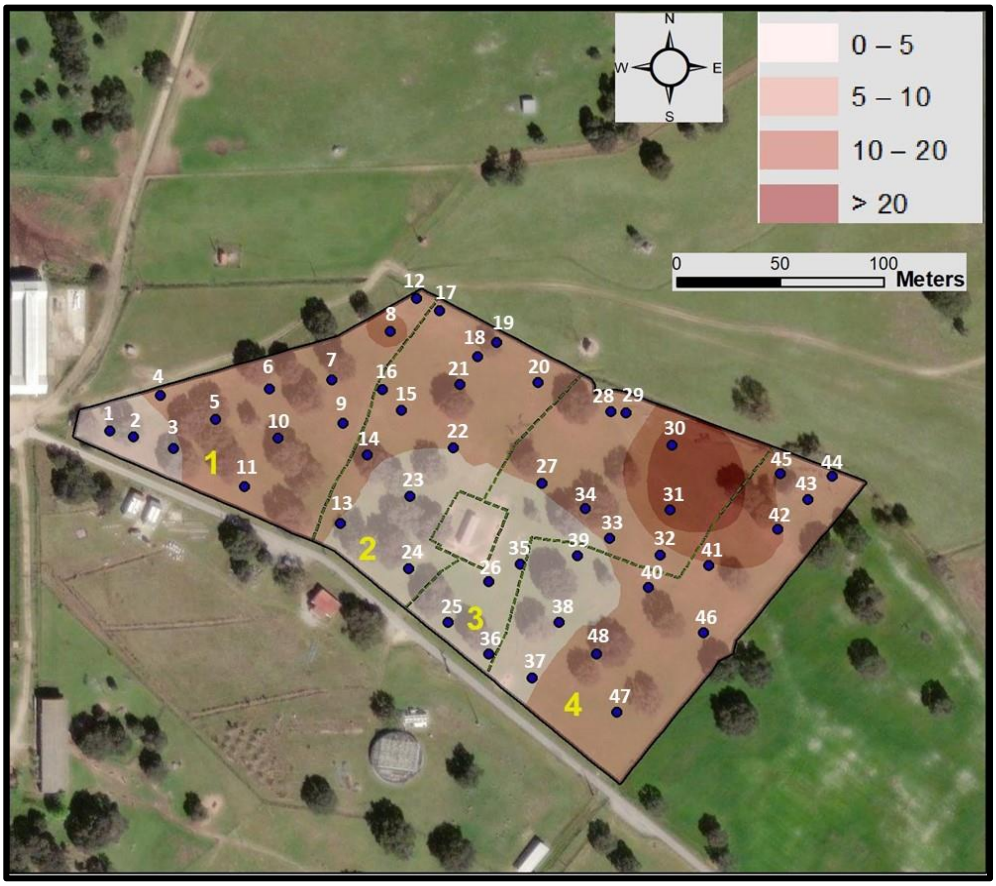

Figure 14. Map with accumulated data over time of observation, for the locations preferred for grazing by the animals (date 1 to date 6). Yellow numbers on the maps correspond to each plot: 1 - P1UC; 2- P2UD; 3- P3TD; 4- P4TC. Black circular shapes represent sampling points (white numbers).

3.5. Soil Compaction Measured by Cone Index

Figure 15 shows soil compaction (cone index) in the two types of grazing and at the two depths (0 to 15 and 15 to 30 cm). Although the stocking rate doubled in the DG, relative to the CG, and the CI values were higher in the DG, there were no statistically significant differences ($p > 0.05$). The average SMC values were 14.7% ± 2.9% for the CG area and 15.2% ± 2.3% in the DG area (depth 0-30cm). Figures 16a and 16b show soil compaction maps from 0 to 15 and 15 to 30 cm.

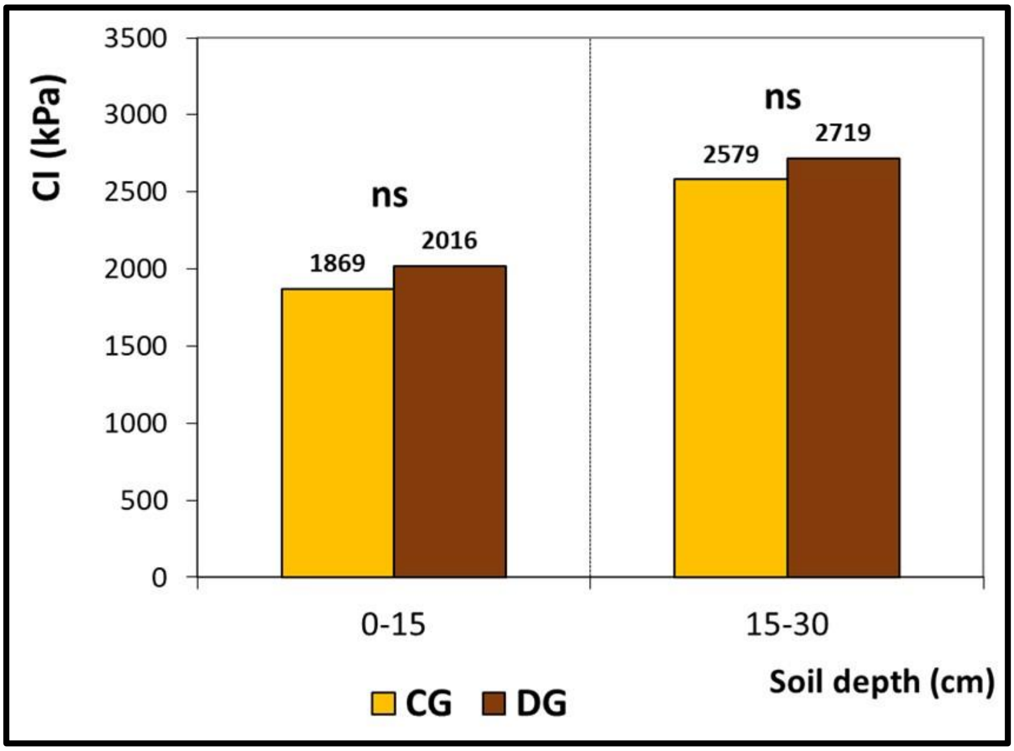

Figure 15. Average cone index (CI, in kPa) for continuous (CG) versus deferred grazing (CG) at 0–15 cm and 15–30 cm soil depths. "ns"—Not significant.

