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Department of Crop Water Stress Management

"Effect of vegetation density on grazing behaviour of free-ranging cattle in grasslands of Northeast Argentina"

Master Thesis

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ABSTRACT

Northeast Argentina is the second biggest livestock production area in the country based on natural and semi-natural grassland. This region presents a low stocking rate of 0.5 AU/ha because it is limited by low grass productivity in winter. As a consequence, low grass consumption in the other seasons leads to a high amount of standing dead biomass pools which build up every year in large grassland areas. The aim of this research is to understand if livestock behaviour is influenced by grass height and grass density. The grazing preference of the cattle was analyzed by using the interception degree as a proxy of the percentage of visibility. In total, 4 paddocks, 3 repetitions and one control were analyzed. Each paddock was subdivided into 12 subplots. Each month, one of the subplots was subjected to the herd effect over three days with a high stocking rate of approximately 150 AU/ha per day as a living tool to trample down all standing plant material. To study the variability of the height, faecal deposition, biomass and interception percentage, a technique of mixed general lineal models was used. This study shows that there exists a clear effect of the treatment until the month 6 for the measurement done in July, 7 for August and 8 for September. Thus, a second treatment effect would be necessary to avoid the high amount of standing biomass. Also, the number of droppings decreased as time passed after impact giving a linear but negative relationship between interception and droppings. This indicates that the animals avoid areas where the grass height is higher than 20 % of interception. Finally, biomass and height measurement increases when the interception does too, having a direct relationship between the variables. The degree of interception methodology can be used as a proxy to determine above ground biomass in grasslands. Further, applied research in other ecosystems is recommended to calibrate this method.

Key Words: Cattle behaviour; above ground biomass density; visibility; herd effect; interception technique; Corrientes Argentina.

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DECLARATION

I, Molo Cecilia Ximena

Born in Resistencia Chaco, Argentina

Matriculation number 539872

Hereby declare on my honor that the attached declaration,

- Homework/ Presentation
- Bachelor Thesis
- Master Thesis
- Diplom Thesis

Has been independly prepared, solely with the support of the losted literature references, and that no information has been presented that has not been officially acknowledge.

Supervisor: Prof. Dr. Asch

Thesis topic: Effect of vegetation density on grazing behaviour of free-ranging cattle in grassland of Northeast Argentina

Semester: 8th

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1. INTRODUCTION

Grassland management in Argentina began with the introduction of cattle by Spaniards around the XVI century. Due to environmental features, cattle found their niche in the "Pampas" areas where they reproduced slowly until the mid-nineteenth century, but without natural enemies. Since the eighteenth century they were used for commercial purposes (Rearte 2002 cited in Chiossone, 2006). Years later with the introduction of refrigeration technology in the nineteenth century, the implementation of package technology began for modern livestock farming. Thereby Argentina became one of the first exporters of beef in the world in the 1970s, with over 60 million head and 1,000,000 tons of meat. Currently Argentina has a per capita consumption of 72 kg meat/ person/year and 500,000 tons of meat are exported. (Rearte 2002 cited in Chiossone, 2006; Rearte, 2010).

In recent years, livestock production was moved towards marginal areas (mostly cattle) as a result of the spread of agriculture. To maintain these production systems it was necessary to develop technologies to improve forage resources (Calvi, 2010). The cultivation of soybeans was the main cause of the change, which went from 5.8 million to 18,000 million ha cultivated land. The Northeast Argentinean region is the second biggest livestock region in the country, which experienced an increase in its stock rising but produces only 2.5 million calves annually, with a weaning percentage not exceeding 45% and a stocking rate of 0.53 AU/ha (Rearte 2002 cited in Chiossone; 2006). The values of primary productivity of many plants communities exceed 4,000 kg DM/ha/year. Due to the low stocking rate which is adjusted to the low grass winter productivity, low grass consumption during the other seasons occurs, and high amounts of standing dead biomass pools build up every year in large grassland areas in north-western Corrientes (Kurtz et al., 2010).

In Corrientes, mixed grazing (cattle, sheep, horses, etc.) predominates, as do the activities of breeding, rearing, etc. (Calvi 2010). 78% of range managers own less than 100 animals and account for less than 13% of provincial stock. On the other hand, 3% of the producers own more than 1,000 head and represent 53% of Provincial stock. There exist different kinds of livestock technology for grassland management such as, fencing, early weaning, herding, the use of season and strategic supplementations (Tanaka et al., 2007). In the past, one management tool was the use of prescribed burning (Bernardis et al., 2005; Fernández et al., 2011;Toledo et al., 2014) but at present this option is not available due to a new law in Corrientes that forbids the use of fire (Corrientes, 2004). Another option for the control of this dead material is the use of mechanical control, for example the roller chopper (Adema et al., 2004), but due to soil characteristics in Corrientes province especially in the rainy season (summer-autumn) where the grass reaches advanced maturity levels, it is difficult or even impossible to implement. High impact grazing (HIG) was recently proven an efficient management alternative to reduce standing dead material (Kurtz et al. 2016). In this work we want to focus on how HIG affects grassland density and we propose an alternative method to measure that density.

Understanding the management of cattle distribution patterns is important in order to use natural resources efficiently (Walburger et al. 2009). Free-ranging ungulates respond more to internal and external stimuli than direct behavior and also depend on inherited attributes such as individual or social learning (to novel stimuli) and spatial memory. Based on these behavioral factors animals decide where to forage, drink, rest and ruminate. Further, animals use audiovisual signs to seek and select their environment and return to previous areas (Launchbaugh and Howery 2005). In order to select a habitat, animals choose an environment that presents certain characteristics such as comfortable thermal regimes, water, and quantity and quality of forage. On the other hand, they would avoid habitats that present elements such as poisonous plants, insects, pests or predators. Accordingly to the mentioned aspects, it could be said that habitat preferences are detected when animals seek and stay in a specific environment. As a result of this, we want to identify which part of the area the animals select for grazing meaning open areas without interference of visibility by vegetation density or areas with high vegetative availability.

Kluever (2008) stated that ungulates' vigilance is affected by the group size. In other words, when the group is bigger than 5 animals the vigilance rate is lower. It means that individual animals benefit from the efforts of the group scanning for predators. In addition, animals increase vigilance in all group sizes when woody vegetation is higher due to the reduced capacity to detect threat. Walburger (2009) found that cattle preferred open areas with less canopy cover. The aim of this study is to understand if livestock behaviour is influenced by grass height and grass density. We hypothesize that animal behavior is affected by tall and dense grass, causing non-acceptance as a result of fear due to a lack of visibility analyzed by optical interception degree as a proxy of the percentage of visibility.

Objectives:

1) To determine if the methodology used to measure the degree of interception can be used as a proxy for grassland biomass.
2) To determine the site selection by animals in order to evaluate if selection is influenced by biomass density. Which part of the paddock do the animals select in order to satisfy their necessities: open area vs. high quantity of biomass?
3) To determine the density of grass that affects the re-entry of and permanence of the animal in the plot.

2. LITERATURE REVIEW

2.1 Grassland characteristics

Livestock production in Argentina is mainly based on natural and semi-natural grassland. Corrientes province's grassland area accounts for 91.5% of its total area, natural forests 7.9%, perennial forage 0.5% and annual forage 0.1% on average (INDEC, CNA 1988 and 2002 cited in Calvi 2010).

Grassland growth is limited by low winter temperatures and poor herbage quality (Royo Pallares et al. 2005) is the reason why the stocking rate is adjusted to the low winter fodder production by the farmers (Calvi, 2010). The zone is characterized by the presence of C4 species, which results in the higher production in summer and autumn. Also these grasslands are affected by the great rainfall variability between years (Royo Pallares et al. 2005). The most important restrictions for livestock production are the low dry matter protein in winter (4 to 6 grams/100 grams of dry matter) which affects cattle consumption. Other factors are phosphor deficiency (0.09 + 0.02 gr/100 gr of dry matter) and sodium (0.06+0.01gr/ 100 gr of dry matter).

Argentinean meat production presents low productivity as a consequence of low extraction rate in livestock (slaughter rate of 13 -14 millions of cattle over a stock of 54-57 millions) approximately 25% low slaughter weight (average 350-360 kg) and lack of use of the available technology (Rearte, 2010). According to Rearte (2010) some possible solutions could be the increase of national production (approximately 54 Million head) by increasing the extraction rate, increasing slaughter weight (using grains and meat proteins flour) and adoption of the available technology. It is important to highlight that in Argentina the production systems implemented produce less methane per kg of meat than other extensive grassland systems.

2.2 Animal droppings

The direct determination of animals' presence on the ground has many difficulties due to, their complex behavior patterns and herding tendency. There are also problems with observations at night, during unfavorable weather conditions and in remote situations. Thereby, indirect methods to estimate occupancy of a site, such as measurements of dung have been used (Welch

1982). Welch (1982) concluded that defecation rate is a good proxy to determine occupancy, even if different factors like variation in intake and food digestibility among areas and among seasons potentially affect defecation.

Masahiko Hirata et al. (2008) described the animals' defecation behavioral patterns. They observed that animals principally choose resting areas or near fence lines. Also, it was determined that animals defecate between 10-19 times per day.

In an attempt to determine the local pressure of grazing, Tsechoe Dorji et al. (2013) used the distance of droppings from pastoralist camps and Pika burrows as an indirect measurement. But they concluded that none of these measurements is a good representation of grazing intensity. Omaliko (1981) stated that animals do not defecate and graze in the same place. This occurs where there exist large areas which allow animals to select where they exhibit various behaviors. Nevertheless, they detected that the worthiness of using herbivore excreta to determine grazing intensity was good. They stressed that if herbivore excreta is used as an indirect measure for grazing, animal behaviour should also be recorded. Moreover, Limb et al. (2010) used the quantity of dung as one parameter to determine where the animal spent more time foraging.

According to Omaliko (1981), it could be said that the level of non-acceptance by the animal to graze in the area near the dung is influenced by climatic conditions. This is attributable to the fact that the season affects the size, amount, and decomposition rate of dung in the field. High temperature and humidity increases the rate of degradation. In that particular study, it was found that the major refusal by animals to forage near to the dung occurs in the wet season. Also, this period coincides with the greatest quantity of herbage and this allows the animal to select others area. This capacity of selection was reduced when the grazing pressure increases (Omaliko 1981).

According to Vadas et al. (2011), "A pad is defined as the dung deposited on the soil surface in an approximately circular geometry during a single faecal voiding". Vadas et al. (2011) developed a new model to simulate dung decomposition and phosphorus transformation. The model assumes dung disappearance as consequence of two factors: decomposition of organic matter and incorporation in soil by macro-invertebrates.

Several studies to determine decomposition and assimilation of dung have been carried on (Holter 1979, Holter and Hendriksen 1988), shows that the rate of disappearance can vary widely depending on climate and dung moisture content. However, they found that dung pads was integrated into soil within 100 days of deposition.

2.3 Structural Heterogeneity

Savory (2005) defines the herd effect as the less used management tool. According to this concept, the disturbance generated by the impact of the hoof animals promotes soil fertility. Limb et al. (2010) found that by generating a localized disturbance, the animals were attracted to the disturbed areas, which produce more structural heterogeneity and presents less pasture height.

Acocks (1967, cited in Hoffman, 2003; Savory 1983; 2005) developed the concept of non-selective grazing based on the fact that in the past, the great diversity of wild animals and their movement in groups made these consume all vegetation once without selection avoiding structural heterogeneity.

