EFFECT OF TOPOGRAPHIC AND TEMPORAL (MATURITY) GRADIENTS ON THE NUTRITIVE QUALITY OF SEMIARID HERBACEOUS COMMUNITIES

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ABSTRACT: Five slopes representative of the "dehesa" grassland communities in the semi-arid zones of Central-Western Spain (province of Salamanca) were studied. Above-ground biomass production was recorded from April to June and the NDF (neutral detergent fibre), ADF (acid detergent fibre), hemicellulose, cellulose, lignin, and digestibility were determined in the dry matter. Principal component analysis was applied to the data. The changes with time along the growth period show a parallel effect on the three positions of the slope, although the effect tended to be greater on the middle and upper zones. There were decreases in the levels of protein, cellular content, and digestibility, and an increase in cell wall components. The variability in nutritive characteristics induced by the phenology and time changes in the communities was reflected in the first factor of analysis, whereas the topographic gradient was related to the second component.

INTRODUCTION

The variability in nutrient characteristics of herbaceous communities of "dehesas" (savannah-like grasslands) depends on the influence of several different factors. Among these, apart from those inherent to the actual plant material, there are other extrinsic factors, such as soil characteristics, climate, etc., that exert a certain control on the structure and function of grasslands.

In this work, two orientations were considered, (i) temporal changes during spring-summer growth, and (ii) the topographic gradients on which such

communities develop. These gradients lead to vectorial relationships among the three differentiated zones of the slopes (upper, middle and lower) that involve the transport of matter, nutrients, water, etc., along them, and that in turn, redefine them as zones of either export, transition, or accumulation.

Regarding the area studied, mention should be made of other studies on nutritional aspects despite their referring to cultivated species (Garcia Ciudad et al., 1984; Garcia Criado et al., 1984) and of others on plant communities (Garcia Criado et al., 1980; Rico Rodriguez et al., 1980; Garcia Criado et al., 1983). Also of interest are the works referring to the ordering of species as a function of their quality (Rico Rodriguez and Garcia Criado, 1984), typification, and community heterogeneity (Garcia Criado et al., 1978; Chocarro Gomez et al., 1987). From a more dynamic perspective, quality has been related with succession (Puerto Martin et al., 1981; Montalvo et al., 1989).

The aim of our study focuses on two aspects: (i) the evolution over time of nutritional parameters, and (ii) the relationship of these with the ordering of communities as obtained with multivariate analysis.

MATERIAL AND METHODS

Study Area

The study area is located in the "dehesa" zone of the province of Salamanca in the Central-Western part of the Iberian Peninsula. Five sampling sites were chosen with the following mean heights above sea level: (1) 820 m; (2) 820 m; (3) 920 m; (4) 1000 m, and (5) 850 m. Their locations in the province of Salamanca are shown in Figure. 1.

The climate in the zone is Mediterranean with cold winters and dry, warm summers. The average annual rainfall is around 500 mm, although the regime varies considerably throughout the year (Figure 2).

The geomorphology of the study area responds to a system of slopes-stream beds with higher zones of greater export and erosion, and other lower zones of accumulation. This system has, in fact, been used as an ecological unit (Gomez Gutierrez et al, 1978). The substrate is siliceous, with numerous slaty or granitic zones. The soils are Brown Mediterranean, although the ridge zones are occupied by skeletal soils.

The study area is occupied by "dehesa" systems. These consist of low density *Quercus ilex* subsp. *rotundifolia* woodlands with wide open spaces of grassland

FIGURE 1. Map of study area and study sites (1, 2, 3, 4, and 5) in central-western Spain.

and sometimes cereal fields. On the upper parts of these systems, the density of evergreen oaks is higher than on the lower parts. Apart from the trees, there are shrubs, although anthropogenic management has tended to reduce their presence. On the lower parts, there are individual specimens of *Fraxinus* sp as well as other species related to humid zones.

For our study, five slopes were chosen, each of them situated on a representative "dehesa" system. On each slope, the upper, middle, and lower zones were sampled separately (see below).

Sampling and Experimental Analysis

Five slopes representative of "dehesa" grassland in the province of Salamanca were chosen. Three zones of different heights were differentiated into the upper, the middle, and the lower zones. On each of these zones, plots 24 m² in size were protected from grazing by a 1-m high fence.

