



# Increase of drought stress negatively affects the sustainability of extensive sheep farming in sub-Mediterranean climate



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## ARTICLE INFO

### Article history:

Received 17 February 2015

Received in revised form

12 January 2016

Accepted 13 January 2016

Available online 29 January 2016

### Keywords:

Climate change

Animal welfare

Net primary productivity

Forage chemical features

Rumen-pasture interaction

Inter-annual rainfall variability

## ABSTRACT

The sub-Mediterranean climate, characterized by inter-annual variability, is undergoing an increase in aridity. We assessed how inter-annual variation of precipitation affects pastoral systems of central Italy, to evaluate whether climate change may cause extensive sheep farming to become unsustainable. Since the assessment of pasture-rumen interaction is considered a key tool in evaluating the status of the system, we collected data on precipitation, soil water deficit, aboveground phytomass, forage chemical composition, sheep rumen keratinization and body condition. We found that drought stress negatively affected forage quantity and quality with a pattern of responses that are partially different from those reported for both Mediterranean and Temperate regions. The most negatively affected plant communities were those of productive habitats. In clipped plots, we also observed a decrease in the re-growth capacity after clipping, especially in plant communities of southerly slopes. Positive correlations were identified for body condition with phytomass and crude protein, and negative correlations for rumen degree of keratinization with crude fibre and Acid Detergent Fibre. We suggested that the body condition of sheep deteriorates because the reduced quantity and quality of pasture changes the sheep rumen, which in turn limits absorption of volatile fatty acid.

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## 1. Introduction

Ecosystem services provided by semi-natural grasslands depend on the composition and diversity of the plant communities, which in turn are influenced by the variability of ecological conditions (landform, soil, and climate), the land use history, and the interplay between herbivory (intensity and timing) and ecosystem productivity (Peeters, 2009). The latter, in turn, is strongly influenced by macro-climate features, especially the amount of rainfall and its seasonal distribution (Knapp et al., 2001; Nippert et al., 2006). The Mediterranean macro-climate has hot, dry summers. Average annual precipitation ranges from 200–300 to 700–800 mm, with two seasonal peaks in spring and autumn, with rainfall amount dropping down in summer (Rivas-Martínez, 2007). Winters are wet, but cool temperatures limit growth (Turner, 2004), especially in the sub-Mediterranean climate, a bioclimatic variant of the

Mediterranean climate, located on the border between the Mediterranean and Temperate regions and including the Mediterranean mountain areas, where winter frost is normal (Blasi, 1994; Rivas-Martínez, 2007). In this bio-climatic region, winter cold stress and summer drought stress have different intensities, depending on the elevation gradient and landform factors such as slope, aspect and angle (Somot et al., 2008; Orsomando et al., 2000) and plants must manifest not only drought stress tolerance but also frost resistance.

In sub-Mediterranean regions, semi-natural grasslands provide adequate nutritional value for only part of the year because the aboveground productivity peaks in late spring, when the community reaches the blooming peak (Catorci et al., 2012a), and drops in summer (Seligman, 1996). There can also be high inter-annual variability in phytomass production owing to annual differences in the amount and distribution of spring and summer rainfall (Bugalho and Milne, 2003). Spring forage contains relatively low levels of fibre and high levels of protein and lipids, but in the summer the level of fibre and tissue lignification increases (Catorci et al., 2012b). In fact, ruminants that depend solely on natural

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pasture start the grazing period with forage of high quality, but after the blooming period the pasture feed values decrease and the welfare of the animals may suffer (Seligman, 1996). Catabolism of adipose tissue due to lack of adequate feed quantity and quality has important consequences, some of which may affect the lymphatic system (Harvey, 2008) and reduce the animals' ability to reproduce (Morgan-Davies et al., 2008). The severity of weight loss depends on the energy deficit and its duration (Hogan and Phillips, 2008), thus in Mediterranean and sub-Mediterranean pastoral systems it could be linked to the length of the dry period in summertime. Moreover, changes in forage quantity and quality produce morphological and functional modifications at different levels of the digestive apparatus (Hofmann, 1989). In particular, the decrease of food nutritional value causes regression of rumen papillae and reduction of ruminal volume (Tamate et al., 1962; Hofmann, 1989; Scocco et al., 2012). In addition, the amount of water contained in the forage modulates the expression of proteins that regulate the amount of water in the saliva (Scocco et al., 2011).

Taking into consideration all these issues, we tested the hypothesis that the inter-annual climatic variability affects grassland productivity and feed value and causes variations in sheep rumen features (degree of epithelium keratinization) and animal body conditions. Moreover, we postulated that there is a significant correlation between grassland features, rumen characteristics and body condition scores. This is a key issue, prompted by Dove's (1996) suggestion that it is useful to think in terms of pasture-rumen interaction in deciding how pasture can best be managed. To our knowledge, no previous studies have focused on this issue in a Mediterranean-type climate. In Mediterranean areas, trends in climate change mainly cause greater aridity during summer (Giorgi and Lionello, 2008) and will likely curtail the sustainability of extensive sheep farming. In this context, assessment of the interplay among inter-annual climatic variability, pasture productivity and sheep status may prove very useful and might help in understanding and predicting the responses of the sub-Mediterranean pastoral systems to global warming.

