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Rain-Use Efficiency Factor and Grazing Capacity in Preveza Prefecture Rangelands, Greece

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Abstract: This study was carried out to examine the short-term response of different types of Preveza Prefecture rangelands in Greece to annual rainfall in terms of rain-use efficiency and grazing capacity. The herbaceous and browse rain-use efficiency factors were estimated after a two-year study (2007-2008) of 54 sites spread over three different altitudinal zones within Preveza Prefecture, representing typical rangeland conditions. The results indicated that the current grazing-livestock population exceeds the total grazing capacity in the grasslands and phrygana range types, where the lowest values of both grazing capacity and rain use efficiency were observed. Also, the evaluation of the grazing capacity and rain use efficiency factors showed that they were independent of rainfall fluctuations across all range types and altitudinal zones. While these factors can be very useful in range management, long-term results are required to improve the accuracy of the evaluations and also to better understand the interactions between these two factors with the altitudinal zones and the range types in Greece.

Key words: Herbage · Browse · Grazing management · Rangelands · Greece

INTRODUCTION

In Preveza Prefecture, rangelands comprise almost 47.700 hectares, representing the 51.3% of its land surface. Traditionally, these lands have been natural pastures, generally extending to mountainous and semi-mountainous areas and have been managed for livestock grazing under communal ownership.

A previous study [1] showed that these rangelands are seriously degraded as a result of overgrazing, which is a typical phenomenon of communal ownership. The selection of the optimum stocking rate is a crucial grazing management decision with respect to rangeland sustainability and is determined by forage production and availability [2]. In the Mediterranean basin, rangelands are characterized by the coexistence of plants with different life cycles, ranging from evergreen sclerophyllous and seasonally dimorphic shrubs to annual or perennial grasslands. Furthermore, in northwestern Greece, warm-season (C_4) plants were found to be dominant at lower and middle altitudinal zones in addition to the upper zone which can be characterized as a cool – warm (C_4-C_3) season plant pasture area depending on the climatic conditions [3]. Generally, the rainfall and the temperature are the major climatic factors contributing to vegetation production of these terrestrial ecosystems. The single most important factor affecting the range type and the biomass production is rainfall [3-5], which mainly limits the primary production in arid and semi-arid areas [6-9]. In the high-rainfall areas, soil characteristics influence the vegetation productivity more than rainfall [10,11]. However, rangeland production is significantly correlated with rainfall, but the magnitude and direction of that relationship varies depending on the range type [8]. Although rangeland production shows a large response to rainfall, it seems that rain seasonality does not play a primary role on range productivity [12,13] but rather the ratio of Net Primary Production to rainfall, the rain-use efficiency (RUE), is the main determinant of productivity. The RUE has a conservative role throughout the various arid zones of the world irrespective of flora and vegetation type because it is closely related to and affected by the ecosystems and is also very sensitive to range condition and depletion status [14]. In this context, Le Houérou and Host [15] suggested that each millimetre of rainfall produced 2 kg/ha of consumable dry matter in the Mediterranean Basin.

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On a worldwide arid-zone basis the RUE value seems to be a valid and useful indicator of range type, condition and productivity [13]. Also, this factor has been utilized for the determination of the potential for cattle production in the Mendoza plain, Argentina [16] and as an index of regional degradation in the African Sahel [17].

In Preveza Prefecture, there are three main range types [3], grasslands, phrygana and shrublands, which extend from lowlands to uplands. Currently adequate comparative data on the effect of the annual rainfall on rangeland production in terms of rain-use efficiency and grazing-capacity does not exist. The RUE and the gracing capacity are two useful indicators of proper range management and range conditions, leading to the evaluation of rangeland production in relation to range type and altitudinal zone.

Therefore, this study was carried out with to the aim of examining and evaluating the short-term response of the different types of rangelands in the Preveza Prefecture to annual rainfall in terms of rain-use efficiency (RUE) and grazing capacity (GC).

