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Effects of orientation on soil moisture, temperature, biomass production, and nutritional composition of natural grassland in the central Chile

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Abstract

The natural dryland grassland of Central Chile serves as the nutritional base for sheep production systems. The orientation of a hill influences solar exposure, potentially affecting soil temperature and moisture, consequently impacting the growth cycle and nutritional quality of the grassland. Therefore, this study aimed to assess the orientation's effect on biomass production and the nutritional quality of the grassland. To achieve this goal, a farm with slopes facing the four cardinal directions (N, S, E, W) was selected for the trial. Three exclusion plots were established for each orientation. Grass samples were collected monthly to measure availability (kg DM/ha), Dry Matter (DM, %), Crude Protein (CP,%), Neutral Detergent Fiber (NDF,%), and Acid Detergent Fiber (ADF,%). Soil moisture and temperature were monitored at depths of 7.5 and 12 cm using a portable TDR 350 moisture sensor, expressed as Volumetric Water Content (VWC, %) and Celsius degrees (°C), respectively. Simple and multifactorial ANOVA were employed for data analysis. Results revealed that the average soil moisture at both depths was highest on the S slope, with 9.6±7.8% at 7.5 cm and 12.2±10.1% at 12 cm. The W slope exhibited the lowest moisture; however, it was not statistically different from the N and E slopes. The higher soil moisture on the S slope corresponded with lower temperatures (24.8±6.6°C), approximately 4°C lower than other orientations. This soil moisture/temperature combination resulted in no significant differences ($p<0.05$) in biomass production between orientations until after senescence (November). Regarding nutritional quality, no orientation effect was observed on DM (%), but differences were noted in ADF, NDF, and CP. The E orientation exhibited the lowest NDF value (52.6±5.0%), the S orientation had the lowest ADF value (37.3±2.7%), and the N orientation showed the lowest CP value (9.2±1.6%). These variations suggest the potential for utilizing orientation differences to accommodate animal categories with varying nutritional requirements.

Introduction

The natural dryland grassland of Central Chile serves as the nutritional base for sheep production systems. However, changes in precipitation and temperature patterns due to global warming have altered the grasslands' growing season, affecting the availability and nutritional quality of the forage throughout the year (Liu et al. 2019). Accurate information about forage availability is essential for efficient and precise grassland management and feed planning in extensive livestock systems (Serrano et al., 2016). Unfortunately, much of the available information regarding the nutritional value and its temporal pattern is outdated, with data spanning several decades (Ruiz, 1996). In Central Chile, the effects of climate change have manifested as reduced precipitation and increased temperatures, highlighting the importance of topographical features that influence soil moisture availability. For example, the orientation of a slope affects solar exposure, which can influence soil temperature and moisture, thereby impacting the growth cycle and nutritional quality of the grassland (Cui et al. 2023). The objective of the study was to evaluate the effect of slope orientation on biomass production and the nutritional quality of the grassland, while also updating the existing information on the production and nutritional quality of natural dryland grasslands in Central Chile.

Methods

The study was conducted on a livestock farm located in the interior dryland of the Las Cabras commune, O'Higgins Region. According to the modified Köppen classification, the area has a warm temperate climate with winter rainfall (Santibañez 2017).

For the research, 12 exclusion plots, each of 100 m^2 (10 x 10 m), were established and distributed across the four cardinal orientations (N, S, E and W, three plot per slope). The study spanned the grassland growth period, from July to December. Samples were collected monthly using a ring with a surface area of 0.09 m^2. In each exclusion plot, once the grass reached a minimum height of approximately 5 cm, three grass samples were collected. Grass was clipped at ground level to ensure sampling during the early growth stages using electric hand shears. The samples were placed in plastic bags, stored in a cooler, and transported to the Animal Feed and Food Quality Laboratory at the O'Higgins University for further processing. Fresh weights were recorded, and the dry matter percentage was determined to estimate biomass availability per hectare. Nutritional composition of the samples was analyzed using a FOSS NIR DS2500, measuring the following parameters: Dry Matter (DM, %), Crude Protein (CP, %), Neutral Detergent Fiber (NDF, %), and Acid Detergent Fiber (ADF, %). Soil moisture and temperature were monitored at depths of 7.5 and 12 cm using a portable TDR 350 moisture sensor. Moisture content was expressed as Volumetric Water Content (VWC, %) and temperature as degrees Celsius (°C). In each exclusion plot, 12 measurements were taken—six per depth. Data analysis was performed using simple and multifactorial ANOVA, with month, orientation, and depth considered as factors.