Savory (1983, 2005) believes that there are two ways to implement or manage the animal impact. These are the herd-animal and density effects. Savory estimated that with these management practices it is possible to achieve an effect on the soil surface that handles the four pillars representing the holistic management theory: nutrient cycling, water cycle, succession and energy flow. Nevertheless, this concept has been discussed and objected to (Briske et al., 2013).

Senft (1987) states the importance of studying the development and dynamic spatial heterogeneity in ecosystems because prediction of animal distribution patterns requires different considerations at different scales. In order to determine foraging decisions at the different scales, they took into account hierarchy theory. According to Senft (1987), in the case of community scale, ungulates have two problems. One is diet selection, in which the animals have to decide which plant or plant parts they will choose from their immediate surroundings, and the second problem is location selection, which includes how to move through the community. In addition, Fortin (2003) supports the idea that animal distribution and resource use have to be analyzed at multi-scale levels due to animals using dissimilar selection criteria at separate scales. Fortin (2003) suggests that large herbivores distribution and resource use at different spatio-temporal scales are affected by abiotic and biotic factors. Further, it was indicated that factors such as the need for other nutrients and, water, energetic costs of foraging and predation risks could have a more powerful influence than the abundance of preferred food types on the dispersion of animals through the landscape. In other words, energy intake maximization rules were not enough to clarify the selection and resource use by ungulates across spatio-temporal scales. Bertiller and Ares (2008) concluded that the primary selection of small ungulates was based on non-nutritional, structural visual cues. The main selected plants were the ones which present low visual impediment and low levels of structure anti-herbivore defences, independent of the abundance or preferred plant cover. In summary, in a hierarchy of decisions, plant abundance was not the main factor influencing the selection of vegetation units. On the other hand, monitoring animal movement through a landscape which presents visual constraints could give criteria to assess the importance of non-nutritional environmental traits on ungulates' decisions.

2.4 Estimation of plant Biomass

There always exists a no-win decision between choosing a large number of fast and inaccurate measurements vs. a small number of slow and accurate measurements due to a scarcity of resources. That is the reason why methods that can reduce tedious biomass analysis in the field are required (Brathen and Hagberg, 2004). Estimates of net primary productivity (NPP) is an important issue for basic and applied ecologists due to its relationship with certain topics as global carbon balance, the location of the missing carbon sink, and predictions of global climate change. (Sala and Austin 2000). However, primary production of grassland is related to the availability of forage and animal carrying capacity from an applied point of view.

According to Odum (1971, cited in Sala and Austin, 2000 p. 31), "Net primary productivity is the rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants". Through the entire trophic web, herbivores feed themselves with the organic matter reserved in plants, and the portion which is not assimilated reaches the decomposers. In other words, only part of the organic matter consumed is absorbed since a portion is lost in animal faeces and urine.

Sala and Austin (2000 p.31), give the following definition: "net ecosystem productivity is the rate of storage or loss of organic matter in the ecosystem in excess of the respiration by all its organisms in all the different trophic levels from autotrophs to decomposers". The importance of the definitions of biomass and productivity concept arises due to them often being confused. For instance, the biomass concept is used to calculate productivity. Further, productivity is taken into account when the time scale of interest is less than a year.

Grassland and steppes are considered fast turnover ecosystems where the relationship between (Aboveground net primary productivity) ANPP and biomass is high and where individuals of relative short life span reside. On the other hand, the forest ecosystem is correlated with a slow turnover rate, low ANPP/ biomass ratio, and large individuals with long life span (Sala and Austin, 2000). In grassland and steppe ecosystems, biomass varies broadly through the different seasons due to water availability, and this results in a problem for the directly estimation of ANPP. In multispecies ecosystems where productivity and senescence occurs at the same time, different methodologies have been proposed, such as the harvest of aboveground biomass technique (Sala and Austin 2000). This direct method is destructive, laborious and reduced the possibility to do extensive sampling. Consequently, the development of several non-destructive and less laborious techniques, such as the Canopy intercepts method (Frank and McNaughton 1990) or the photo-graphic technique (Paruelo et al. 2000; Tomasel et al. 2001) has been an important issue.

3. MATERIALS AND METHODS

3.1 Study area

This study was conducted in the north-eastern Argentina, in the Corrientes province, specifically, at the research station called INTA (Instituto Nacional de Tecnologia Agropecuaria) Corrientes (27° 39' S; 58° 46' W) (Figure 1). The annual temperature of the study area oscillates between a high of 21.16°C and a low of 15.89°C (Figure 2). The mean annual precipitation is approximately 1303.8 mm, with less precipitation in winter (Figure 3). The province has a subtropical climate: humid with frequent water excesses in autumn and spring and moderate water deficits, mainly in summer (Escobar et al., 1996). According to Carnevalli (1994), Corrientes province is free of frost from later spring (October) until the beginning of autumn (April). The precipitation is higher in the northeast part of the province (1500 mm) than in the southwest (1000mm). The season with the highest precipitation is autumn and winter the lowest. Soil water deficit is frequent in summer.

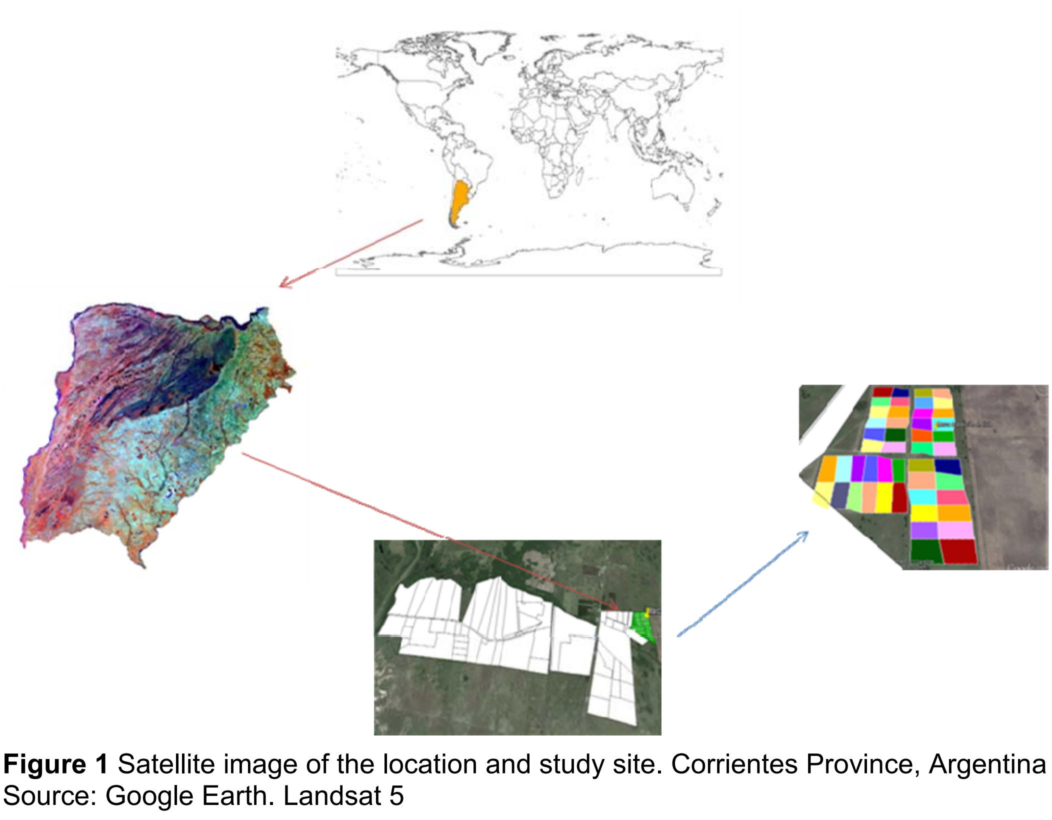

Figure 1 Satellite image of the location and study site. Corrientes Province, Argentina Source: Google Earth. Landsat 5

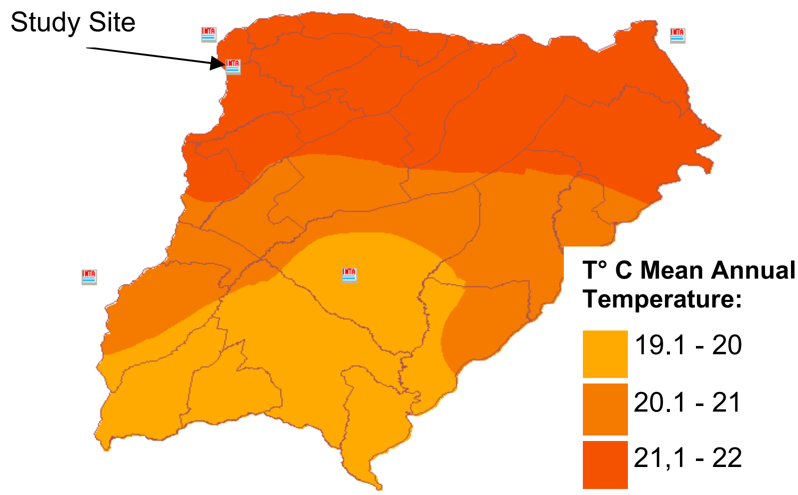

Figure 2 Mean Annual Temperature in Corrientes Province. Source: http://sig-ctes.inta.gob.ar/sig/

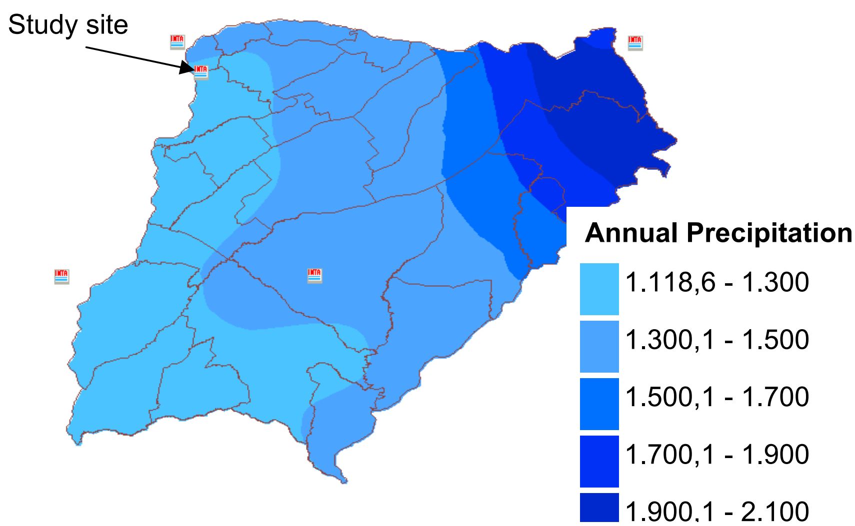

Figure 3 Annual Precipitation in Corrientes Province, expressed in mm. Source: http://sig-ctes.inta.gob.ar/sig/

3.2 Soils

The soil at the research area was classified as "aquic argiudoll" locally and named Treviño series (Escobar et al., 1996). This type of soil presents moderate to slow permeability, and it is frequently waterlogged during short periods of time. The soil can be used for agriculture due to its characteristics, but with some limitations due to susceptibility to water erosion and water logging.

3.3 Vegetation

The principal vegetation is C_4 tussock species like *Andropogon lateralis* and*,* *Sorghastrum nutans*; intertussock species like *Paspalum notatum, Sporobolus sp.,* and *Cynodon dactylon;* and some main weeds like *Eryngium sp. y Vernonia sp*.(Burkart A., 1975).