MATERIALS AND METHODS

Studied Area: This study was performed in the Preveza Prefecture in Epirus, northwestern Greece, for two consecutive years: 2007 and 2008. The studied area is distinguished by its diversity of landscapes and natural alternations. Vegetation belongs to the eumediterranean zone of *Quercetalia ilicis*, class *Quecion illicis* [18,19] and ranges from typical Mediterranean (macchie, phrygana) in the lower areas to sub-alpine in the more humid and higher areas.

Long-term records regarding climatic conditions of the lower altitudinal zone of the studied area were provided by the Hellenic National Meteorological Service indicating a typical Mediterranean climate characterized by rainy, cold winters and dry, warm summers. These data presented a mean monthly temperature of 8.7°C and 26.5°C for January and July, respectively and a mean annual rainfall reaching up to 1084.6 mm for the period of 1976-1997. For our experiment, three automatic weather stations (Onset HOBO weather station) were placed, one in each altitudinal zone, to record data regarding the local rainfall levels and the temperature fluctuations. The data obtained from the weather stations showed considerable variations of the above-mentioned climatic factors among the altitudinal zones throughout the two years of the experiment (Figure 1).

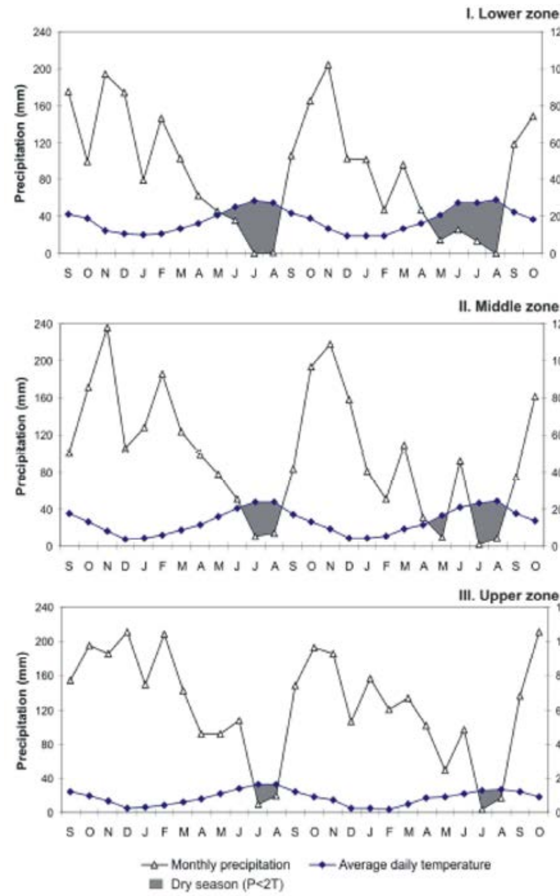

Fig. 1: Ombrothermic diagrams of the three altitudinal zones in Preveza grasslands. Data obtained from September 2006 to October 2008 from three weather stations, one in each altitudinal zone.

Forage Production Determination: To determine the maximum annual production of each range type in the studied area, 18 sites were selected each year for sampling, each having the same environmental and site characteristics (aspect, slope and soil). These sites were grouped into three topographical zones based on their altitude above-sea level, us upper (above 1001m), middle (501-1000m) and lower zones (0-500m). At every site, three main range types were recognized according to Papanstasis and Noitsakis [3]: grasslands, phrygana and kermes-oak shrublands (Table 1). Three plots of 20 m^2 each (one in grassland and one each in the adjacent phrygana and kermes-oak shrubland) were fenced to avoid grazing during the experimental period.

Throughout the two years of the study, hand-clipped samples were collected from each plot at the stage of maximum forage production. This stage differed among the altitudinal zones because of the climatic condition

Table 1: Preveza sites: general characteristics.