Results

Grassland growth began in July; however, due to the limited grass height, sampling was not feasible. Consequently, 324 samples were collected from August to December. Although an effect of orientation and month on biomass availability was observed ($p<0.05$), significant differences were only detected in December. On the N- and W-facing slopes, maximum biomass availability was observed in October (Figure 1). In contrast, on the S- and E- facing slopes, peak biomass availability occurred in November. Subsequently, plant senescence began, resulting in a slight decrease in biomass availability.

Orientation and month also had a significant effect on the dry matter, crude protein, acid detergent fiber (ADF), and neutral detergent fiber (NDF) contents. The N-facing slope exhibited lower nutritional quality during most of the evaluated months, characterized by lower crude protein concentrations and higher NDF and ADF concentrations (Figure 2).

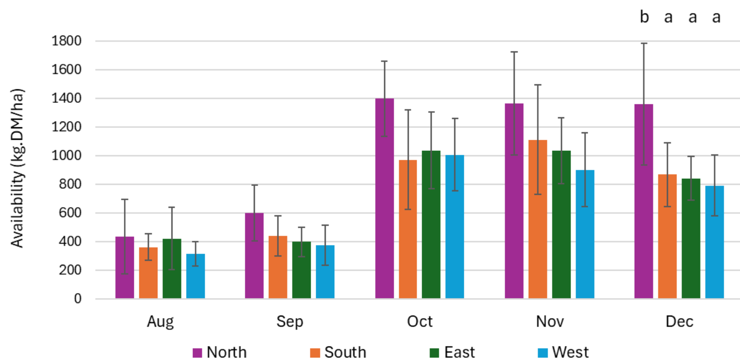

Figure 1. Effect of month and orientation on average biomass availability

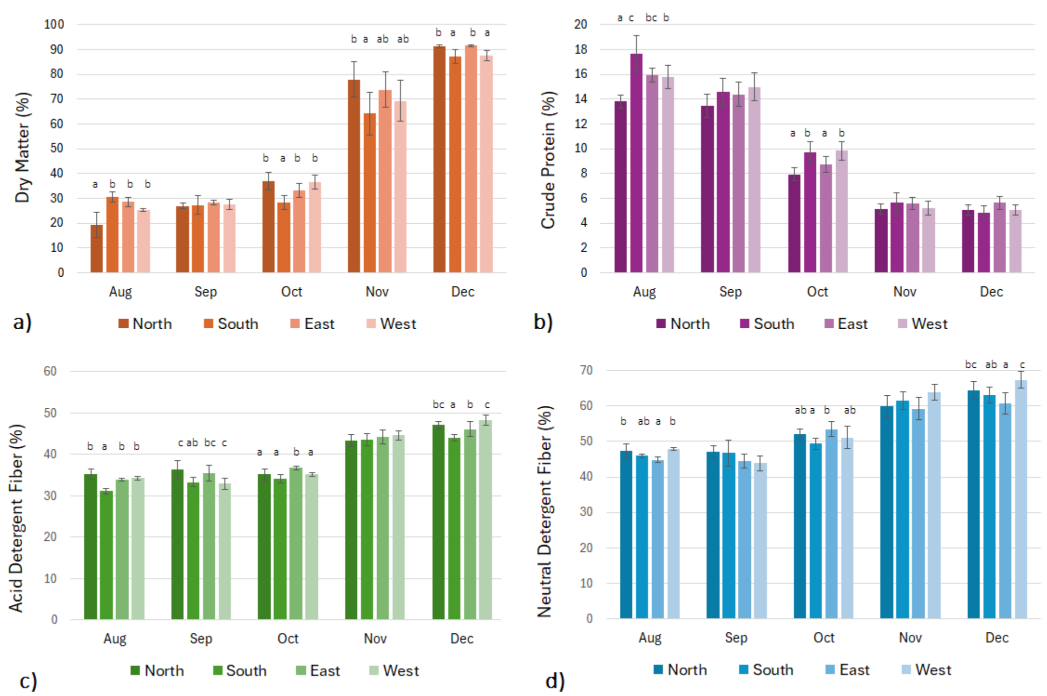

Figure 2. Monthly variation in Dry Matter content (a), Crude Protein (b), Acid Detergent Fiber (c), and Neutral Detergent Fiber (d) of the grassland.

Soil temperature and moisture variables were recorded from July to December (Figure 3). Both month and orientation significantly affected these variables at both depths (7.5 cm and 12 cm) ($p<0.05$). Depth significantly influenced soil moisture but had no effect on temperature. Soil moisture decreased rapidly from July to October, with the rate of decline slowing from October to December. From August to December, the S-facing slope consistently exhibited significantly higher soil moisture content compared to the other orientations ($p < 0.05$). At 12 cm depth, soil moisture was lower on the S- and W-facing slopes compared to measurements taken at 7.5 cm in all evaluated months. Soil temperature trends were similar across the N-, E- and W-facing slopes. On the S-facing slope, however, the temperature increase exhibited a lag of approximately two months compared to the other orientations.

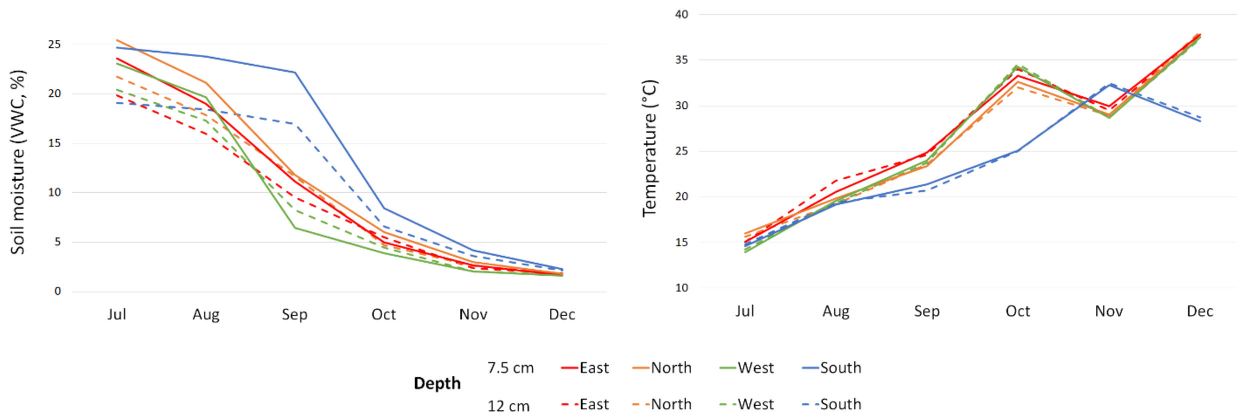

Figure 3. Effect of month, orientation, and depth on soil moisture and temperature

Discussion

Topographic factors such as slope and orientation influence the range of microclimatic conditions, including solar radiation, temperature, and soil moisture (Bennie et al.2008). These variables, which are critical for the growth of the grassland species, determine their productivity, and nutritional composition, demonstrating the potential for utilizing orientation differences to accommodate animal categories with varying nutritional requirements. In the southern hemisphere, S-facing slopes receive the least solar exposure throughout the day, resulting in lower soil temperatures (Figure 3). These lower temperatures reduce evapotranspiration, helping to maintain higher soil moisture levels and creating a greater moisture differential between the 7.5 and 12 cm depths during the wet months (Figure 3). The lower temperatures on the S-facing slopes likely delayed the onset of growth, resulting in shorter growth cycles and lower biomass availability. This growth delay contributed to lower fiber levels and higher protein content in August and September. However, as the microclimates generated by slope orientation can influence species composition, further studies are needed to identify the species present on each orientation (Zhang et al., 2022).

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