3.4 Sampling design

The study area is made up of 24 hectares, which were divided into 6 hectare paddocks. In total, 4 paddocks were studied, 3 repetitions and one control. In addition, all paddocks were subdivided into 12 subplots. Each subplot occupied 0.5 hectare and represented one month of the year. The 12 subplots (12 months) per paddock resulted in a total number of 48 subplots in the entire experiment (Figure 4).

Every month, one of the subplots was subjected to the herd effect for a period of three days, with high stocking rates (approximately 150 LU/ha per day) in order to combine consumption, urination, dung, trampling and incorporation to the soil of mainly dry dead material (Figure 5).

Each subplot was closed with electric fences and the herd effect was used as a living tool to trample down all standing plant material. After the high impact grazing, the fences were removed, and the animals put into another subplot in a different paddock (repetition). In each repetition, including the control, a stocking rate of 0.5 AU/ha day was used to simulate the stocking rate of the zone. (Kurtz et al., 2007).

The trial started in July 2012 and ended in June 2014. The picture samples for this study were taken during July, August and September 2013.

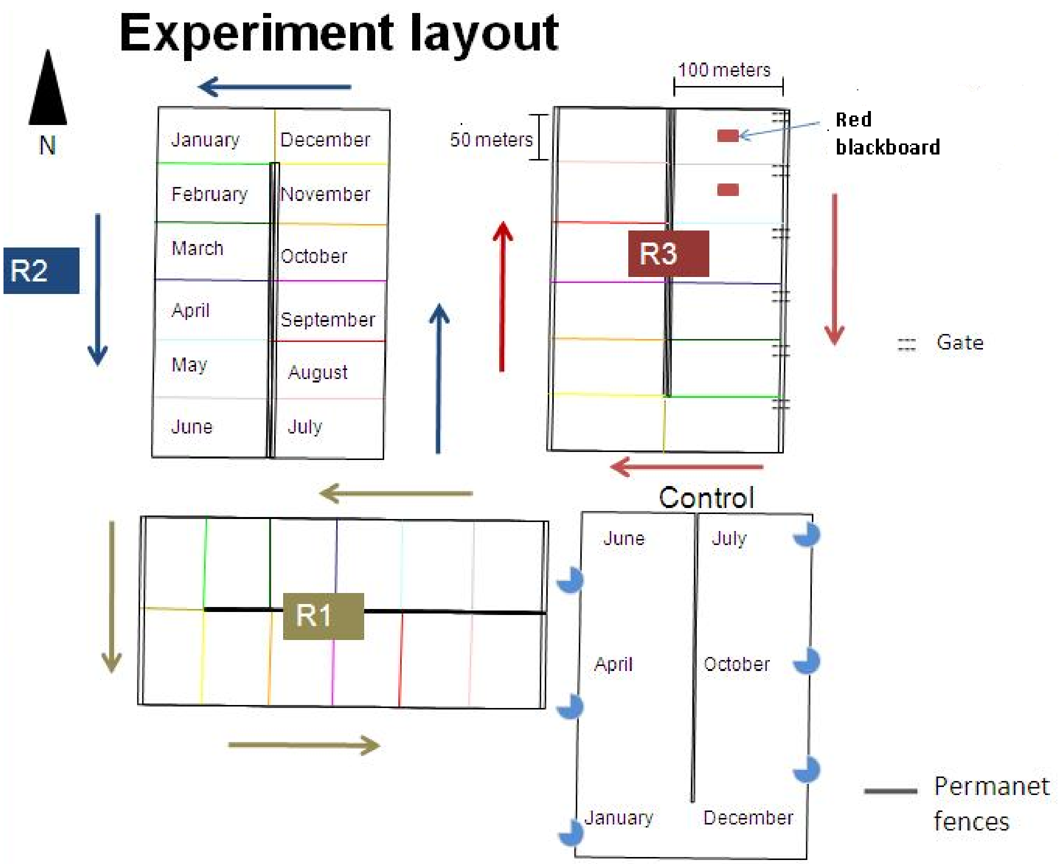

Figure 4 Experimental area with three paddocks that were subjected to grazing impacts by cattle (Repetition R1, R2 and R3) and one control paddock (Control) without grazing impacts.

Note: Each subplot represents one month of the year (12 subplots in total). The impact was started the month of July and ended in June. The red blackboard was placed in the center and pictures were taken from four direction (E, W, N, S) and three distances (2, 5, 10 m).

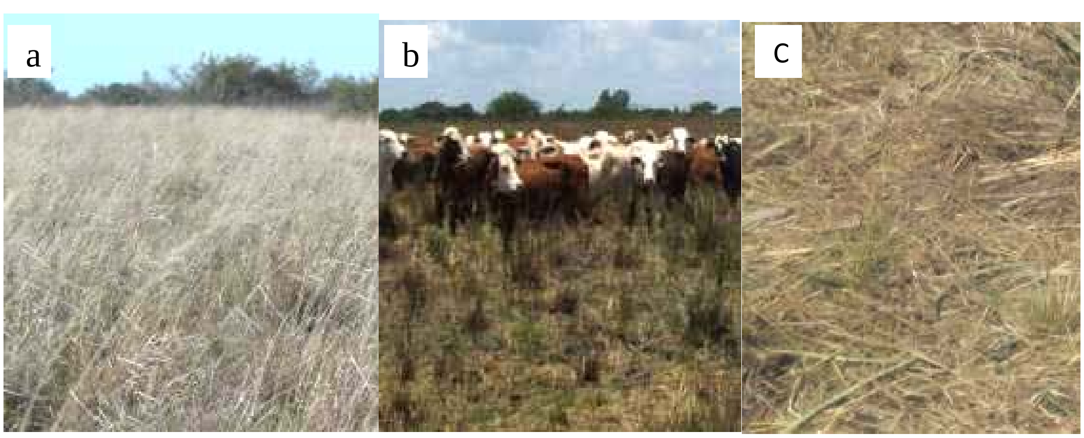

Figure 5 a) site before impact. b) Cattle producing herd effect. c) Subplot after high grazing impact. Source: Mr. Juan Jose García Alevras

3.3 Studied variables

3.3.1 Interception Measure

The interception measurements were done using a red square frame (1.05 meters each side with two legs of 0.70 meters) and a digital 16.1 mega pixel camera (Figure 6). A tripod to maintain the camera at 1.20 meters above ground was always used as well a tape measure to calculate the distance between the camera and the blackboard. What was measured was therefore the interception between the blackboard and grass biomass at a 10 meters distance gap.

The pictures were taken in all 48 subplots (12 x 4). In every subplot four pictures were taken at north, south, east and west per each subplot. At the end, a total of 192 pictures were taken (12x4x4).

This procedure was repeated three times, in three different months: July, August and September 2013.

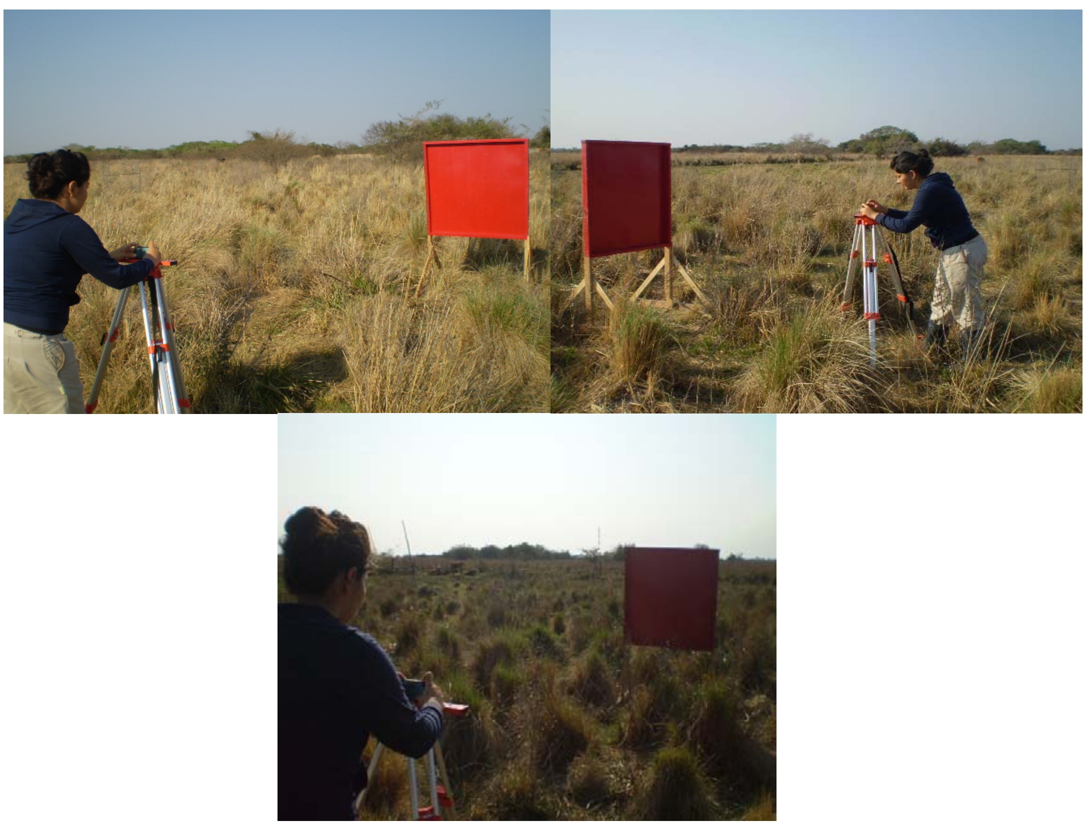

Figure 6 Taking the pictures on the field Corrientes, July 2013. Own source

After the pictures were taken, ERDAS IMAGINE 9.1 software was used to analyze and classify the pictures. ERDAS IMAGINE is a raster image processing software (Figure 7).

The pictures were processed in three phases. Firstly, the pictures were cut with the program ERDAS 9.1 and stored as tagged image file format (Tiff) because this standard file allows you to save with a high quality image, 48 colour bits, and also store more than one image in the same file (Rodriguez Estrada 2009). Second, the pictures were classified using an unsupervised classification (isodata) procedure, where the pixels corresponding to vegetation class were counted to get the percentage of interception (Figure 8). Finally, the percentage of grass was calculated using a Rule of Three, and by means of subtraction I considered 100% the blackboard background.