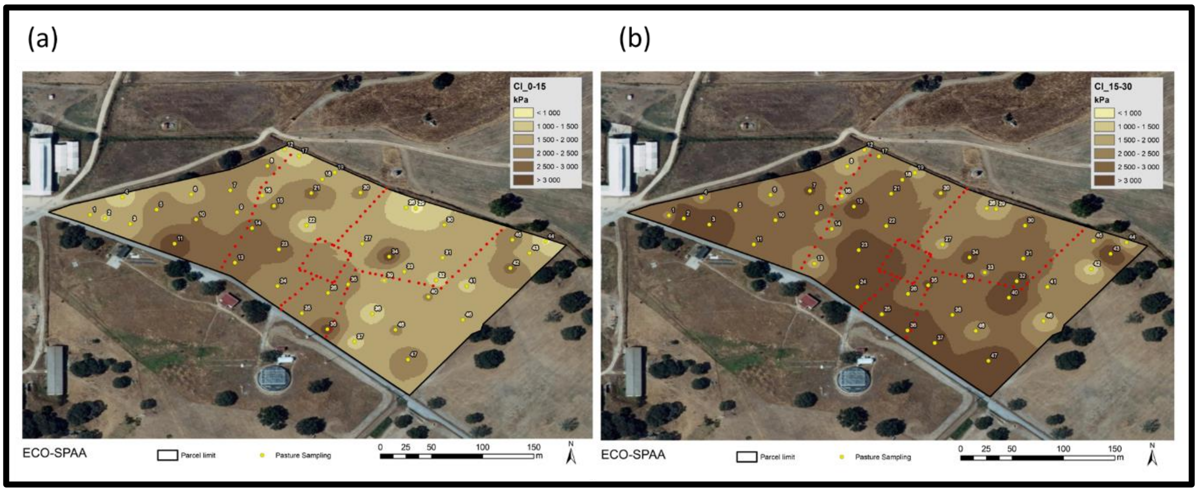

Figure 16. Cone index (CI) map (a) at 0–15 cm and (b) 15 - 30 cm depth.

4. Discussion

4.1. Relationship among Climatic Variables and, Height and Pasture Quality

During autumn, the combination of temperature and rainfall was sufficient to allow the pasture to germinate and grow satisfactorily. During winter, especially in January, the low temperatures limited pasture growth, and this continued until February. The average pasture height in the plots subject to DG, in mid-December, was 42.5 mm in P2UD and 44 mm in P3TD, which meant that the animals had to be removed from both plots and only returned on February 11th, when the average height in P2UD and in P3TD was nearly 100 mm. The absence of animals for nearly two months allowed some pastures to recover despite the slow growth rate. Pasture resting periods are essential

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after each grazing period to allow the plants to restore their reserves and produce new leaves [16]. The same authors state that recovery time depends on the plants' response capacity, soil humidity, and temperature. Measuring pasture height, **as an** indirect **indicator of** photosynthetically active leaf area, is crucial for managing the pasture itself, as well as grazing, showing high correlations with pasture biomass production [44,45]. Furthermore, Bell et al. [22] state that pastures with an average height of less than 70 mm tend to have low nutritional value. Iason et al. [46] found that daily pasture intake, by sheep in CG, was limited when the pasture was 30 mm height, which did not occur above 55 mm.

At the beginning of the spring, as temperatures rose, there was a lack of rainfall, penalizing pasture growth rate. These typical winter irregularities in pasture growth, with meagre growth rates, were greatly accentuated by the lack of rainfall in March, leading to the animals in DG having to be removed from their plots.

The application of dolomitic lime appears to have a positive influence on pasture height, resulting in greater heights in the plots P3TD and P4TC, when compared to plots P2UD and P1UC, respectively. Between P2UD and P3TD treatments, the variations in height amplitudes were quite similar. However, considering that both treatments have the same grazing intensity, given the additional decrease in pasture height in the P2UD, a lower pasture growth rate can be inferred, which could be attributed to the application of dolomitic lime. According to Carvalho [47], the application of dolomitic lime in some soils can increase the production of dryland pastures up to five times. In previous work carried out, by our team in this test field, there was a positive effect of liming in the soil, although very slow, on pH and the Mg/Mn ratio. Therefore, the continuation of these studies in the long term is justified.

4.2. Relationship between Preferred Grazing Locations, Type of Grazing, Stocking Rate, Floristic Composition, and Pasture Height, during the Observation Period

The stocking rate used in CG was higher than in the usual production systems (2 to 3 sheep per hectare) [48]. Even so, biomass availability in all plots meant that sheep could choose the areas with the most preferred species (CG and DG).