FIGURE 2. Ombrothermic diagram of the study area. Data refer to a 10-year climatic zone.

The sampling and collection of the herbaceous material was performed fortnightly during the spring-summer period of 1990, making a total of five or six cuts, depending on the slopes considered. Thus for each cut/zone/slope, three sampling squares were obtained (0.25 m^2), collecting the biomass included within these limits. This material was separated manually into three main botanical groups (grasses, legumes, and other families as "others") and then dried in forced air oven until constant weight was reached. The samples were then ground through a 0.5-mm sieve and homogenized. Following grinding, the initial communities were reconstituted, maintaining the same proportion of families as found in the separated samples.

In the prepared samples, the following determinations were made: crude protein (crude protein: % N Kjeldahl $\times 6.25$), cellular content (CC), neutral detergent fibre or cell wall (NDF), acid detergent fibre (ADF), hemicellulose, acid

detergent lignin, cellulose, digestible cell wall (DNDF), available cellular content (DCC) and estimated dry matter (DMD) according to a summative system described by Goering and Van Soest (1970) with modifications introduced by Garcia Criado (1975).

Principal component analysis (PCA) was applied to a matrix of 79 observations (5 slopes x 3 zones x 5 or 6 cuts) for the 10 parameters.

RESULTS AND DISCUSSION

Evolution of Organic Parameters

The mean values found for the five "dehesa" zones studied as regards the parameters, CC, NDF, ADF, hemicellulose, lignin, and cellulose on each of the slope zones during spring-time growth which are shown in Figures 3 and 4

The CC (Figure 3) tends to decrease in all three cases. On comparing the different zones, it is seen that the upper levels corresponded to the higher and middle zones, with a similar value in the fifth cut as compared with the lower zone which is lower in all cuts. It is this zone of accumulation that the least decrease was observed.

In the first growth phases, the cellular content accounts for more than 50% of the dry weight of the samples. Up to this level, the upper and middle zones decrease in the fifth cut, whereas in the lower zone, one does so in the third cut. The CC, CP, and DMD determinations were the only parameters that decreased with the development of the pasture towards maturity in summer, while the wall components showed an opposite trend.

For the percentage of ADF and NDF, these increase as the degree of maturity advances in all three zones. In absolute values, this is most evident in the lower zone. In general, these values also highly correlate with the botanical characteristics of the zones since the lower zone is dominated by grasses, while in the upper zone, the pasture is more diversified (Corona et al., 1991) which leads to the content of wall components is more greatly reduced.

Hemicellulose shows a less well defined behaviour, although it consistently increases as plants become more mature, especially in the lower zone (Figure 3). This is closely related with the proportion of legumes in the samples, whose presence is greater on the upper zone (Corona et al., 1991). The legumes contain less hemicellulose than the grasses, and hence the upper zones have smaller contents of this component. Therefore, the greater presence of legumes is reflected

CELLULAR CONTENT

NDF

FIGURE 3. Temporal changes in cellular content (CC), neutral detergent fibre (NDF), acid-detergent fibre (ADF), and hemicellulose in the three zones of the topographic gradient.

FIGURE 4. Temporal changes in lignin and cellulose contents in the three zones of the topographic gradient.

in a higher digestibility of samples in which their presence is in greater amounts (García and Ferrer, 1974).

Lignin content is reduced in the lower zones, whereas in the upper and middle zones, their content is higher and similar to each other (Figure 4). However, the evolution of all three zones show a parallel trend, starting with smaller variations but then followed by a significant increase. The increase in lignin in the cell walls of the pasture-land plants is greater in the upper and middle zones, but is more constant and sustained in the lower zone. This is probably related to the generally faster evolution of the export zones as compared with those of accumulation since the latter have more available water and nutrients as well as a higher retention capacity for these components which results in a more certain development.

Cellulose has an ascending trend in all three zones, the highest content found in the lower zones as a result of a greater content of grasses in this zone. The upper and middle zones have similar proportions of cellulose (Figure 4).