Figure 7 First step classified pictures. Own source

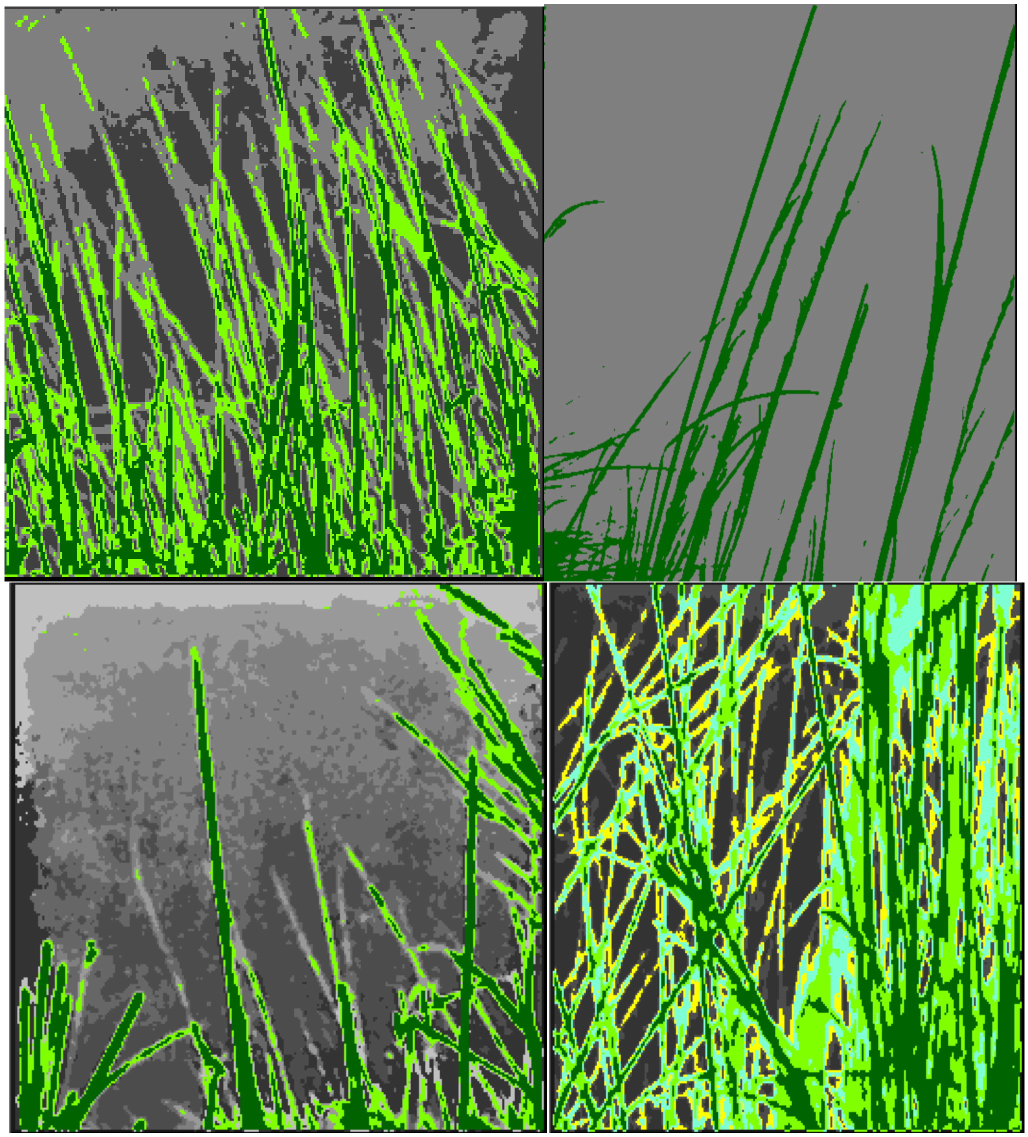

Figure 8 Second Step refined classified pictures. Own source

3.3.2 Determination of aboveground plant biomass

The determination of aboveground plant biomass was carried out in each plot of the three paddocks and the control. For the determination, the grass was harvested at two randomly chosen points at 1 cm height from the ground in a 1 m² area in all subplots. The material was first fresh weighed and separated into two parts: green and dead plant material. For this step, the quadrant reduction method was used, which consisted of obtaining a subsample of approximately 25 % of the harvested biomass which is easier to manage. Finally, the material was oven dried at 75 °C for 72 hours and weighed again. Biomass was harvested in July, August and June 2013.The biomass dataset was provided by Ditmar Kurtz.

3.3.3 Droppings

The assessment of dung was conducted following transects across the plots in the three different paddocks and the control. In order to have a guide, two permanent wooden sticks crossing each plot were placed in the ground.These two sticks formed a cross line along the plot. Walks along this cross line were done considering the area within one meter from each side of the line. A total area of 647 m² was considered per subplot. All of the points where a dropping was detected were marked with GPS. As with the other variables analyzed before, the three months considered were July, August and September 2013 (The droppings dataset was provided by Ditmar Kurtz).

3.3.4 Grassland height measurement

The measurement of grass height was carried out by a student of the local university (Mr Juan Jose García Alevras), using a ruler to determine the height of the grass and a GPS device to reach each point where the height was measured based on a previously uploaded grid (Figure 9). Every morning in all subplots including the control, grass was measured at every point. In each subplot, the height of the Biomass was measured at 10 points (Figure 10).

Figure 9 GPS Map Garmin CSX60 and ruler brand CST/ Berger extendable up to 5 meters.

Figure 10 Grass height measurement using GPS to reach the sample site and the ruler for the measurement. Source: Mr. Juan Jose García Alevras

3.4. Data Analysis

To study the variability of the height, faecal deposition, biomass and interception percentage technique, Mixed General Linear Models was used.

This model considers as fixed effects time and months after high grazing impact and as random effects paddock and different structure of variances of the random effects and / or predicted as:

$$\mathbf{y_{ijk}= \mu+ \alpha_i+\beta_j+ \gamma_k+\xi_{ijk}} \qquad \text{with } i=1,...,a;\ j=1,...,b;\ k=1,..,n_i$$

where:

y_{ij} is the response of the i_{th} time in the j_{th} months

μ corresponds to the general average

α_i the effect of the i_{th} time

βj the effect of the j_{th} months

γ_k are additional effect (Interaction), of the combination of time and months.

ξ_{ijk} is random error associated with each observation, is assumed (usually) with normal and independently distributed with zero and common variance σ^2.

Various statistical structures based on the model variances of error ($var(\xi_i) = \sigma^2 .g^2$) were tested, where *g* is known as a function of variance. Errors with different variance functions are modelled to consider a model of homogeneous variances. The right model is selected taking into account the values of the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) where the lower the values the better (Montgomery *et al.*, 2004). The variance components were estimated by restricted maximum likelihood method. Data were analyzed with the InfoStat, 2014 software.

To find the best model, first I began estimating a few simple parameters, and then parameters were added up to the model data structure. After selecting the model, multiple comparisons of the type DGC were made (Di Rienzo *et al.*, 2002) and using multivariate clusters analysis technique (UPGMA) on a distance matrix of means to assess whether there are differences between yields. This method of comparison of means uses the multivariate technique of cluster analysis. This test checks the type I error and improves its overall performance.

To detect the differences between the various factors involving the experiment, the following statistical assumptions were validated:

H_0: $\boldsymbol{\alpha_i} = 0$ H_0: $\boldsymbol{\beta_j} = 0$ H_0: $\boldsymbol{\gamma_k} = 0$

H_a: $\boldsymbol{\alpha_i} \neq 0$ H_a: $\boldsymbol{\beta_j} \neq 0$ H_a: $\boldsymbol{\gamma_k} \neq 0$

4. RESULTS

4.1 Interception

From the interception samples analyzed for the measurements of July, August, and September it can be said that the Interception is higher when more time passed by after the high grazing impact (Table 1)**.** Table 1 shows significant differences due to the time when the interception was calculated, the sub-plot (=month) where the interception was calculated and an interaction between months after the impact and time.

Table 1 p-values of the time were interception was calculated, months (sub-plot) and interaction between time and months

Effects	p-value
Time	0,0116
Months	<0,0001
Time:Months	<0,0156

In Figure 11 interception July, we can observe low percentage of interception (less than 20%) extending from month 1 to 6 after treatment HGI compared to the months (7-12 MAI) which shows higher interception. The months September, October, November and July inclusive have higher percentage of interception than the control.

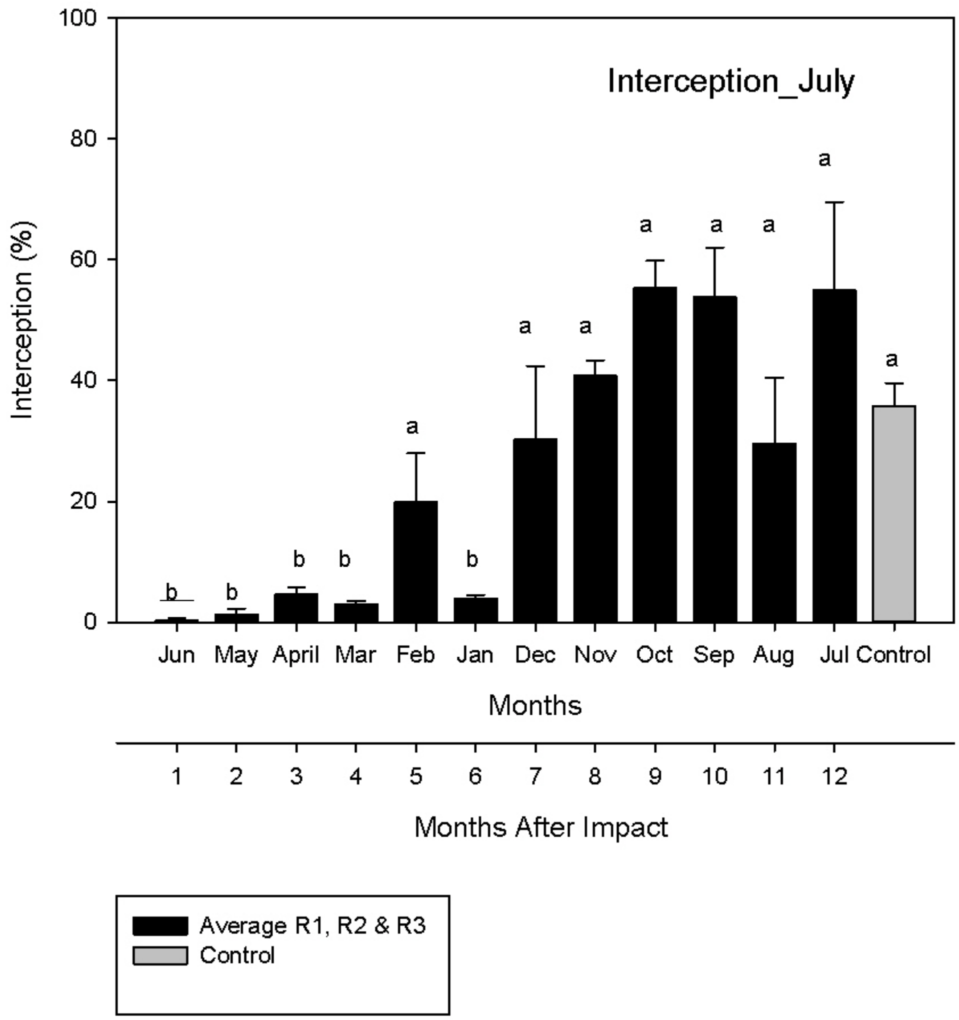

Figure 11 Interception degree in the subplots under the treatment high grazing impact (HGI), and interception of grassland in control. Time July
Note. All variables are expressed in percentage. Error bars indicate the standard error of the means ($p < 0.05$).

Figure 12 Interception August, we can observe also that until 7 months after impact the percentage of Interception (less than 20%) is low compared with the months (8-12 MAI). From month number 8 it can be observed how the percentage of interception increases and is higher than control.