The specific research goals were: i) to understand the effect of inter-annual climatic variability on pasture productivity and forage chemical features with respect to different plant communities (chosen considering a drought stress gradient due to landform factors), and ii) to understand the impact of drier conditions on sheep body condition and on the degree of rumen keratinization.

## 2. Materials and methods

### 2.1. Study area and farming system

The study site (a farming system of about 500 ha) is located along the calcareous mountain ridge of central Italy (42°56'53"N; 13°00'35"E), between 1000 and 1250 m a.s.l. It is characterized by a mean annual temperature of 10 °C, annual rainfall of 1035 mm, and summer annual rainfall of 197 mm. The average growing season (number of days with minimum temperature over 6 °C) is 160–180 days yr<sup>-1</sup>, lasting from late April to late October. Normally, a period with drought stress occurs in August.

The plant landscape is composed of different semi-natural grasslands, interrupted by small beech copses and croplands. The pastoral landscape is characterized by perennial *Bromus erectus*-dominated grasslands, referred to the classes *Festuco-Brometea* (on slopes) and *Molinio-Arrhenatheretea* (on the flat bottom of the valley). South-facing slopes are covered by shallow rocky soils (5–15 cm) and characterized by xeric pastures with open swards. North-facing slopes are covered by fairly deep soils (30–50 cm) and characterized by semi-mesophyllous pastures with a dense sward. Flat areas host hay meadows (cut once a year in July) growing on

deep soils (60–100 cm).

The seasonal trend of annual phytomass productivity follows a bimodal distribution, with peaks in late spring (higher) and early autumn (lower). In dry years, a lack of green forage characterizes the system in summertime (Catorci et al., 2012b).

Semi-extensive shepherding characterizes the study area; traditionally pastoral activities start in June and continue until the end of October. Real livestock stocking rate is about 190–200 livestock units (considering 500 ha), while the theoretical carrying capacity is about 200–210 livestock units (Catorci et al., 2012b). During summer-days after manual milking, shepherds lead flocks, protected by sheepdogs, to pasture. In the evening, they return to the sheepfolds and are milked again. They do not receive any other source of feed. Sheepfolds (simple fenced areas with a watering place and small buildings for shepherds) are quite far from mountain villages and used only during the summertime. During winter, sheep are housed in stables placed near the villages and are fed with dry hay and cereals. The income of farmers in the study area comes from the sale of cheese and lambs.

### 2.2. Data collection

The research was performed in 2007 and 2008. For each year, we gathered meteorological data (average daily temperature and rainfall amount) from the climatic station of the Torricchio Mountain Natural Reserve, which is located at 1160 m a.s.l. in the middle of the study area. To evaluate the average temperature and rainfall values, we used thermo-pluviometric data (1971–2000) of the climatic station of Rasiglia (794 m a.s.l.), which is located near the study area. The thermometric data were interpolated according to Cerquetti and Cruciani (1987), who asserted that in the Umbria-Marche Apennines, temperatures decrease by 0.43 °C for every 100-m increase in altitude.

In order to assess the aboveground phytomass, we randomly positioned 30 fenced enclosures of 4 × 4 m in the study area; 10 enclosures were placed in each topographic position (namely, on the north- and south-facing slopes and on the flat areas in the valley bottoms). We divided each enclosure into 16 plots of 1 × 1 m and randomly selected nine of them. Every 15 days from May 2nd to the end of October, the aboveground phytomass was collected from one of the nine plots in each enclosure. Plots were clipped 1.0–1.5 cm from ground level in order to simulate herbivore grazing. Every time we clipped again the plots previously mowed, in order to know the re-growth capacity of the grasslands during the growing period.

To provide a proxy for the soil water deficit, we needed to know soil texture, so 30 soil samples were collected in 2007 (next to the fenced enclosures): 10 on south-facing slopes, 10 on north-facing slopes and 10 on flat areas. Each soil sample was a mixture of five sub-samples. Soils were collected from the ground surface to the bedrock or as far as 50 cm of depth, if the soil was deeper. Soil samples were analysed according to the methodological standards established by Italian Ministerial Decree of 13 Sept. 1999. The parameters determined were percentage of skeleton (rock debris) and texture (percentage of sand, silt, and clay).

To assess the effect of the inter-annual climatic variability on sheep condition and rumen features, we assessed both Body Condition Scores (BCS) and the degree of epithelial keratinization of the rumen ventral sac (VSK). The VSK was chosen because it has been demonstrated to be the ruminal compartment that shows modification strictly related to pasture vegetative cycle (Scocco et al., 2013). The BCS is considered a more sensitive indicator of the nutritional status of the animals than body weight, which takes into account the total weight of the gastrointestinal contents and can lead to over- or under-estimation of the animal status and welfare

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