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SHORT COMMUNICATION

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Effects of summer rainfall variations on sheep body state and farming sustainability in sub-Mediterranean pastoral systems

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Abstract

In sub-Mediterranean climate the grassland aboveground phytomass production peaks in late spring and drops in summer, when the decrease of the pasture feed value may lead to the worsening of the animal welfare. Our goal was to define the summer rainfall values leading to a decrease of semi-extensive farming system sustainability in sub-Mediterranean regions. Summer rainfall variations reflect in the aboveground phytomass production and on the sheep body state. Differences of body condition score (BCS) among years were significant in late summer, which is the mating period for sheep. In the driest year the BCS of end August drops down to 2.1, largely below the value considered sufficient to ensure the animal breeding/milking performances (2.5). Reduction of summer rainfall greater than 15–20% compared to the normal average value (thus less than expected by the scenario of climate change) might be detrimental for semi-extensive rearing sustainability in sub-Mediterranean climate.

Additional key words: animal welfare; climate change; semi–extensive farming; Apennine grasslands, drought stress.

Abbreviations used: BCS (body condition score), T1 (late May), T2 (mid July), T3 (end of August).

Authors' contributions: Conceived and designed the experiments: PS and AC. Acquisition, analysis and interpretation of data: PS, KP, AM and AC. Statistical analysis: FMT. Wrote the paper: PS, FMT and AC. Obtained funding: AC.

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Introduction

The sub-Mediterranean climate is a bioclimatic variant of the temperate climate characterized by winter cold stress and summer drought stress, with a marked inter-seasonal and inter-annual variability. It is located on the border of the Mediterranean and temperate regions and mostly includes mountain areas arranged around the Mediterranean basin (Rivas-Martínez, 2007). In sub-Mediterranean regions, semi-natural grasslands provide adequate nutritional value only for a part of the year. In fact, the phytomass production peaks in late spring and drops in summer; moreover, spring forage contains low levels of fiber and high levels of protein and lipids, while the summer ones have high tissue lignification (Catorci *et al.*, 2012). Ruminants that during summer depend solely on natural 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). In fact, the decrease of food nutritional value causes regression of rumen papillae and reduction of ruminal volume leading to the weight loss and the worsening of animal body state (Hofmann, 1989; Scocco *et al.*, 2012). Catabolism of adipose tissue has important consequences also on the animals' ability to reproduce (Morgan-Davies *et al.,* 2008). The severity of weight loss depends on the energy deficit and its duration (Hogan & Phillips, 2008), thus in sub-Mediterranean-type pastoral systems it is linked to the length of the dry period. Models of climate change for the whole sub-Mediterranean region forecast the increase of drier conditions in summer, with 4 °C warming and over 25 % precipitation reduction in the worst scenarios (Giorgi & Lionello, 2008). A more marked inter-annual variability, higher summer water shortage, and the seasonality of the changes (namely, maximum change in summer and minimum in winter) are expected as well. Since rainfall availability directly affects plants, changes in the rainfall regime could have serious consequences for ecosystem functions and services besides on extensive farming sustainability (Köchy *et al.*, 2008; Nardone *et al.*, 2010). On the other hand, maintenance of sheep disturbance is an indispensable tool in order to preserve the grasslands biodiversity (Grime, 2001). Accordingly, quantifying the effects of summer aridity on animal welfare and defining the lower threshold value of summer rainfall allowing for the maintenance of a sufficient level of animal welfare are key issues in order to draw up management plans and adaptations to face the global warming effects (Nardone *et al.*, 2010). We hypothesized that amounts of summer rainfall far below than those usually affecting the studied pastoral system, reducing forage yield worsen the sheep body state. Moreover, we wish to define the values of summer rainfall able to ensure a sufficient sheep welfare.