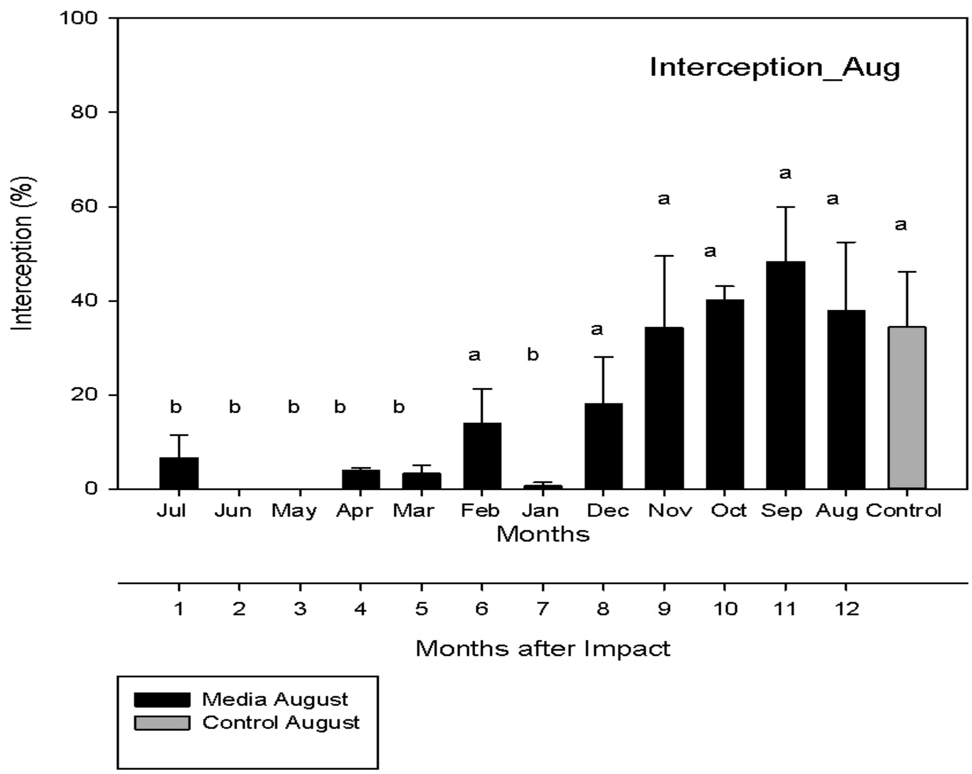

Figure 12 Interception degree in the subplots under the treatment high grazing impact (HGI), and interception degree in the control. Time August
Note. All variables are expressed in percentage. Error bars indicate the standard error of the means ($p < 0.05$)

From Figure 13 Interception September, we can differentiate two groups: one that extended from 1 to 8 MAI with a low percentage of Interception (less than 20%) in relation with the second group (9-12 MAI), which presents a higher interception that the first group of sub-plots. It can be seen that the effect of the treatment in September extended for a longer period of time in comparison with the treatment in the earlier time (July and August). The months of January, November, October and September present higher percentage of interception than the control.

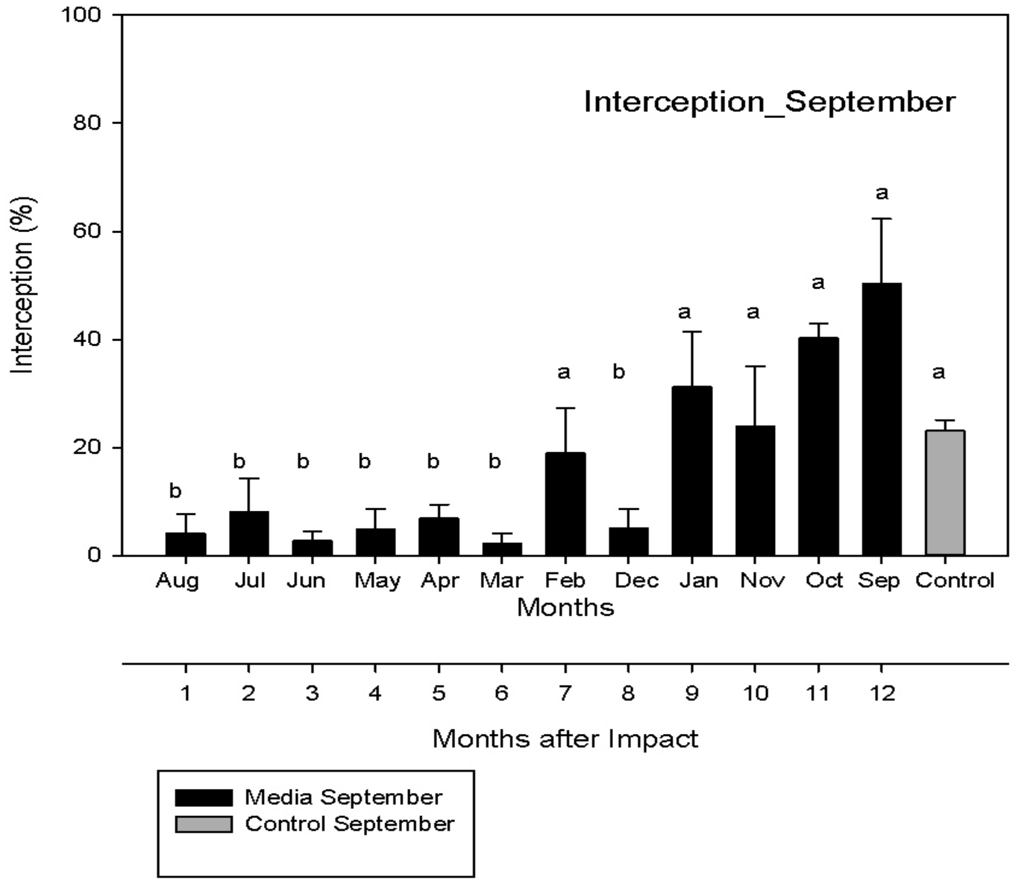

Figure 13 Interception degree in the subplots under the treatment high grazing impact (HGI) and interception degree in the control. Time September
Note. All variables are expressed in percentage. Error bars indicate the standard error of the means ($p < 0.05$).

4.2 Droppings

The droppings sample analyzed obtained for the months July, August and September confirm that the number of droppings depends on the subplot and also on the time of measurement (Table 2). Table 2 shows significant differences due to the time when the amount of droppings was measured (July, August and September), the amount of droppings in each sub-plot (=month) and there is an interaction between both.

Table 2 p-values of the effects of time when the number of droppings were measured, months (sub-plot) and the interaction between both.

Effects	p-value
Time	0,0032
Months	<0,0001
Time: Months	<0,0001

Table 2 shows that there is an interaction between months after impact and time (p-value < 0.05), thus a test of comparison of mean of interactions was performed.

Table 3 Test comparison of Mean, droppings.

	Time					
Months	August		September		July	
Jul	90,33	a	89,33	a	103,00	a
Aug	112,33	a	123,67	a	19,33	c
Sep	9,00	c	118,00	a	12,67	c
Oct	11,67	c	11,67	c	10,33	c
Nov	21,00	c	16,00	c	24,33	c
Dec	30,33	b	30,00	b	29,33	b
Jan	39,00	b	36,00	b	36,67	b
Feb	42,33	b	36,33	b	30,67	b
Mar	32,33	b	41,67	b	35,67	b
Apr	63,33	b	59,33	b	62,33	b
May	53,67	b	54,67	b	64,67	b
Jun	68,33	b	58,00	b	71,33	b

Means with common letter are not significantly different (p> 0.05)

As a result of microbiological degradation and environmental factors, the droppings number decreased as time passed after impact (Figure 14). The first three months after impact, there were a high number of droppings (40-125), followed by 35 to 40 droppings among 4 and 8 MAI, and finally a low number of droppings, detected 9 to 12 MAI.

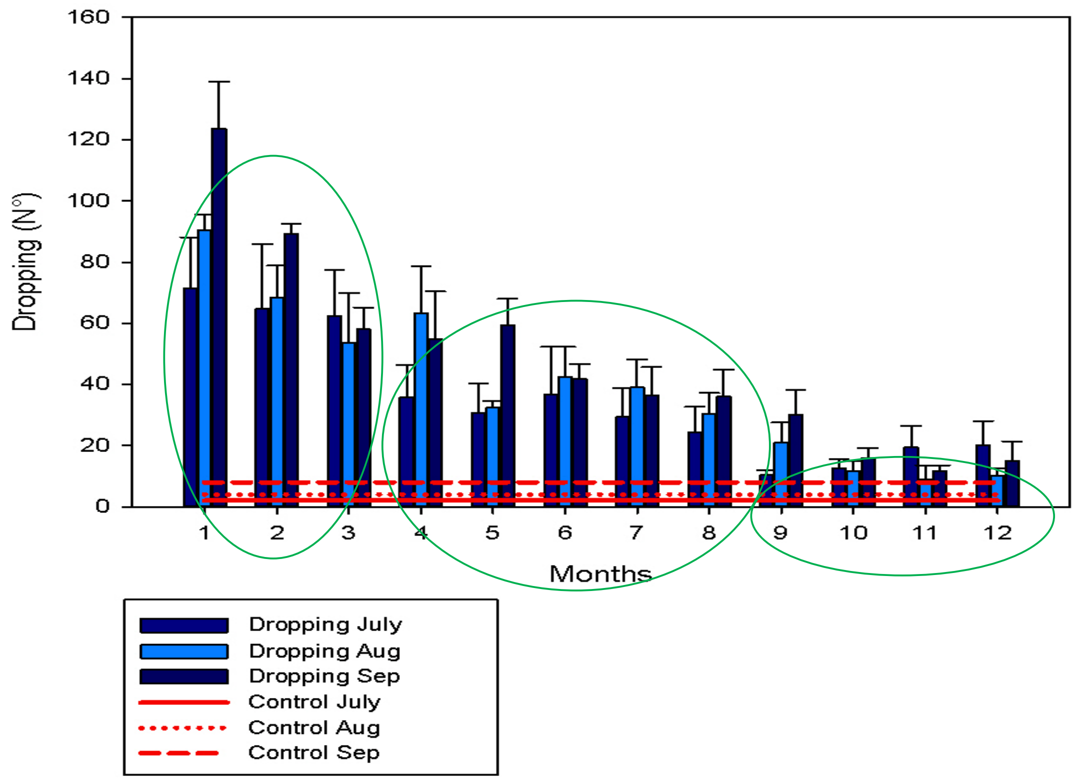

Figure 14 Faecal deposition (number), in all months of treatment (12) after high impact grazing (HGI)

Note. The three bars are the mean number of dropping for the paddocks R1, R2 & R3 during the three measurement times July, August and September 2013. The three lines represent the amount of dung in the Control during the same period.

4.3 Interception vs. dropping

For data collected during July, there is a clear linear but negative relationship between droppings number and grassland interception (Figure 15).

