Tropical and Subtropical Agroecosystems

SHORT NOTE [NOTA CORTA]

PREDICTION MODEL OF THE DIGESTIBILITY OF NATURAL-HERBACEOUS PASTURES IN THE CANARY ISLANDS

[MODELO DE PREDICCIÓN DE LA DIGESTIBILIDAD DE PASTURAS HERBÁCEAS NATURALES EN LAS ISLAS CANARIAS]

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SUMMARY

Knowing the energy content of pastures is necessary in order to estimate the livestock carrying capacity of grasslands. Taking into account the high cost of analyses for determining the digestibility of herbaceous biomass as an estimate of its energy content, this study proposes a model for predicting digestibility values on the basis of the most significant factors. For that purpose a multifactorial univariate analysis of variance (ANOVA) was carried out on digestibility to find out which factors, being easy to obtain, will allow to predict it with accuracy. From this analysis, we searched for a model which would allow predicting the energy content of samples taken in the field, on the basis of easily collected variables. There are three factors (plant group, vegetation type and month) which determine the digestibility of the herbaceous production in the areas of study, and therefore can be used to predict the quality of herbaceous primary productivity in the calculation of livestock carrying capacity. The model resulted of high predictability value (R^2 = 0.76), permitting the estimation of the digestibility of dry matter in a simple way. Using this model the costs of determination of livestock carrying capacity will be considerably reduced, therefore facilitating the development of grazing management in relation to land use zoning, especially in new areas that has not been examined yet.

Key words: carrying capacity, digestibility, energy, grazing management, plant group

INTRODUCTION

Livestock activities in general, including goat grazing in particular, has not been a problem in the Canary Islands until the creation of natural protected areas, regulated by administrative laws, in order to preserve the natural values of ecosystems and the landscape. Since 1998 different studies have been carried out, trying to make compatible and sustainable both goat grazing and environmental conservation. One of the main problems of field work lies on data collection, which could be hard and expensive. Trying to minimize those difficulties several prediction models have been already developed to estimate herbaceous and shrub biomass (Patón et al., 2006, Bermudo et al., 2006).

One of the main difficulties when calculating the livestock carrying capacity of a given territory with natural ecosystems is determining the energy content of primary productivity. Prices of chemical-nutrient and of *in vitro* digestibility analyses are expensive*;* cutting samples of plants is time consuming as well as the arduous separation of different species in order to make plant groups (e.g. legumes, grasses and other families). All these make the developing of a simple model of prediction of pastures energetic value very useful in order to facilitate the determination of the carrying capacity for livestock land use planning. Carrying capacity could be estimate according to the formula proposed by Paladines (1992).

MATERIALS AND METHODS

The experimental work was carried out in different areas of the islands of Tenerife and La Gomera, in the Canary Islands, where average monthly rainfall is of 335 $l·m^{-2}$, with an inter-annual variation coefficient of 35.2%, with 85% of rainfall taking place between November and April. Average temperature is 23^oC, with little variation (Bermejo, 2003). Cuts were made in different vegetation communities comprising forested vegetation (evergreen forest), shrublands (transition and coastal shrublands) and pastures. Due to the orography of the studied areas cuts were located in sites with different macro-orientation (north or south) and slope. These two variables are related with differences in climatic conditions (mainly with rainfall) and development of soil respectively, which as a last resort condition the vegetation communities and species growing in each site (Fernández-

Palacios and de Nicolás, 1995).

In vitro digestibility analyses of 172 samples of herbaceous pasture were carried out in accordance with Tilley and Terry's (1963) double samples methodology with the modifications introduced by the Ankom - Daisy procedure (Ankom, 1998). The pasture samples used in the digestibility analysis were extracted from 435 random cuts of 1 m^2**,** carried out with pruning scissors at a distance of 5cm above the ground level (Paladines, 1992), between the years 1999 and 2001. In the laboratory the plants of each cut were divided into three groups (legumes, grasses and others families). Subsequently, the samples were dried with a heater at 60°C during 48 hours and weigh, in order to determine the dry matter. The dry samples were ground and sieve with a 1mm net. After separating into three groups, the *in vitro* digestibility analysis of these samples was carried out, in order to estimate the Kj energy content per Kg. of dry matter of herbaceous production, on the basis of the calculation of the digestibility of organic matter. The calculations of the energy content from digestibility of the organic matter were carried out applying the following function (ARC, 1980, Aguilera, 2001):

$$ED\ (Kj \cdot Kg \cdot ms^{-1}) = 0.0185 * DMO\ (gr \cdot Kg \cdot ms^{-1}) \quad (1)$$