Range type	Altitudinal Zone	Plant community (based on dominant species)	Sites selected
Grassland	Lower - Middle	*Bromus squarosus L. - Hordeum bulbosum L. - Anthyllis vulneraria L. - Trifolium repens L.*	12
Grassland	Upper	*Festuca ovina L. - Lotus corniculatus L - Stipa pulcherrima K. Koch*	6
Phrygana	Lower-Middle-Upper	*Phlomis fruticosa L.*	18
Shrubland	Lower-Middle-Upper	*Quecus coccifera L. – Phillyrea media L. - Arbutus unedo L.*	18

alternations (Figure 1). Specifically, in the lower and middle zones herbage samples were collected at the end of May, while in the upper zone herbage samples were collected one month later, at the end of June. Sampling was done by cutting vegetation in eight randomly selected quadrants of 0.25 m^2 each inside of each enclosure. For the grassland and phrygana range types, sampling was done by cutting the herbaceous vegetation using hand shears at approximately 5 cm above soil level, while for the kermes oak shrublands samples were obtained by cutting all new twigs. All samples were immediately placed into individual paper bags and transported to the laboratory. Dry sample weights were recorded after the samples were dried for 48 h at 60°C and weighed to determine the dry matter production on a gr/m^2 basis.

Calculations: The rain-use efficiency (RUE) is determined as the amount of dry matter (DM) produced in a given area over a given period of time per unit of rain and is usually expressed in kg dry matter ha^{-1} mm^{-1}. In this study, RUE was estimated by dividing the amount of the forage dry matter produced in a hectare by annual rainfall. The estimation of the grazing capacity in the present study was based on the following assumptions: (a) the Animal Unit (AU) was defined as one 50-kg ewe and lamb, or the equivalent (1 beef cattle = 6.67 ewes); (b) forage intake by a ewe was 1.0 kg DM per 50 kg of liveweight [20] (c) cattle and sheep grazed only in grasslands and phrygana for a period of seven months per year (six months in the upper zone), while goats graze only in oak dominated shrublands for a period of 11 months per year (six months in the upper zone); (d) it was assumed that the 50% of the overall area of the shrublands was grazed by the goats due to their very high density avoiding by this way its utilization; (e) the proper use factors were 50 % for the grasslands and phrygana and 70% for the shrublands; (f) the average grazing livestock population of the Preveza Prefecture, in AU, for the period of 2004-2008 was taken from data provided by local self-organized authorities (municipalities), in which producers pay for rangeland utilization (rangeland right) to receive European Communities subsidies and (g) the total area for each range type in each altitudinal zone was adapted from data generated by the Forestry Department of the Epirus Region.

Statistical Analyses: Statistical differences were tested using a two-way analysis of variance (ANOVA) following the generalized linear model (GLM) procedure of SPSS version 16 for Windows [21]. Levene's test for homogeneity of variance and the Kolmogorov-Smirnoff test for normality were used, but no transformation of the data was needed. Least-square differences (LSD) [22] were used to determine significant differences among means when significant ANOVA results occurred ($P < 0.05$). Pearson's correlation was employed to examine relationships between each response variable (rain-use efficiency and grazing capacity) and climatic variables and altitude.

RESULTS AND DISCUSSION

Rain Use Efficiency (RUE): From the results gathered, generally, significant interactions ($P < 0.001$) were observed among the altitudinal zone, range type and rain-use efficiency (Table 2). It was found that the RUE was significantly ($P < 0.001$) higher in the lower altitudinal zone than in the middle and the upper zones for all range types (Figure 2).