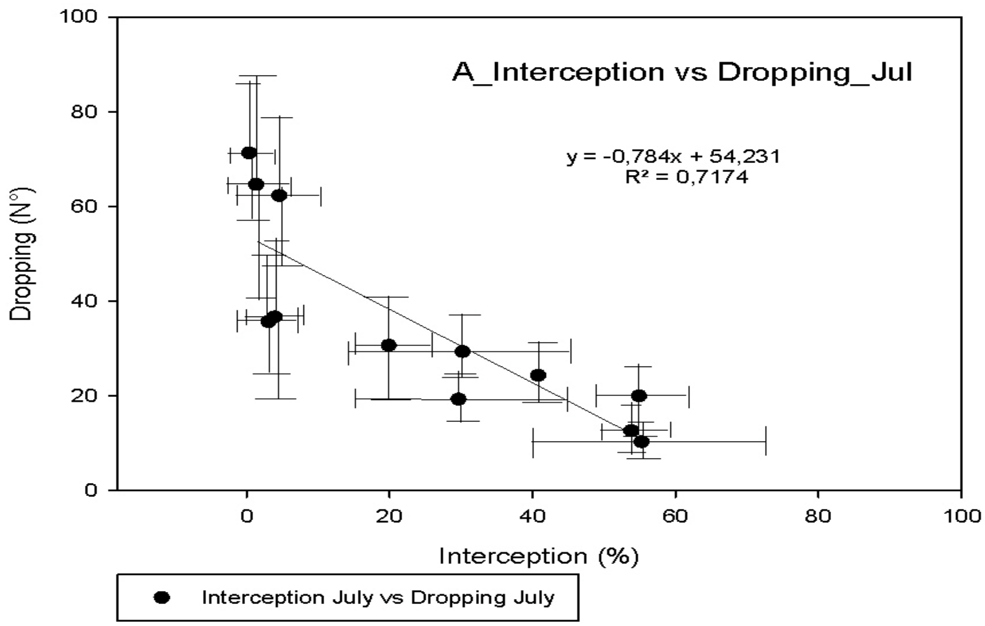

Figure 15 Relationship between interceptions (percentage) and faecal deposition (number), after impact.
Note: Measured in July 2013. Error bars indicate the standard error of the means ($p < 0.05$).

For data collected during August 2013, there is also a clear linear, but negative, relationship between number of droppings and grassland interception (Figure 16).

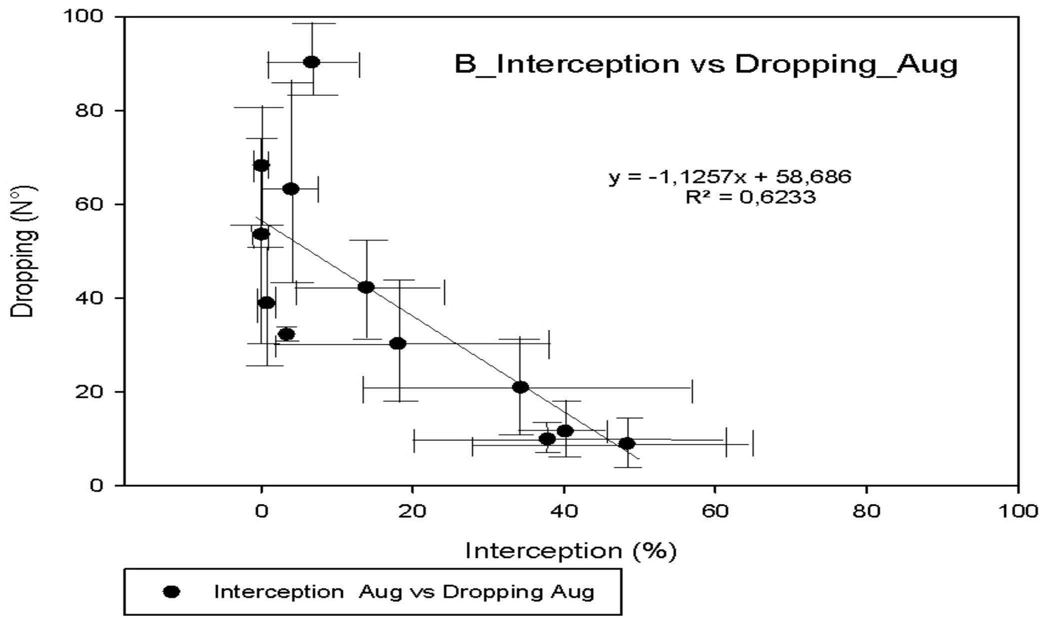

Figure 16 Interaction between interception (percentage) and faecal deposition (number), after impact.
Note: Time August. Error bars indicate the standard error of the means ($p < 0.05$).

September data showed a similar pattern as previously described (Figure 17). August and September showed steeper slopes than July.

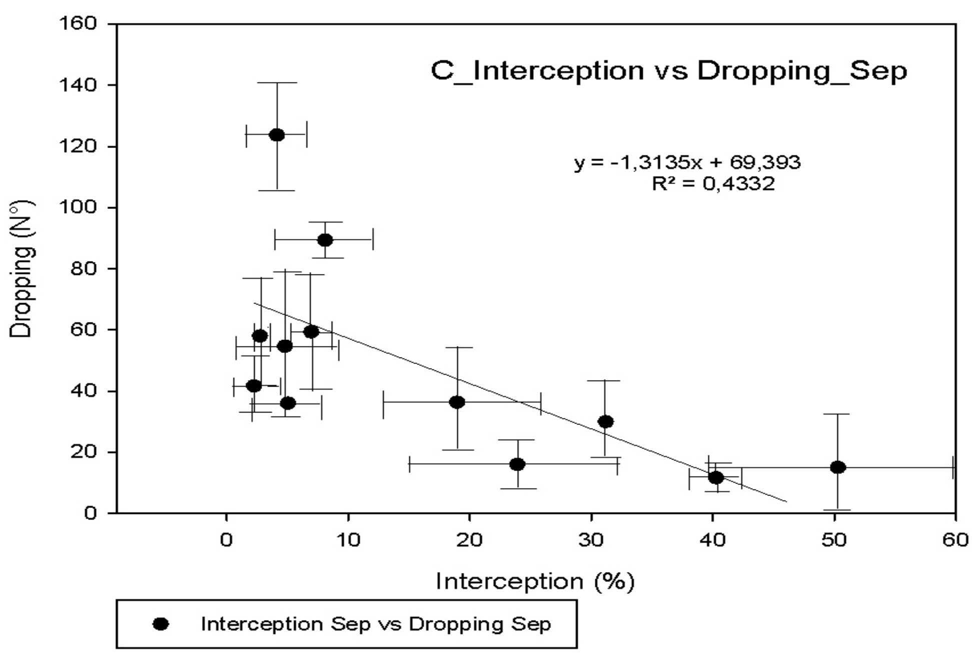

Figure 17 Interaction between interceptions (percentage) and faecal deposition (number), after impact.
Note: Measured during September 2013. Error bars indicate the standard error of the means ($p < 0.05$).

4.4 Biomass

For data collected during July (Figure 18) the biomass explains 62% of the interception registered with the camera and the red background. This means that as biomass increases, logically, the interception does, too.

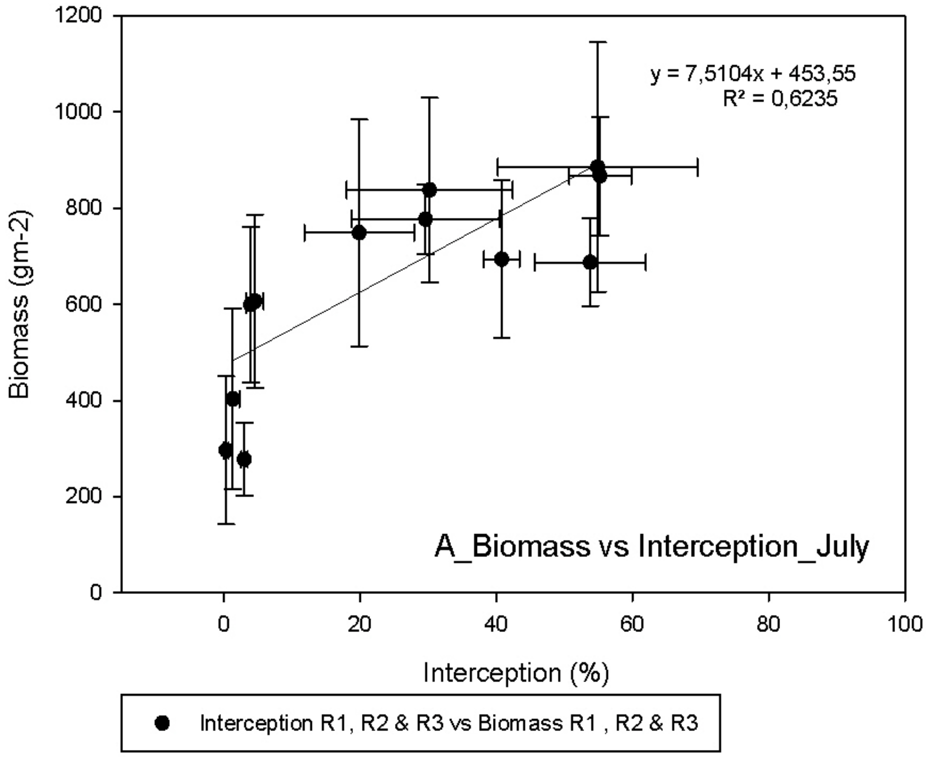

Figure 18 Interaction between biomass (grams per m²) and interception (percentage) after impact in the 12 months under treatment.
Note: Time July. Error bars indicate the standard error of the means ($p < 0.05$).

For data collected during August, we can observe the same patterns as in July where 67% of the biomass explains the interception registered.

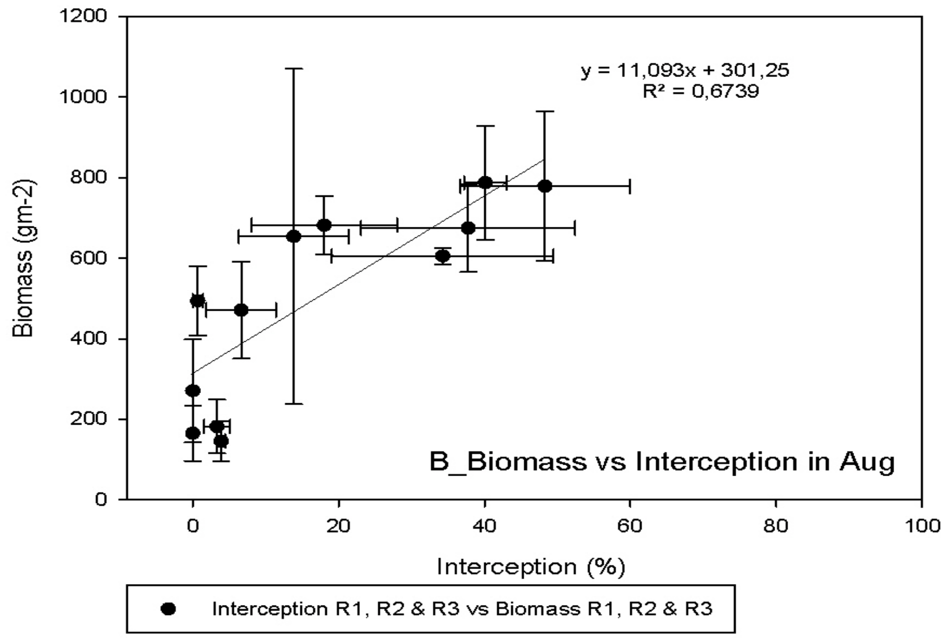

Figure 19 Relationship between biomass (grams per m²) and interception (percentage) after high impact grazing.
Note: Measured in August 2013. Error bars indicate the standard error of the means ($p < 0.05$).

For data collected during September, the biomass explains only 32% of the interception (Figure 20).