Material and methods

The study site is a farming system of about 500 ha, located on the calcareous mountain ridge of central Italy (coordinates 33T 337637N, 4756969E; coordinates system WGS84), between 1,000 and 1,250 m a.s.l., on a north-facing slope. The pastoral landscape is characterized by semi-mesophylous *Bromus erectus*-dominated grasslands, referred to the *Festuco-Brometea* class. Mean annual precipitation from 1950 to 2000 was 1,100 mm, while mean summer rainfall (June, July and August) was 205 mm, with a short period of summer water deficit usually lasting from mid-July to mid-end August; average annual temperature was 11 °C (Pesaresi *et al.*, 2014). Pastures undergo semi-extensive shepherding; traditionally pastoral activities start in June and continue until the end of October. Sheep have no feed supply in summer. Real livestock pressure is about 190–200 livestock units, while the theoretical carrying capacity is about 200–210 livestock units (Catorci *et al.*, 2012). During winter, sheep are hosted in stables near the villages and nourished with dry hay and cereals.

We performed the research in 2007, 2008, and 2009. We gathered meteorological data (average daily temperature and rainfall amount) of each year from the climatic station of the "Montagna di Torricchio" Natural Reserve, located at 1,160 m a.s.l. in the middle of the study area, and calculated the summer rainfall for each year. In order to assess the phytomass production, we randomly positioned ten fenced stands of 4 × 4 m and divided each stand into 16 plots of 1 × 1 m. Seven of them were then randomly selected in each stand and clipped in each of the three years. From June 2nd to the end of August, every 15 days the phytomass was collected from one of the seven plots in each stand. Plots were clipped 2 cm from ground level to simulate herbivore browsing; forage was oven-dried for 48 h at 90 °C and then weighed. To have an indicative average value of the summer phytomass production for each year, we averaged phytomass data obtained from June to August in each stand. Finally, we averaged mean phytomass data for all the fenced stands. To assess the body state of sheep, we used the body condition score (BCS) method (which 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 (Ferguson *et al.*, 1994; Caldeira *et al.*, 2007). Several endocrine and metabolic blood indicators also confirmed the reliability of the BCS and recent research demonstrated that it is strongly related to both pasture and ruminal features (Caldeira *et al.*, 2007). A total of 36 (12 for each year) Comisana × Appenninica one year old sheep was used; all the animals were nulliparous and housed without rams to avoid interference from changes linked to reproduction. The sheep were housed in a stable until the start of the experimental period (late May). Afterwards, they grazed (together with the flock) on mountain pasture from June to October. We evaluated sheep body status at three times by means of BCS method (Scocco *et al.*, 2013): after a period when nutrition was based on dry hay and cereals (T1); after the period of highest productivity and of pasture flowering peak (T2); and after the maximum of pasture dryness (T3).

We calculated the basic statistics (mean and standard error of mean) for average BCS values at each time of each year. Given that data did not meet the assumptions required for parametric tests, for each time we performed a Kruskal-Wallis test to assess whether there were statistically significant differences among years ($p < 0.05$). We used the Jonckheere-Terpstra test to test if the trend of BCS mean values significantly increased from 2007 to 2009. Significance of trend ($p < 0.05$) was assessed by 5000 permutations. To perform statistical elaborations we used the R software (v 3.0.2; R Foundation for Statistical Computing, Vienna, AT; http://www.R-project.org) and the *stats* and *clinfun* R-packages.

Results and discussion

Data elaborations highlighted high differences among years with regard to annual rainfall (833, 1413, and 1098 mm in 2007, 2008, and 2009, respectively) and summer rainfall (67, 170, and 235 mm in 2007, 2008, and 2009, respectively). Summer rainfall of 2007 and 2008 were lower than the average rainfall value of the study area from 1950 to 2000 (–70 % in 2007 and –17 % in 2008). Instead, 2009 showed a 15 % increase in summer rainfall. The average phytomass production showed high differences as well, with the lowest value (149 g/m^2) in 2007 and the highest (280 g/m^2) in 2009, while in 2008 it was 183 g/m^2. This trend followed that of the summer precipitation. The values of BCS showed a clear decreasing trend from T1 to T3 in 2007 and 2008 (Table 1). BCS did not show any trend in T1 (chi-squared = 0.57, p = 0.751) and in T2 (chi-squared = 2.36, p = 0.308) during the three-year period. A difference among years was detected only in T3 (chi-squared = 11.44, p = 0.003). The existence of a general increasing trend from 2007 to 2009 was confirmed by the results of the Jonckheere-Terpstra test (JT = 667.5, p = 0.002).