Grazing systems with high stocking rates are often identified as responsible for the degradation of soil, pasture, and trees in the Montado ecosystem. Animal trampling due to high stocking rates is correlated with negative effects on soil properties [15]. However, in our case, there were no significant differences between the two grazing systems tested (CG and DG), which encourages producers in the Montado ecosystem to intensify sheep production, with a greater number of animals per hectare, in DG (grazing periods depending on pasture height). Although the CI values in the plots subject to DG were higher than those recorded in CG, the fact that there were no significant differences takes us to the concept of sustainable intensification. Higher CI values were recorded at depths of 15 to 30 cm. However, several studies report that soil compaction due to animal trampling occurs mainly in the surface layers of the soil [49-51].

The greater amplitudes in pasture heights in the CG treatments indicate a tendency towards more selectivity. In the DG, this amplitude is smaller, although there are areas where the pasture has been consumed more than others. In general, the spots with the lowest grazing preference were those with the highest pasture heights. Furthermore, according to Di Grigoli et al. [52], even in the most preferred areas, where biomass availability decreases, sheep end up ingesting growing plants (due to delay in phenological cycles) with high CP content and low NDF content. The distribution of sheep grazing, across the pasture, depends on external factors, such as topography, and climate [27].

On the six observation dates (**Figure 13**), in all treatments, there was a tendency for the lowlands to be preferred grazing areas, where legume plants prevailed [37]. In heavily grazed areas, all plants can have access to light, with benefits for *Fabaceae* family [19]. On the other hand, on the six observation dates and treatments, the areas less grazed by sheep were those near the road (Figure 13). This explanation is only partially valid for P3TD and P4TC. In fact, the animals at P2UC and P1UC tended to avoid areas closer to the road; however, when the favored species began to congregate at other points, the animals increased their frequency in those areas. The fact that sheep graze less time near the road can be a result of frightening factors related to passing by cars and trucks changing their behavior. Clair & Forrest [53] states that vehicle traffic alters the natural behavior of elk, reducing their normal behavioral patterns and increasing levels of vigilance. Incidental observations were made that allow us to infer that these points were grazed during the night, or at the end of the day and in the early hours of the morning, when the passage of vehicles was almost non-existent.

During the observation period in P2UD, there was some avoidance of the areas along the road, except for point 13, where the watering trough is located.

On the first dates of observation, the frequency of drinking was low, but as spring progressed (from April), the higher fiber content of the pasture and the higher temperature led to a greater frequency of visits to the watering trough. As a result, the animals tended to graze much closer to this area. In the dryland pastures, the choice of a grazing area, often reflects the effort to reduce energy expenditure when walking, rather than a true feed preference [23].

In P3TD there was an area highly preferred by sheep for graze (points 30 and 31). In this same plot, the points in the high and middle zone were the least preferred. Sheep prefer to graze areas with an average pasture height of 60mm rather than 300mm [54].

In P4TC, the preferred area for grazing, on all observation dates, was in the lowland area, where more leguminous species were identified. Only the area near points 38 and 39 was less grazed (characterized by high pasture close to the road).

In winter (January 14th), at the peak of spring (May 4th), the botanical species were identified at each sampling point. In this work we include only the inventory of botanical species identified in the places preferred by sheep to graze.

Of the plants identified at the sampling points, which are most preferred for grazing, some, such as *Senecio vulgaris L.*, *Senecio jacobaea L.*, *Echium plantagineum L.*, *Iris xiphium L.*, *Ranunculus ollissiponensis* subsp *ollissiponensis Pers.* are toxic to ruminants in certain phenological states, and sheep avoided them [55]. On the other hand, other botanical species belonging to the *Fabaceae* family (clovers and *Ornithopus compressus* L.*)* are not very palatable in the first phenological stages and are only consumed by sheep in the middle and late spring and summer as dry feed.

In April, preferred grazing areas expanded to almost all the plots. This fact may have occurred due to the decrease in the amount of water in the soil and the wind that was felt at the end of March and beginning of April, which harmed the development of the pasture, leading to the early maturation of some species. In areas with a high availability of biomass, sheep will tend to prefer places where the species have a higher nutritional value, trying to select plants that have a higher CP and a lower fiber content [56]. Different preferred grazing locations, throughout the season, may reflect different pasture characteristics in terms of quality and quantity [28]. Also, the floristic composition of the pasture is affected by grazing, namely through selectivity, stocking rate and grazing season [14].

In points 3, 4, 5, 10 and 11, several botanical species characteristics of nitrophilous zones, with low palatability, low nutritional value or even toxicity, were also identified. The *Poa* genus shows significant initial growth but tends to have a short cycle, reducing its palatability early on. Sheep appreciate the *Cynodon* genus at certain stages of its phenological state. Still, they soon show high levels of fiber and significant reductions in CP content, causing sheep to reduce their preference for these plants. The plants of the genus *Rumex* and *Arum* are toxic, and normally avoided by animals as well as *Urtica* genus [55]. These areas have a high density of *Urtica* spp., which sheep tend to avoid. Similar situations were observed in P2UC at points 23 and 24 and in P3TD at points 25 and 36. On the other hand, other parts of these locations had shade from the tree canopy, which may protect the pasture from wind and sun, thus preserving a higher soil moisture level. These plants display more green leaves, corresponding to an early stage in the phenological cycle. The higher percentage of organic matter (due to the tree leaves and branches) and the shade provided greater soil moisture in spring and a consequent delay in the plants' phenological cycles. This probably occurred at the end of May, in the upper part of the plot P4TC, when grazing animals were observed near the watering trough, and under the tree shade. Also, animals prefer plants in their initial phenological stages when they contain less fiber and more protein [56].