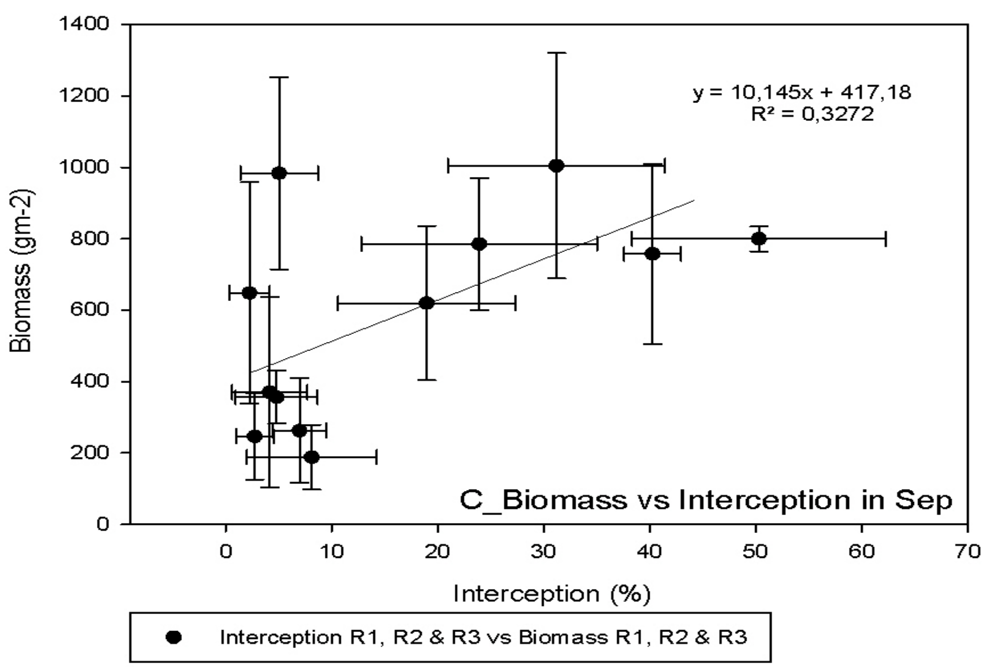

Figure 20 Relationship between biomass expressed in grams per m² and interception expressed as percentage, after high impact grazing.
Note: The measurements were done in September 2013. Error bars indicate the standard error of the means ($p < 0.05$).

4.5 Height

The height sample analysis obtained for July, August, and September affirms that there exists an interaction between the height of the grass and months after impact (Table 3). Figure 21 shows, the effect of the treatment on grass height and the growth dynamic over the year.

Table 4 The interaction between months after the impact and time (p-value <0.05)

Effects	p-value
Time	0,0001
Months	<0,0001
Time: Months	<0,0001

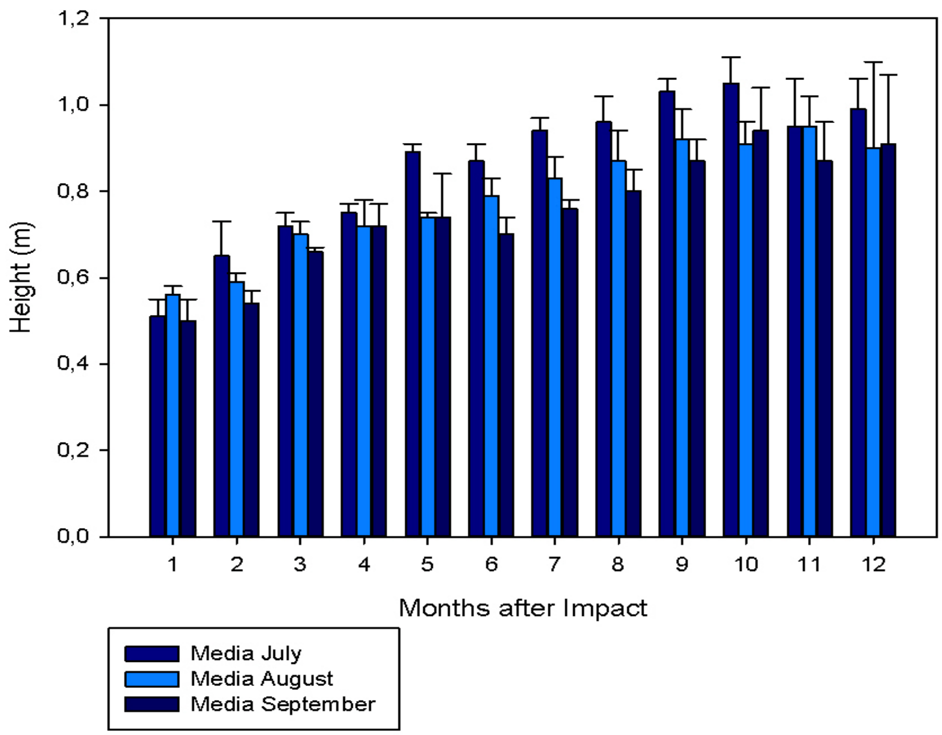

Figure 21 Grass height (m) as affected by time after high grazing impact. The error bar indicate error standard (n=3) Data shown for measurements in July, August and September 2013.

4.6 Interception vs. height

For data collected during July 2013, grassland height and the calculated interception were directly related R^2= 0.74 (Figure 22).

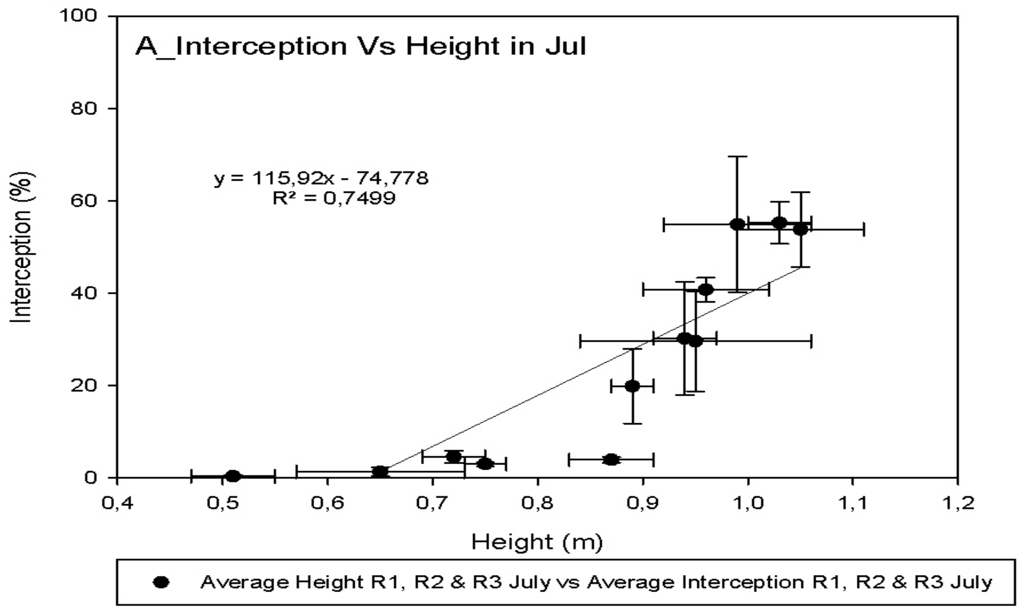

Figure 22 Relationship between interceptions (percentage) and height (meters).
Note: Measured in July 2013. Error bars indicate the standard error of the means ($p< 0.05$).

For data collected during August, we can observe the same patterns as in time July where the R^2 was 0.64 (Figure 23).

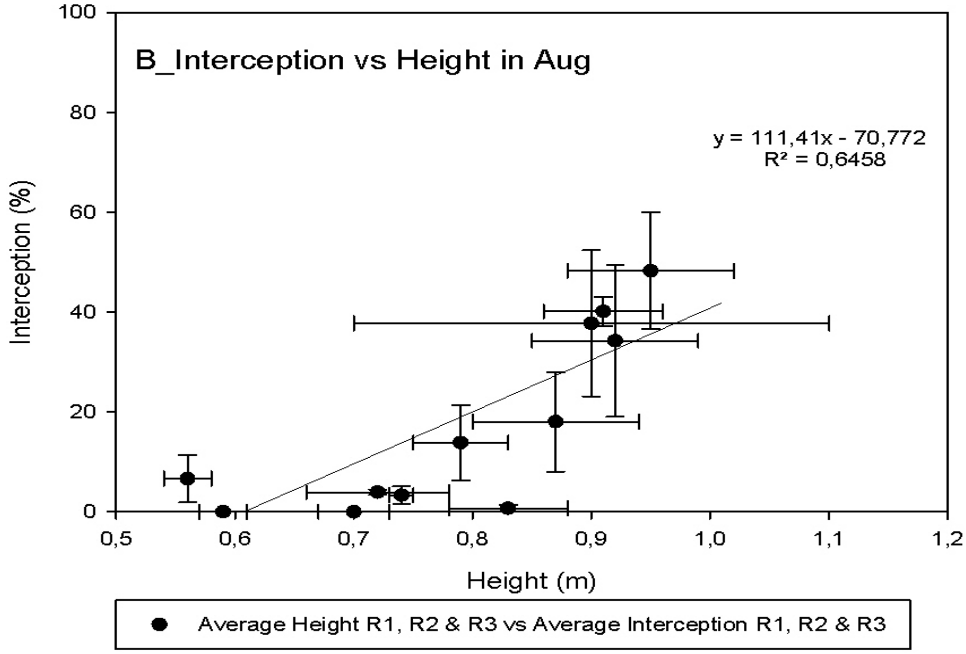

Figure 23 Relationship between interception (percentage) and height (meter) after high grazing impact.
Note: Measured in August 2013. Error bars indicate the standard error of the means ($p < 0.05$).

For data collected during September, the grassland height explains only 52% of the Interception (Figure 24).

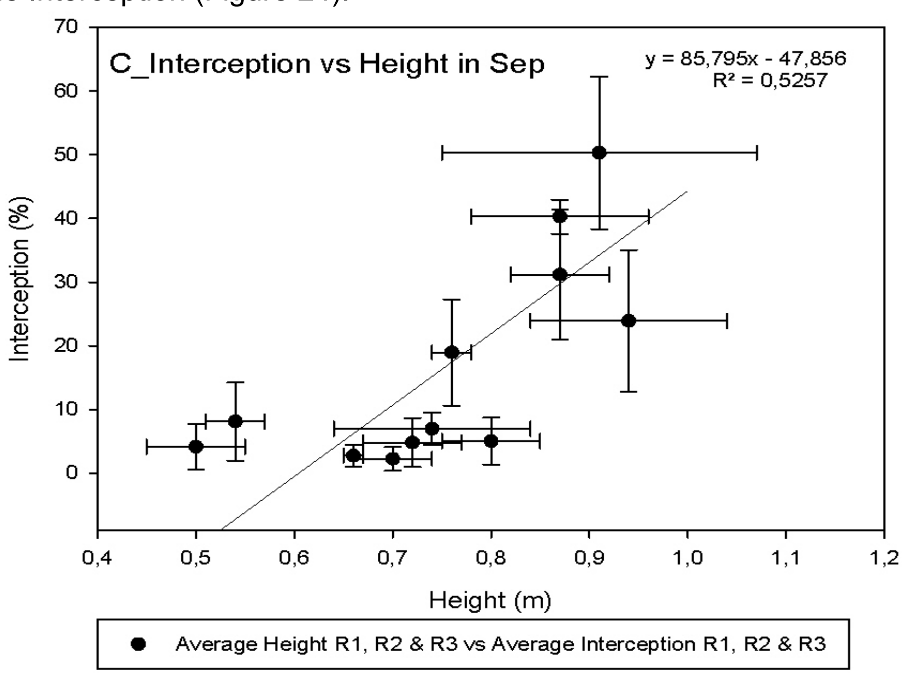

Figure 24 Relationship between interception (percentage) and height (meters), after high grazing impact.
Note: Measured in September 2013. Error bars indicate the standard error of the means ($p < 0.05$).