ED: Kj of digestible energy per Kg of dry matter
DMO: gr. of digested matter per Kg of dry matter
We used the multifactorial univariate analysis of variance (ANOVA) in order to contrast the hypothesis of that there are no significant differences in the percentage of digestibility of organic matter ($Kg \cdot Kg \cdot ms^{-1}$) due to the factors considered. The model included the following variables and its interactions: plant group (legumes, grasses and others families), month (February, March, April, May, June, August), slope (< 10%, 10% - 66% and > 66%), macro-orientation (north, south), vegetation type (pastures, transition formations, coastal shrubland, evergreen forest**)** (Table 1) and the interaction month*plant group. Next, the Scheffé homogeneity test was carried out for the plant group, month, and vegetation type, with the aim of establishing the possible groups of classes which determine differences in the digestibility of organic matter. The hypotheses of normality (Kolmogonov - Smirnov test) and of homoscedasticity (Levenne test) were previously contrasted. All tests were done using SPSS 14.1 (SPSS, 1986).

Table 1. Description of the four categories of the vegetation type factor.

Denomination	Description
Coastal shrubland	Vegetation mainly distributed below 600 m.a.s.l. of altitude. Limited by hidrical stress is dominated by adapted shrubs *Euphorbia* ssp., *Periploca laevigata* or *Kleinia neriifolia* and combined with terophytes as *Hyparrhenia hirta*, *Cenchrus ciliaris*, *Brachypodium distachyon*, *Stipa capensis*, etc.
Transition formations	Vegetation distributed between 600-1200 m.a.s.l. in the transition from shrublands to forests. Originated mainly by human deterioration of potential communities. Formed by a mixture of shrubs *Artemisia thuscula*, *Plantago arborescens*, *Rumex lunaria*, *Bituminaria bituminosa*, *Teline canariensis* or *Cistus monspeliensis* and grasses as *Hyparrhenia hirta* and other ruderal species.
Pastures	Pastures are anthropically generated; they grow mainly in abandoned fields and grazed areas. They are formed by grasslands that get shrivel in the dry season, spotted with some shrubs *Euphorbia* spp., *Launaea arborescens*, *Rubia fruticosa*. Dominant species are grasses *Hyparrhenia hirta*, *Brachypodium disachyon*, *Stipa capensis*, *Phalaris coeurlescens*, and numerous ruderals *Galactites tomentosa*, *Plantago lagopus*, *Echium plantagineum*, etc.
Evergreen forest	Forest mainly compound by *Myrica faya* and *Erica arborea* growing in the border of the laurel forest, sometimes is cleared by cuts and develops a herbaceous understory with *Brachypodium sylvaticum*, *Bituminaria bituminosa*, *Rubus ulmifoilus* and many terophytes.

RESULTS

The suggested UNIANOVA model is characterized by the high percentage of explained variance (R^2 = 0.76) which indicates its high predictive value (Table 2) and therefore, the reliability of the significance levels reached in the factors. As observed in the results of the model, the factors with a significant level higher than 99.9% are: month, plant group and vegetation type. Thus, these three factors will allow us to predict the digestibility of organic matter and determine the carrying capacity.

Table 2. Result of the model of multifactorial univariate ANOVA, with the digestibility of the organic matter (Kg·Kg·ms $^{-1}$) as dependent variable.

Factor	*F*	*P*-value
Month	39.461	0.000
Plant group	21.278	0.000
Vegetation type	15.390	0.000
Macro-orientation	6.721	0.002
Slope	2.856	0.061
Month*Plant group	1.925	0.046
	R^2	0.76

The plant group analyzed with the Scheffé *a posteriori* test (Table 3) generated the configuration of an independent group for each one, with a higher mean for legumes with respect to the rest, and the grasses group being that of lowest digestibility. For the variable month, the test resulted in three well defined groups which correspond with three annual seasons (spring, summer and winter), the samples taken in summer (August) had the lowest digestibility values (Table 3), whilst the samples taken in spring (between April and June) gave the highest values; and in the winter (February and March) intermediate values were obtained.