In June, the vegetation was dry, and sheep grazed at a greater variety of locations, suggesting that they had no natural preference for a particular area, confirming Santos [26] description that grazing selectivity decreases as pasture quality decreases. According to Carreira et al. [37] there were no significant differences in the probability of occurrence of most of the identified plants in the four treatments. However, the DG tends to favor the appreciation of plants with greater palatability and nutritional value, also contributing to the reduction of botanical species of lower feed value for sheep.

5. Conclusions

In the treatments associated with deferred grazing, the dolomitic lime provided higher pasture growth rates, resulting in fewer days where animals were absent from in this plot. The lower number of grazing days (around 80) in the plots subject to deferred grazing was compensated by the greater number of sheep per hectare in these plots, compared to continuous grazing. In this sense, when we calculated sheep grazing days, we found that in plots subject to deferred grazing, pasture consumption was 50% higher. Pasture quality was not affected by the type of grazing and the application of dolomitic lime.

Throughout the period of sheep grazing observations, a similar pattern of preferred grazing areas was observed among the four treatments, with the lowland areas presenting more grazing density.

At the beginning of summer (June), the pasture was almost dry, and sheep grazed more evenly across the plots, with no evident areas of preferential grazing. Higher stocking rates (P2UD and P3TD) did not provide a more homogeneous distribution of grazing area across the fences. Even with 16 sheep per hectare, highly preferred areas were observed, especially in P3TD, which means that if there are no biomass limitations, there will always be areas of the pasture and species that the sheep prefer to graze first. The floristic composition does not seem to have been decisive for the choice of grazing locations.

The fact that in deferred grazing, soil compaction is not statistically different from that in continuous grazing, shows that the sustainable intensification of sheep production in the Montado is possible, without degrading this ecosystem.

The results indicate that higher stocking rates, wisely used to maintain adequate recovery periods, tend to favor a more uniform biomass growth, revealing greater species homogeneity and variability. However, given climate variability and the trend towards higher levels of aridity, studies will be needed over several years to analyze the evolution of soil organic matter and compaction and the monitoring of species and their relative preponderance to preserve biodiversity.

This study can be the source for more informed decision-making by agricultural managers, to promote the sustainability of the Montado ecosystem, as well as the efficiency of ruminant production systems, aiming for animal welfare.

Supplementary Materials: Not applicable.

Author Contributions: Experimental work: E.C., J.S., C.P.G., A.F.P. and J.L.C.; Conceptualization: A.F.P., E.C., J.S., C.P.G. and M.C.; methodology: J.S., E.C., C.P.G., A.F.P. and M.C.; software: L.L.P., P.I., L.P. and F.M.; validation: A.F.P., J.S. and C.P.G.; formal analysis: L.L.P., P.I. and F.M.; investigation: E.C., A.P., J.S., C.P.G. and A.F.P.; resources: A.F.P. and J.S.; data curation: E.C. and C.P.G; writing—original draft preparation: E.C.; writing—review and editing, A.F.P., J.S., S.S. and J.L.P; visualization: A.F.P., J.S., S.S., C.P.G., J.L.P. and M.C.; supervision: A.F.P., J.S., S.S., C.P.G., A.P. and M.C.; project administration: A.F.P. and J.S.; funding acquisition: A.F.P. and J.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Botanical species identified (winter) in preferred grazing spots on each plot in March.

Botanical Specie	spot 8	spot 9	spot 18	spot 19	spot 30	spot 31	spot 32	spot 45	spot 47
Chamaemelum mixtum	0	0	1	0	0	0	0	0	0
Erodium cicutarium subsp. *bipinnatum*	0	1	1	1	1	0	1	0	1
Calendula arvensis	0	1	0	0	0	0	0	0	0
Chamaemelum fuscatum	1	0	0	0	0	0	0	0	0
Diplotaxis catholica	1	1	1	0	1	0	1	0	1
Echium plantagineum	1	0	1	1	1	0	1	1	1
Geranium molle	0	1	0	0	0	0	0	0	0
Hypochaeris glabra	0	1	0	0	0	0	0	0	0
Iris xiphium	0	1	0	0	0	0	0	0	0
Leontodon taraxacoides	0	0	1	0	0	0	0	1	1
Ornithopus compressus	1	0	0	0	0	1	0	1	0
Plantago lanceolata	0	0	0	1	0	0	0	0	0
Plantago sp	0	1	0	0	0	0	0	0	0
Ranunculus ollissiponensis subsp. *ollissiponensis*	0	0	0	0	0	0	0	1	0
Senecio jacobaea	0	0	0	0	1	0	0	0	0
Senecio vulgaris	1	1	1	1	1	0	1	0	0
Spergula arvensis	1	0	0	0	0	0	0	0	0
Stachys arvensis	0	0	0	0	1	0	1	0	0
Stellaria media	0	0	0	1	0	0	0	0	0
Urtica urens	0	0	0	1	0	0	0	0	0
Genus Trifolium	1	0	0	0	0	1	0	0	0
Several grass species	1	0	0	1	1	0	1	1	1

1-presence; 2-absence.

Table A2. Botanical species identified (Spring) in preferred grazing spots on each plot in May.