5. DISCUSSION

5.1 Interception vs. dropping relationship

In this study, it was investigated how animal behaviour is affected by tall and dense grass. The grazing preference of cattle in relation to grass height and density was analysed by using the interception degree as a proxy of the percentage of visibility and the number of dropping as an indicator of site preference. Our results show that animals prefer the area where the grass grows more actively or where there exists structurally heterogeneous patches (Figure 25). This coincides with previous research on rangelands Limb et al. (2010) were it was found that after creating a focal disturbance with a tracked vehicle, animals foraged preferentially in areas which present a grazing lawn. These results were supported with the faecal pat density and shorter tillers of little bluestem.

Our first finding that animals prefer the area where there exists structurally heterogeneous patches, can be explained because the droppings density (number of droppings per sub-plot) was significantly different between 3 to 6 MAI and 6 to 12 MAI (Figure 25). We considered that the high number of droppings observed in the first 3 months is due to the effect of the treatment and as consequence it was not considered as a proxy for site preference. This statement is supported by previous research of Omaliko (1981) where it was found that the breakdown rates of dung took place around the first 4 or 6 to 12 weeks. Further, Holter 1979 and; Holter and Hendrikssen 1988, studying dung decomposition in temperate areas, found that in three different years of measurement the dung disappeared in less than 100 days. Therefore, it is assumed that the animals spent more time in this part of the paddock. Also, the months 3 to 6 coincided with a percentage of interception degree less than 20 % (aproximate height between 0.70 and 0.80 m) for the three measurement times (July, August, and September), indicating the preference of the animals for an open area. This agrees with our hypothesis, where we expected that the animal would spend more time grazing in open areas where the height of the grass is lower than 0.70 m. In addition, this statement was corroborated with other results found in research done at the same experimental site, through visual observation of animal behavior, where it was concluded that animals grazed more time on the subplots between the third and sixth month after the impact (Kauselmann, 2014 bachelor thesis).

In summary, due to the low number of droppings found when the percentage of interception was higher than 20% (registered in month number 7 after impact in July, month number 8 in August and month number 9 in September) it is recommended that a second HIG treatment is implemented to control the grass height when the interception degree is approximately 20%, before there is evidence of exponential grass growth which affect the re-entry of the animals to the field.

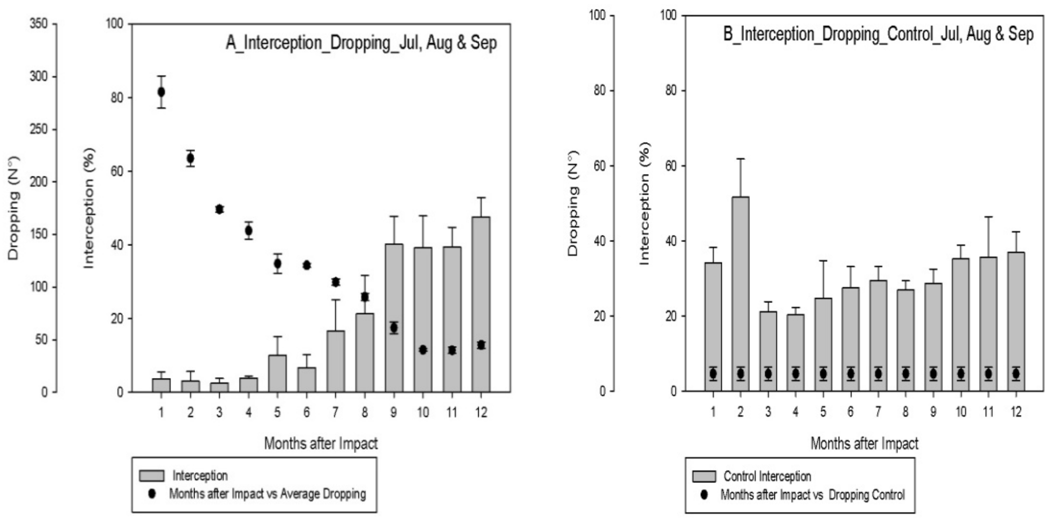

Figure 25 Relationship between interception (percentage) and droppings (number) in all months of treatment (12) after high grazing impact.

5.2 Digital camera

Harvesting plant material is the typical method to estimate aboveground net primary production (ANPP) in grassland ecosystems. However, it is a time consuming method and consequently expensive, making it difficult to estimate spatial and temporary variability. Also, in the long term in permanent plots, it is not useful to use a destructive method to assess ANPP (Byrne et al., 2011). Thus, as in previous studies the use of a digital camera (Paruelo et al., 2000; Tomasel et al., 2001; Limb et al., 2007; Przeszlowska et al., 2009; Byrne et al., 2011) was proposed as a double-sampling non-destructive technique to determine the grade of interception of the grass. In this study, the combination of digital camera and blackboard were proposed as an alternative to measure the degree of interception.

With the objective to estimate the accuracy and precision of non-destructive methods in the assessment of ANPP, Byrne et al. (2011) utilized a digital camera as a complement to the traditional method of biomass harvest. In their study, digital images of each 0.5 m² plot and 1.25 m elevation were analyzed with an internal processor based on the ratio of green pixels to total pixels. However, they found that only 10% (R^2= 0.10) of the variability in short grass steppe and 21% (R^2=0.21) of the variability in biomass on the mixed grass prairie were explained with the digital camera method.

Our results show that biomass and interception are positively related (Figure 18 & 19); it was found that 62% of the biomass for the July time measurement can be explained by the interception and 67% for the time August. However, it is necessary to consider that the red frame used in this experiment had a minimum height of 0.70 m, and biomass content below 400 g/m² was recorded as zero percentage of interception. We hypothesized that cattle have a view horizon above 0.7 m, which is why the frame was built at that height. In figure 20, the low value (R^2 = 0.32) can be explained because low levels of biomass are not intercepted by the red frame and the camera.

Previous studies have found that the use of a digital camera to assess variation (precision) among different horizontal visual obstruction methods (Robel pole and Nudds' coverboard) in a tall-grass prairie resulted with lower CV values averaged. Further, they concluded that only 20 samples were needed for the digital image technique to acceptably sample the horizontal visual obstruction (95% confidence) contrasted with the Robel pole 158 and the Nudds' coverboard 233 samples (Limb et al. 2007).

Additional evidence of the use of digital camera comes from studies based on the estimation of green area index from green cover measurement on a short-grass prairie vegetation (Przeszlowska et al., 2006). In that study, it was found that the analysis of digital camera images with ERDAS 8.5 produced a model where the variables measured (green cover and sampling date) were significant in predicting green area index (R^2=0.72).

Differing from Limb et al (2007)'s procedure, our backdrop was colored (red color), and we used color recognition software to assess vegetation density. However, even if the shadow cast by the surrounded vegetation was reduced with the colored backdrops in contrast with the white backdrops proposed by

Limb el al. (2007) I agree that careful backdrop placement is important as well as considering the position of the sun when determining the timing of the sampling.

To summarize, it can be said that the photographic method as a non destructive methodology is a useful approach to assess biomass or vegetation density. Paruelo et al. (2000) and Tomasel el at. (2001) concluded that even though the photographic method needed to be calibrated, the possibility of increasing the number of samples (as compared to harvest method), allows a higher accuracy. Further, it can be beneficial in small plot size or restricted areas and can be used for developing a mapping of rangeland vegetation (Przeszlowska et al., 2006).

5.3 Interception vs. height

In Figure 21, 22 and 23, the relationship between interception and height is positive. However, when the height of the grass is less than 0.70 m, the percentage of interception is zero and for this reason it is suggested that can be explained only 74%, 64% and 52% respectively.

Therefore, the multiple correlation coefficient for July was 0.87%. It means that not only biomass but also the height of the grassland could be explained in part by the interception obtained.

Table 5 Multiple correlation coefficient in July

Regression statistics July	
Multiple correlation coefficient	0,87
Determination coefficient	
R^2	0,76
R^2 adjusted	0,70
Typical error	12,07
Observations	12

In the case of August, the multiple correlation coefficient was 0.86%.

Table 6 Multiple correlation coefficients in August

Regression statistics August	
Multiple correlation coefficient	0,86
Determination coefficient	
R^2	0,75
R^2 adjusted	0,69
Typical error	9,87
Observations	12

Finally, the multiple correlation coefficients for September were 0.72%.

Table 7 Multiple correlation coefficients in September

Regression statistics September	
Multiple correlation coefficient	0,72
Determination coefficient	
R^2	0,52
R^2 adjusted	0,42
Typical error	12,47
Observations	12

Both methods, interception photographic and height measuring are an indirect, non-destructive and quantitative. The data collection is fast, easy, economical and reliable, once validated.

In contrast, the novel interception photographic method has a number of disadvantages; for example, it is difficult to get accurate pictures during windy days as it is difficult to maintain the frame in the correct position. In addition,, sunlight and cloudiness created issues when the picture was digitally analyzed and classified. An additional disadvantage is the lab time needed to analyze the pictures with the software and the need to develop certain skills for accurate pixel classification.

5.4 Suitability of different methods as GPS, visual observation and number of droppings

Cattle tracking using GPS is less time consuming and less prone to errors than visual observation.(Ganskopp et al., 2001; Agouridis et al., 2004; Sickel et al., 2004; Ungar et al., 2005). However, there are few negative implications of the use of this technology, such as malfunction of the GPS which reduced the amount of collected data (Agouridis et al., 2004). The use of GPS technology and relating it to the percentage of interception as an indirect measure of plant density was the main idea of this research. However, due to battery problems, it was not possible to develop this relationship, as was also cited in other studies (Ungar el at. 2005).

Being that both methodologies, number of excretions and percentage of interception, are indirect measures that do not determine the exact cattle activity, it would have been appropriate to look for a complementary method such as visual observation or GPS tracking. For the time being it will be recommended for future investigations.

6. CONCLUSION

I have identified that the novel non-destructive methodology used in this study to determine indirect grassland interceptions, is suitable to infer cattle visibility. This variable, together with the number of droppings of (8-125) was used to analyze the cattle grazing preferences.

Based on the findings relating to the environmental habitat preferences are of animals, this study suggests that animals prefer and chose open areas for grazing, without the interference of visibility by vegetation density. This coincides with the research results by Limb et al., 2009. Furthermore, using percentage degree to determine how HIG treatment affects grassland density, it was concluded that a second treatment effect (HIG) would be necessary to avoid a high amount of standing biomass.

In this research I also found that interception, pasture height and biomass are strongly related having a multiple correlation coefficient of R^2= 0.87 in July; R^2= 0.86 in August; and R^2=0.72 in September. The photographic interception could be a valuable alternative for range managers seeking not only to calculate biomass density, but also working towards understanding cattle behaviour and predicting spots of potential land degradation, or planning the distribution within paddocks in the context of sustainable management practices.

To summarize, the measurement of interception with a digital camera and a blackboard will be a useful tool for rangeland managers who need a non-destructive, easy, and low budget technique to estimate vegetation density.

Based on the results of this study, it is recommended the use of the proposed technique in order to increase the sample size and undertake long term studies in grasslands, where harvesting techniques are impractical or nearly impossible.

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