In general, the increased in cell wall components with the advance of maturity is very closely correlated with the morphological changes occurring from an increase in the length of daylight, the higher temperature in the plant canopy which lengthens the stems, a decrease in leaf elongation, and an increase in the accumulation of photosynthesis products. Furthermore, the upper zones monopolize energy in terms of a rapid increase in their biomass (cellulose, lignin). These zones are unable to compete with the behaviour of the lower zones by increasing their renewal rates (Díaz Pineda, 1988).

Digestible Dry Matter and Protein

The protein levels and digestibility (DCC, DNDF, DMD) results are shown in Figure 5. The figure shows that all the parameters exhibit a descending trend on all three parts of the slope, with the exception of DNDF, which tends to remain stable during the last cuts.

In general, the behaviour of the DNDF parameter is rather irregular, the upper and middle zones displaying lower values. In the lower zone, the higher DNDF values tend to remain stable, slightly decreasing towards the end of the cycle (5th and 6th cuts).

The DCC also displays a continuously descending trend, although it remains fairly stable during the 3rd, 4th, and 5th cuts on the lower zone which is also the zone with the lowest values.

DMD tends to decrease, although in general, the values of digestibility of the dry matter are always above 60. This kind of behaviour is to be expected since

DCC

DNDF

FIGURE 5. Evolution of digestibility and crude protein during primary growth in three zones of topographic gradient.

digestibility decreases with high temperatures and maturity. It is also closely related to the botanical composition, and in this case and as was mentioned above, the proportion of grasses, legumes, and "others" in each of the zones as well as their evolution over time are characteristic for each part of the slope. Thus, the low proportion of legumes and the high proportion of grasses on the lower part of the slopes is responsible for its high contents in hemicellulose and ADF, which decreases digestibility. This is not sufficient for the DMD of these zones to be lower than that of the upper zones. There is, therefore, a certain compensatory effect exerted by the botanical composition which means that differences among zones are not as large as might be expected.

Of note is the marked parallelism between DMD and protein content. Both parameters are always higher in the lower zones of the topographic gradients, increasing the palatability of the grass in these zones (De Miguel et al., 1986).

Protein levels decrease in all the zones during growth, although in comparative terms, the highest content is always found on the lower zones. Protein levels are essential for suitable ruminant nutrition since there are minimum levels at which the animals must have in order to properly function and at which complete carbohydrate absorption will not decrease owing to a lack of nitrogen. Different authors have offered varying figures for these critical values, ranging from 7% (Milford and Minson, 1966) to 9% (Smith et al., 1965). In our case, these minimum values are only reached in the final cuts.

Principal Component Analysis

The ordination of the samples from the communities, considering their previous classification according to the degree of maturity and that part of the topographic gradient to which they belong, are on the factor plane defined by the two first axes of the principal component analysis is shown in Figure 6. It is seen that the temporal gradient is associated with axis 1, accounting for 63% of the total variance. As principal weighting factors, this axis has NDF and cellulose on its negative part (related with the more advanced stages of growth) and CC and DCC on the positive part of the axis (where the early phases of the cycle are situated). Protein and DMD also exert an effect.

Considering the gradient of the slope, an altitudinal arrangement is found with respect to axis 2 (absorption 27%) on which the most important weighting factors are protein, DNDF and DMD for the positive part of the axis (where the lowest parts of the slope are located) and lignin on the negative part (separating the upper and middle parts).

FIGURE 6. Situation of the samples on the plane limited by the two first axes of the principal component analysis applied to the nutritional data.

It is seen that the upper and middle parts always appear intermingled in the plot of PCA. This is probably related to the difference between the real spatial separation (by the fences placed in the field) and the separation deduced as a result of the nutrient analyses, with the result that the transition zone is more similar to the upper zone than the lower zone.

CONCLUSIONS

The evolution of the parameters during growth is dominated by the decrease in CC, protein, and DMD, and an increase in the other parameters, that is, by a coarsening and lignification of the pasture with the consequent loss of palatability

and quality. The topographic gradient has its own botanical characteristics that are reflected in the nutritional values of each zone.

Our multivariate study detected an association of the two studied gradients with some of the nutritional variables considered—the first factor being related to maturity and the second to topographical differences.

The most advantageous period for grazing is governed by the balance between quality and yield, which is most appropriate between the 4th and 5th cuts.

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