Botanical Specie	spot 3	spot 4	spot 5	spot 8	spot 10	spot 11	spot 12	spot 17	spot 20	spot 30	spot 31	spot 41	spot 47
Agrostis castellana Boiss. & Reut.	0	0	0	0	0	0	0	0	0	0	0	0	1

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Agrostis pourretii Willd.	0	1	0	0	0	0	1	0	0	0	0	0	0
Anagallis arvensis L.	0	0	1	0	0	0	0	0	0	0	1	0	0
Anthriscus caucalis M.Bieb.	0	0	1	0	0	0	0	0	0	0	0	0	0
Arum italicum subsp. *italicum*	0	0	1	0	0	0	0	0	0	0	0	0	0
Avena barbata subsp. *lusitanica* (Tab.Morais) Romero Zarco	0	0	0	0	0	1	0	0	0	0	0	0	0
Bromus hordeaceus L.	0	0	0	1	1	1	0	0	0	1	1	1	1
Bromus sterilis L.	1	0	1	0	1	0	0	0	0	0	0	0	0
Callitriche stagnalis	0	0	0	0	0	0	1	1	0	0	0	0	0
Carduus tenuiflorus Curtis	1	0	1	0	0	0	0	0	1	0	0	0	0
Cerastium glomeratum Thuill.	1	0	1	0	0	0	0	1	0	1	1	0	0
Chamaemelum fuscatum (Brot.) Vasc.	0	1	0	0	0	0	1	1	0	0	0	0	0
Chamaemelum mixtum	0	1	0	1	1	1	0	1	1	1	1	1	1
Crepis capillaris (L.) Wallr.	0	0	0	1	1	0	0	0	0	0	1	0	0
Crepis vesicaria subsp. *taraxacifolia* (Thuill.) Thell.	1	1	0	0	1	1	0	0	0	0	1	0	0
Cynodon dactylon (L.) Pers.	0	0	0	0	0	0	1	1	0	1	0	0	0
Diplotaxis catholica (L.) DC.	1	1	0	1	0	1	0	0	1	0	1	1	1
Echium plantagineum L.	0	1	0	1	0	1	0	1	1	1	1	1	0
Erodium cicutarium subsp. *bipinnatum* (Cav.) Tourlet	0	0	1	0	0	0	0	0	1	0	0	0	1
Geranium molle L.	1	0	1	0	1	1	1	0	0	1	0	0	0
Geranium purpureum Vill.	0	0	0	0	0	0	0	0	0	1	0	0	0
Hedypnois cretica (L.) Dum.-Courset	1	0	0	0	1	1	0	0	1	0	0	0	0
Hordeum murinum subsp. *leporinum* (Link) Arcang.	1	0	1	1	0	1	0	0	0	0	0	1	1
Hypochaeris glabra L.	0	0	0	0	1	0	0	0	1	0	0	0	0
Hypochaeris radicata L.	0	0	0	0	1	0	0	1	0	1	1	0	0

Juncus bufonius L.	0	0	0	0	0	0	1	1	0	1	1	0	0
Lathyrus angulatus L.	0	0	0	0	0	0	0	0	0	1	1	0	0
Leontodon taraxacoides (Vill.) Mérat	0	0	0	0	1	1	0	1	0	1	1	0	0
Lythrum borysthenicum (Schrank) Litv.	0	1	0	0	0	0	1	1	0	0	0	0	0
Medicago polymorpha L.	1	0	1	0	0	1	0	0	0	0	0	0	0
Mentha pulegium L.	0	1	0	0	0	0	0	0	0	0	0	0	0
Ornithopus compressus L.	0	0	0	0	1	0	0	0	0	1	0	0	0
Plantago coronopus L.	0	1	0	0	0	1	1	1	0	0	1	0	0
Plantago lagopus L.	0	0	0	1	1	1	0	0	1	1	1	0	0
Plantago lanceolata L.	0	0	0	0	0	0	0	0	0	0	1	0	0
Poa annua L.	0	1	0	0	0	0	1	1	0	0	0	0	0
Polygonum aviculare L.	0	0	0	0	0	0	1	0	0	0	0	0	0
Polypogon maritimus Willd.	0	0	0	0	0	0	0	1	0	0	0	0	0
Ranunculus parviflorus L.	1	0	1	0	0	0	0	0	0	0	1	0	1
Rumex bucephalophorus L.	0	0	0	1	1	1	1	0	0	0	1	0	0
Rumex pulcher subsp. *woodsii* (De Not.) Arcang.	1	1	1	0	0	0	0	1	0	0	0	0	1
Senecio jacobaea L.	0	1	0	0	1	0	1	1	0	1	0	0	0
Sherardia arvensis L.	1	0	0	0	0	0	0	0	0	0	0	0	0
Silene gallica L.	0	0	0	1	0	1	0	0	0	0	1	0	0
Sisymbrium officinale (L.) Scop.	0	0	1	0	0	0	0	0	0	0	0	0	0
Stachys arvensis (L.) L.	0	0	0	0	0	1	0	0	0	1	1	0	0
Tolpis umbellata Bertol.	0	0	0	0	0	0	0	0	1	1	0	0	0
Trifolium campestre Schreb.	0	0	0	0	0	0	0	0	1	0	0	1	0
Trifolium glomeratum L.	0	0	0	1	0	0	1	1	1	1	1	0	0
Trifolium medium subsp. *medium*	0	0	0	0	0	0	0	0	0	1	0	0	0
Trifolium repens L.	0	0	0	0	1	0	0	1	1	1	1	0	0
Trifolium resupinatum L.	0	0	0	0	0	0	1	1	0	0	0	0	0
Trifolium scabrum L.	0	1	0	0	0	0	0	0	0	0	0	0	0
Trifolium subterraneum L.	0	0	0	0	0	0	1	1	1	0	0	0	0
veronica sp	0	0	1	0	0	0	0	0	0	0	0	0	0
Vulpia bromoides (L.) S.F.Gray	0	0	0	0	0	0	0	0	0	1	0	0	0

Vulpia geniculata	1	1	1	1	1	1	1	1	1	1	1	1	1

1-presence; 2-absence.