Regarding to the vegetation type, the Scheffé test generated three groups. The transition formations are in a separate group, whilst the coastal shrubland and pastures are grouped together and the latter with the evergreen laurel forest constitute a third group with the highest mean value of digestibility (Table 3). Attending to the significance level, the pastures would form a group with the evergreen laurel forest, leaving the coastal shrubland and the transition formations in two separate groups.

The highest values of digestibility of organic matter were found in the evergreen laurel forest and pastures correspond with the bigger proportion of species of the legumes group (especially *Bituminaria bituminosa)*, compared to the coastal shrubland or the transition formations which are richer in grasses, especially *Hyparrhenia hirta* (Table 1).

DISCUSSION

The influence of the plant group agrees with the findings of Rodríguez et al. (2004) in one of the areas of the island of Tenerife, given that they did not find significant differences between legumes and other families, which can be due to the problems derived from a smaller number of samples (79 samples). The legumes of the areas under study have higher energy content and differ significantly from grasses and other families. Thus, grazing areas with a higher combination of species from this group will have richer energy content and will therefore be more highly valued.

Table 3. Marginal means, confidence intervals (CI) and results from the Scheffé *a posteriori* test for the digestibility of organic matter (Kg·Kg·ms $^{-1}$ for the most significant variables (P < 0.001)).

		Mean	95% CI	Scheffé Test groups		
				1	2	3
plant group	grasses	0,378	± 0,048			
	legumes	0,525	± 0,059			
	Other families	0,462	± 0,051			
month	February	0,335	± 0,061			
	March	0,383	± 0,062			
	April	0,550	± 0,045			
	May	0,640	± 0,061			
	June	0,507	± 0,086			
	August	0,316	± 0,068			
vegetation type	transition	0,366	± 0,064			
	coastal shrubland	0,415	± 0,062			
	pastures	0,522	± 0,062			
	evergreen forest	0,518	± 0,079			

The important level of significance of the month factor could avoid the need of separating the pasture samples into grasses, legumes and other families. These results coincide with research on the productive cycle of herbaceous species (Skapetas et al., 2005), and bushy species (Ammar et al., 2004) and their annual evolution of quality in Mediterranean areas and in semiarid pastures (Pérez et al., 1998), in which the highest nutrient content is reached at the end of the rainy season (April), thereafter beginning to decrease due to plant exhaustion and the increase in cellular wall content. However, the season is not a good factor of prediction because of the high climatic variability among different years determining that April could not always coincide with the end of the rainy season.

The high p-level obtained for the vegetation type factor does not match the results of Patón et al. (2005), since in the analysis that these authors made on the variation of metabolising energy content there are not significant differences among the 16 Mediterranean ecosystems analysed, despite the differences in floristic composition among them. However, the authors suggest that the small number of samples is again the factor accounting for this finding. Although the vegetation type appears as a significant factor in the studied regions this factor could only help to predict energy content of pastures from areas of the Canary Island but not in other regions. Other variables such as the slope turned out to be not significant in contrast with the results obtained by Pérez et al. (1998) in semiarid pastures.

The management of grazing based on the determination of livestock carrying capacity**,** understood as the energy per unit of surface that fodder productivity can offer to livestock, requires a precise knowledge of the energy content of that productivity. However, the determination of digestibility is a very expensive process, in excess of 25€ per sample. The development of this model intends the reliable prediction of the energy content of herbaceous productivity, so that grazing management studies, carried out in the Canary Islands, become less expensive.

The model described here, explaining a high percentage of the variance, transforms the resulting marginal means (Table 3) in useful estimates for determining the carrying capacity. Considering that there are three factors with a level of significance ($P < 0.001$), the marginal means of some of these three factors can be selected to estimate the energy content of the samples collected in new studies. The selection of one factor or another is a function of the information available at the time of taking samples of herbaceous productivity. Therefore, applying the results obtained from the model, the carrying capacity (Kj of digestible energy per hectare) can be determined using the following function:

$$CC = X_{ijk} * 0.0185 * Y_{jk} \qquad (2)$$

CC: Carrying Capacity (Kj of digestible energy per hectare).
X_{ijk}**:** Kg of dry matter per hectare of the sample i of level j of factor k (plant group, vegetation type or month).
Y_{jk}: Marginal mean of digestibility of organic matter of level j of factor k (plant group, vegetation type or month).
The plant group, the month and the vegetation type are the most efficient estimates of the energy content of the samples. Their high significance levels allow their use in calculating livestock carrying capacity without expending time and money in new digestibility analyses.

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