Consistently with previous research (Vázquez de Aldana *et al.*, 2008; Kafle & Bruins, 2009) we observed that the variation of rainfall amount reflects in the phytomass production of grasslands, since the year with higher summer rainfall had the higher average summer phytomass production and vice versa. In 2007, phytomass values were lower than in 2008 and in 2009 of about the 19 % and the 47 %, respectively; in 2008 they were lower than in 2009 of about 35 %. Therefore, in the 2007 summer (the driest one), sheep grazed in poor pastures while in 2009 forage yield was higher and, likely, of greater nutritional value, since summer rainfall worsens the forage feed value, because of the senescence of summer leaves, which is a mechanism of drought resistance (Catorci *et al.*, 2012; Volaire *et al.*, 2014). Actually, in 2007 the mean BCS decreased in T3 (2.1) as well as in 2008 (2.3); instead in 2009 mean values ranged from 2.7 to 2.8, and no trend was detected from T1 to T3. Differences among BCS values were statistically significant only in T3. It is noteworthy that T3 corresponds to the driest summer period besides the first mating period for sheep; in this physiological condition, BCS should be higher than 2.5, while values ranging from 2.0 to 2.5 are considered sufficient only for animals not intended for breeding or milking (Boucquier & Thériez, 1989). Since in the considered farming system the mean BCS exceeded 2.5 in 2009, which was characterized by greater phytomass production related to higher summer rainfall values (235 mm), we can argue that these conditions ensured a state of well-being sufficient to guarantee a good performance of sheep. Instead, in 2008, the BCS of at least half of the observed sheep, lied within the interval 2.0–2.5, while in 2007, when summer rainfall (65 mm) and phytomass production dropped, the mean BCS of T3 was just above 2.0, namely the threshold value considered sufficient to maintain animal well-being only in not for breading/milking individuals (Boucquier & Thériez, 1989). We can conceive that the rainfall amount of 2007 was harmful for the sustainability of sheep semi-extensive farming in sub-mediterranean farms. Instead, the value of summer rainfall of 2008 (170 mm) might be considered close to the threshold value for the maintenance of a quite sufficient BCS. The summer rainfall value of 2008 is lower but not so far from that of the 1950–2000 period (205 mm). Following these statements, we can argue that in the study case the reduction of summer precipitation greater than 15–20 % compared to the normal average value (thus slightly lower than that predicted by the scenario of climate change) may be detrimental for sheep rearing sustainability.

In conclusion, our results were consistent with Hanson *et al.* (1993), who indicated that forage variation due to the worsening of climatic condition might be large enough to bring about considerable decreases in animal productive performances. Obviously, our results need to be corroborated by a wider number of years and variables (*e.g.* air temperature, pasture composition, altitudinal gradients, sheep breed, flock governance, etc.) to build a more reliable predictive model. However, our results give new insights on the impact of climate change on the sub-Mediterranean semi-extensive farming systems.

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Table 1. Descriptive statistics of body condition score (BCS) in each year of observation.

Time	2007			2008			2009		
	Mean ± SE	Med	IQR	Mean ± SE	Med	IQR	Mean ± SE	Med	IQR
T1	2.6 ± 0.1	2.6	2.5 – 2.7	2.6 ± 0.1	2.6	2.4 – 2.8	2.8 ± 0.2	2.8	2.4 – 3.1
T2	2.5 ± 0.1	2.4	2.4 – 2.5	2.6 ± 0.1	2.7	2.4 – 2.8	2.7 ± 0.1	2.7	2.6 – 2.8
T3	2.1 ± 0.1	2.1	1.9 – 2.2	2.3 ± 0.1	2.3	2.2 – 2.4	2.8 ± 0.1	2.7	2.7 – 2.8

SE, standard error; Med, median; IQR, interquartile range; T1, after feeding with dry hay and cereals; T2, after feeding on pasture at flowering peak; T3, after feeding on pasture at maximum dryness.

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