References

1. Pinto-Correia, T., Ribeiro, N., & Potes, J. (2013). Livro Verde dos Montados. In *Instituto de Ciências Agrárias e Ambientais Mediterrânicas - Universidade de Évora* (Issue January). http://www.icaam.uevora.pt/Noticias-e-Informacoes/Temas-e-Eventos-Arquivo/Livro-Verde-dos-Montados
2. David, T. S., Pinto, C. A., Nadezhdina, N., Kurz-Besson, C., Henriques, M. O., Quilhó, T., Cermak, J., Chaves, M. M., Pereira, J. S., & David, J. S. (2013). Root functioning, tree water use and hydraulic redistribution in Quercus suber trees: A modeling approach based on root sap flow. *Forest Ecology and Management*, *307*, 136–146. https://doi.org/10.1016/j.foreco.2013.07.012
3. Feio, M. (1991). Clima e Agricultura: exigências climáticas das principais culturas e potencialidade agrícolas do nosso clima. Ministério da agricultura, pescas e alimentação. Lisboa. ISBN 972 – 9175 – 25 – X
4. IUSS Working Group WRB. World Reference Base for Soil Resources 2014, International Soil Classification System for Naming Soils and Creating Legends for Soil Maps; Update 2015; World Soil Resources Report 106; Food and Agriculture Organization (FAO): Rome, Italy, 2015; 188p
5. Serrano, J. (2019). *Utilização eficiente dos recursos no Montado: sensores próximos e detecção remota no apoio à tomada de decisão*. Perspectiva 2020. 18–25.
6. Carvalho, M., Goss, M. J., & Teixeira, D. (2015). Manganese toxicity in Portuguese Cambisols derived from granitic rocks: causes, limitations of soil analyses and possible solutions Toxicidade de manganês nos Cambissolos derivados de rochas graníticas em Portugal: causas, limitações das análises de solo . *Revista de Ciências Agrárias*, *38*(4), 518–527. http://dspace.uevora.pt/rdpc/bitstream/10174/18708/1/
7. Daniels, M. B., Delaune, P., Moore, P. A., Mauromoustakos, A., Chapman, S. L., & Langston, J. M. (2001). Soil Phosphorus Variability in Pastures: Implications for Sampling and Environmental Management Strategies. *Journal of Environmental Quality*, *30*(6), 2157–2165. https://doi.org/10.2134/jeq2001.2157
8. Belo, C. C., Coelho, I., Rolo, J., & Reis, P. (2014). Sistemas agroflorestais em Portugal continental. Parte II: montados, condições de uso do solo e evolução. *Revista de Ciências Agrárias*, *37*(2), 122–130.
9. Sternberg, M., Gutman, M., Perevolotsky, A., Ungar, E. D., & Kigel, J. (2000). Vegetation response to grazing management in a Mediterranean herbaceous community: A functional group approach. *Journal of Applied Ecology*, *37*(2), 224–237. https://doi.org/10.1046/j.1365-2664.2000.00491.x
10. Watkinson, A. R., & Ormerod, S. J. (2001). Grasslands, grazing and biodiversity: Editors' introduction. *Journal of Applied Ecology*, *38*(2), 233–237. https://doi.org/10.1046/j.1365-2664.2001.00621.x
11. Brougham, R. W. (1960). The effects of frequent hard grazings at different times of the year on the productivity and species yields of a grass-clover pasture. *New Zealand Journal of Agricultural Research*, *3*(1), 125–136. https://doi.org/10.1080/00288233.1960.10419866
12. Teague, W. R., & Dowhower, S. L. (2003). Patch dynamics under rotational and continuous grazing management in large, heterogeneous paddocks. *Journal of Arid Environments*, *53*(2), 211–229. https://doi.org/10.1006/jare.2002.1036
13. Norman, H. C., Wilmot, M. G., Thomas, D. T., Barrett-Lennard, E. G., & Masters, D. G. (2010). Sheep production, plant growth and nutritive value of a saltbush-based pasture system subject to rotational grazing or set stocking. *Small Ruminant Research*, *91*(1), 103–109. https://doi.org/10.1016/j.smallrumres.2009.11.022
14. Xiao, X., Zhang, T., Angerer, J. P., & Hou, F. (2020). Grazing seasons and stocking rates affects the relationship between herbage traits of alpine meadow and grazing behaviors of tibetan sheep in the Qinghai–Tibetan plateau. *Animals*, *10*(3). https://doi.org/10.3390/ani10030488
15. Teague, R., Provenza, F., Norton, B., Steffens, T., Barnes, M., Kothmann, M., & Roath, R. (2008). Benefits of multi-paddock grazing management on rangelands: Limitations of experimental grazing research and knowledge gaps. *Grasslands: Ecology, Management and Restoration*, 41–80.
16. Voisin, A., & Lecomte, A. (1968). *La vaca y la hierba : Cómo obtener buenos rendimientos del ganado vacuno*. Editorial Tecnos.
17. Barcella, M., Filipponi, F., & Assini, S. (2016). A simple model to support grazing management by direct field observation. *Agriculture, Ecosystems and Environment*, *234*, 107–117. https://doi.org/10.1016/j.agee.2016.04.027
18. Barriga, P. A. B. (2019). *Produção de novilhos em pastagem de inverno com diferentes intensidades de pastejo e adubação nitrogenada em integração lavoura-pecuária*. Tese de doutoramento. Programa de Pós-graduação em Agronomia, Universidade Tecnológica Federal do Paraná, Câmpus Pato Branco
19. Mendes, P., Meireles, C., Vila-Viçosa, C., Musarella, C., & Pinto-Gomes, C. (2015). Best management practices to face degraded territories occupied by Cistus ladanifer shrublands – Portugal case study. *Plant Biosystems*, *149*(3), 494–502. https://doi.org/10.1080/11263504.2015.1040483
20. Holechek, J. L. (1983). Considerations concerning grazing systems. *Rangelands*, *5*(5), 208–211.

21. Santos, M. E. R., Afonso, L. E., Carvalho, B. H. R., do Rêgo, A. C., Queiroz, G. J. da S., Médica, J. A. de A., de Moraes, L. S., & do Carmo, L. L. S. (2019). Apparent selectivity of sheep in deferred marandu palisadegrass pastures with variable initial heights. *Arquivo Brasileiro de Medicina Veterinaria e Zootecnia*, *71*(5), 1727–1734. https://doi.org/10.1590/1678-4162-10750
22. Bell, M. J., Mereu, L., & Davis, J. (2018). The Use of Mobile Near-Infrared Spectroscopy for Real-Time Pasture Management. *Frontiers in Sustainable Food Systems*, 2(November). https://doi.org/10.3389/fsufs.2018.00076
23. Sales-Baptista, E., Ferraz-de-Oliveira, M. I., Terra-Braga, M., de Castro, J. A. L., Serrano, J., & d'Abreu, M. C. (2022). Characterization of grazing behaviour microstructure using point-of-view cameras. *Plos One*, *17*(3), e0265037. https://doi.org/10.1371/journal.pone.0265037
24. Riedel, J. L., Casasús, I., & Bernués, A. (2007). Sheep farming intensification and utilization of natural resources in a Mediterranean pastoral agro-ecosystem. *Livestock Science*, *111*(1–2), 153–163. https://doi.org/10.1016/j.livsci.2006.12.013
25. Hirata, M., Kunieda, E., & Tobisa, M. (2010). Short-term ingestive behaviour of cattle grazing tropical stoloniferous grasses with contrasting growth forms. *Journal of Agricultural Science*, *148*(5), 615–624. https://doi.org/10.1017/S0021859610000353
26. Santos, B., Voltolini, T., & Salla, L. (2010). Comportamento de Pastoreio - Behavior of grazing. *Revista Electrónica de Veterinaria REDVET*, *11*(4), 1–33.
27. Sibbald, A. M., Shellard, L. J. F., & Smart, T. S. (2000). Effects of space allowance on the grazing behaviour and spacing of sheep. *Applied Animal Behaviour Science*, *70*(1), 49–62. https://doi.org/10.1016/S0168-1591(00)00145-3
28. Zhang, H., Liu, N., Yang, G. W., Badgery, W. B., Guo, Y. P., & Zhang, Y. J. (2022). Diet selection of sheep shifted from quality to quantity characteristics of forages as sward availability decreased. *Animal*, *16*(6), 100546. https://doi.org/10.1016/j.animal.2022.100546
29. Du, W. C., Yan, T., Chang, S. H., Wang, Z. F., & Hou, F. J. (2017). Seasonal hogget grazing as a potential alternative grazing system for the Qinghai-Tibetan plateau: Weight gain and animal behaviour under continuous or rotational grazing at high or low stocking rates. *Rangeland Journal*, *39*(4), 329–339. https://doi.org/10.1071/RJ16119
30. Fan, X., Xuan, C., Zhang, M., Ma, Y., & Meng, Y. (2022). Estimation of Spatial-Temporal Distribution of Grazing Intensity Based on Sheep Trajectory Data. *Sensors*, *22*(4). https://doi.org/10.3390/s22041469
31. Jamieson, W. S., & Hodgson, J. (1979). The effect of daily herbage allowance and sward characteristics upon the ingestive behaviour and herbage intake of calves under strip-grazing management. *Grass and Forage Science*, *34*(4), 261–271. https://doi.org/10.1111/j.1365-2494.1979.tb01478.x
32. Pulido, R. G., & Leaver, J. D. (2003). Continuous and rotational grazing of dairy cows - The interactions of grazing system with level of milk yield, sward height and concentrate level. *Grass and Forage Science*, *58*(3), 265–275. https://doi.org/10.1046/j.1365-2494.2003.00378.x
33. Serrano, J., Shahidian, S., da Silva, J. M., & de Carvalho, M. (2018). A holistic approach to the evaluation of the montado ecosystem using proximal sensors. *Sensors (Switzerland)*, *18*(2), 1–24. https://doi.org/10.3390/s18020570
34. Serrano, J., Shahidian, S., da Silva, J. M., Moral, F., Carvajal-Ramirez, F., Carreira, E., Pereira, A., & de Carvalho, M. (2020b). Evaluation of the effect of dolomitic lime application on pastures - Case study in the Montado mediterranean ecosystem. *Sustainability (Switzerland)*, *12*(9). https://doi.org/10.3390/su12093758
35. Serrano, J., Shahidian, S., Costa, F., Carreira, E., Pereira, A., & Carvalho, M. (2021a). Can soil ph correction reduce the animal supplementation needs in the critical autumn period in mediterranean montado ecosystem? *Agronomy*, *11*(3). https://doi.org/10.3390/agronomy11030514
36. Serrano, João, Shahidian, S., Machado, E., Paniagua, L. L., Carreira, E., Moral, F., Pereira, A., & de Carvalho, M. (2021b). Floristic composition: Dynamic biodiversity indicator of tree canopy effect on dryland and improved mediterranean pastures. *Agriculture (Switzerland)*, *11*(11), 1–25. https://doi.org/10.3390/agriculture11111128
37. Carreira, E., Serrano, J., Gomes, C. J. P., Shahidian, S., Paniagua, L. L., Pilirito, A., Lopes Castro, J., Carvalho, M., & Pereira, A. F. (2022). Effect of Sheep Grazing, Stocking Rates and Dolomitic Limestone Application on the Floristic Composition of a Permanent Dryland Pasture, in the Montado Agroforestry System of Southern Portugal. *Animals*, *12*(19), 2506. https://doi.org/10.3390/ani12192506
38. Serrano, João, Carreira, E., Shahidian, S., de Carvalho, M., Marques da Silva, J., Paniagua, L. L., Moral, F., & Pereira, A. (2023). Impact of Deferred Versus Continuous Sheep Grazing on Soil Compaction in the Mediterranean Montado Ecosystem. *AgriEngineering*, *5*(2), 761–776. https://doi.org/10.3390/agriengineering5020047
39. Russel, A. (1984). Body condition scoring of sheep. *Practice*, 6, 91–93.
40. Cannas, A.; Boe, F. (2003). Prediction of the relationship between body weight and body condition score in sheep. *Ital. J. Anim. Sci.*, 2 (Suppl. 1), 527–529.

 doi:10.20944/preprints202403.1294.v1

41. Walton, P.D.; Martinez, R.; Bailey, A.W. (1981). A Comparison of Continuous and Rotational Grazing. Rangel. Ecol. Manag. 34, 19.
42. Marley, C.L.; Fraser, M.D.; Fisher, W.J.; Forbes, A.B.; Jones, R.; Moorby, J.M.; Macrae, J.C.; Theodorou, M.K. (2007). Effects of continuous or rotational grazing of two perennial ryegrass varieties on the chemical composition of the herbage and the performance of finishing lambs. Grass Forage Sci. 62, 255–264.
43. AOAC. (2005). Official Method of Analysis of AOAC International, 18th ed.; AOAC International: Arlington, AT, USA.
44. Fonseca, L., Mezzalira, J. C., Bremm, C., Filho, R. S. A., Gonda, H. L., & Carvalho, P. C. d. F. (2012). Management targets for maximising the short-term herbage intake rate of cattle grazing in Sorghum bicolor. *Livestock Science*, *145*(1–3), 205–211. https://doi.org/10.1016/j.livsci.2012.02.003
45. Moraes, A., Carvalho, P. C. de F., Anghinoni, I., Lustosa, S. B. C., Costa, S. E. V. G. de A., & Kunrath, T. R. (2014). Integrated crop-livestock systems in the Brazilian subtropics. *European Journal of Agronomy*, *57*, 4–9. https://doi.org/10.1016/j.eja.2013.10.004
46. Iason, G. R., Mantecon, A. R., Sim, D. A., Gonzalez, J., Foreman, E., Bermudez, F. F., & Elston, D. A. (1999). Can grazing sheep compensate for a daily foraging time constraint? *Journal of Animal Ecology*, *68*(1), 87–93. https://doi.org/10.1046/j.1365-2656.1999.00264.x
47. Carvalho, M. A Seca E a Intensificação Sustentável Dos Sistemas Agro-Pecuários: Desafios E Soluções. Dossier Secas e Cheias—Como Gerir. 2018, pp. 24–27. Available online: http://dspace.uevora.pt/rdpc/bitstream/10174/23541/1/ (accessed on 7 November 2023).
48. Potes, J.M. O Montado no Portugal Mediterrânico; Edições Colibri: Lisboa, Portugal, 2011; 193p.
49. Mayerfeld, D.; Kruger, E.; Gildersleeve, R. & Rickenbach, M. (2022) Impacts of different grazing approaches on woodland ecosystem properties. Agroforestry Systems, 96, 527–540.
50. Sharrow, S. (2007). Soil compaction by grazing livestock in silvopastures as evidenced by changes in soil physical properties. Agroforestry Systems, 71, 215–223.
51. Benavides, R.; Douglas, G.B.; Osoro, K. (2009). Silvopastoralism in New Zealand: Review of effects of evergreen and deciduous trees on pasture dynamics. Agroforestry Systems, 76, 327–350.
52. Di Grigoli, A., Todaro, M., Di Miceli, G., Genna, V., Tornambè, G., Alicata, M. L., Giambalvo, D., & Bonanno, A. (2012). Effects of continuous and rotational grazing of different forage species on ewe milk production. *Small Ruminant Research*, *106*(SUPPL.), S29–S36. https://doi.org/10.1016/j.smallrumres.2012.04.030
53. Clair, C. S., & Forrest, A. (2009). Impacts of vehicle traffic on the distribution and behaviour of rutting elk, Cervus elaphus. *Behaviour*, *146*(3), 393-413.
54. O'reagain, P. J., & Schwartz, J. (1995). Dietary selection and foraging strategies of animals on rangeland. Coping with spatial and temporal variability. In International symposium on the nutrition of herbivores (Vol. 4, pp. 419-424). In *proceedings In: INTERNATIONAL SYMPOSIUM ON THE NUTRITION OF HERBIVORES* (Issue February, pp. 419–424).
55. Quintas, H., Cordeiro, A. & Aguiar, C. (2014). Plantas tóxicas para ruminantes. Publicações ciência & vida. ISBN: 978-972-590-093-2
56. Heady, H. F. (1961). Continuous vs. Specialized Grazing Systems: A Review and Application to the California Annual Type. *Journal of Range Management*, *14*(4), 182. https://doi.org/10.2307/3895147