During the first year of the experiment, the RUE values found in all range types were very low despite the very high annual rainfall. More specifically, the phrygana range type gave a RUE varying between 0.77 and 1.95 kg DM ha^{-1} $mm^{-1}$and was the lowest ($P < 0.01$) among all range types and for all altitudinal zones. This provided evidence that these rangelands are not properly managed and so, they are in an unfavorable condition [23]. The RUE is known to be substantially lower in degraded ecosystems and considerably higher in pristine conditions [14, 16,17]. During the second experimental year, rain-use efficiency showed an increase across all range types despite the fact that rainfall levels were lower. This may be due to either increased forage production (phrygana and shrublands) or a relatively lower grassland production. This probably resulted from the temporary

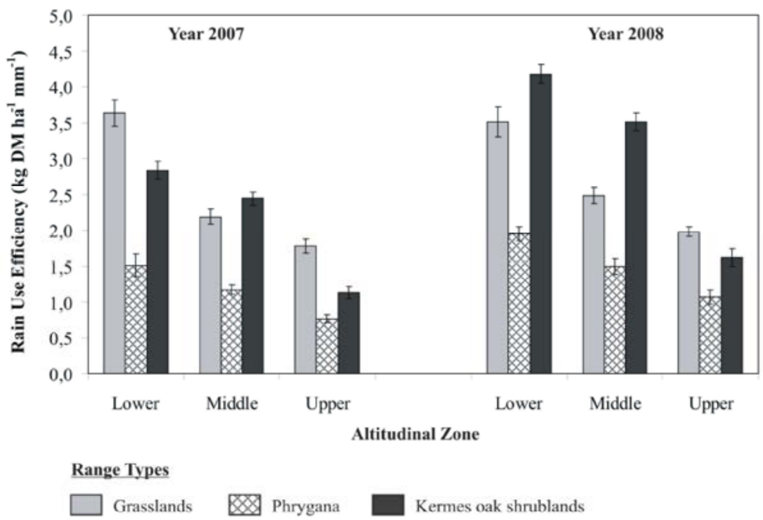

Fig. 2: Rain-Use Efficiency in different range types and altitudinal zones over the two-year study period. Vertical bars ± s.e.

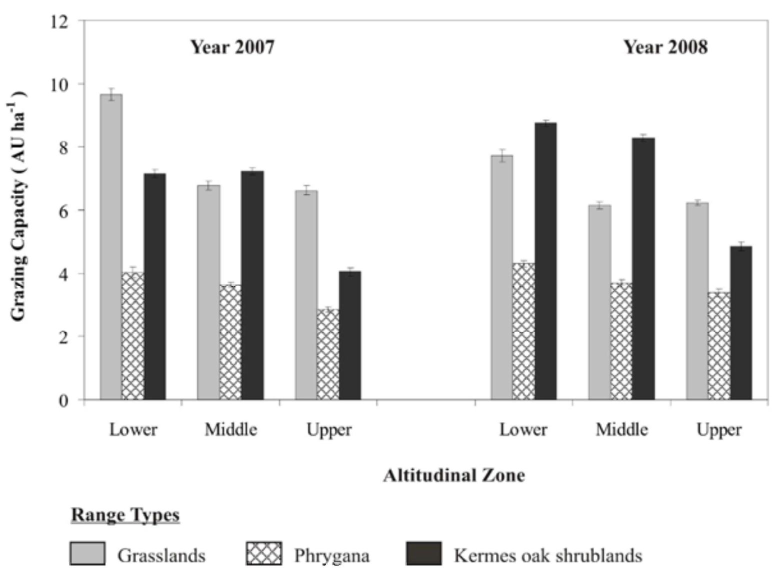

Fig. 3: Grazing capacity in different range types and altitudinal zones over the two-year study period. Vertical bars ± s.e.

undergrazing of the studied area, a fact in agreement with the results of Le Houérou *et al.* [23] who stated that rangeland restoration techniques may increase the productivity by a factor of from three to five and occasionally even more.

The Pearson-correlation results showed significant relation among altitudinal zone, annual rainfall ($r = 0.804$; $P < 0.01$) and RUE ($r = -0.626$; $P < 0.01$). Because annual rainfall increases with the altitude above sea level, one would expect higher RUE values in the upper zone than in the others. However, such an assumption is not justified, first because the forage production in the lower zone is significantly ($P < 0.001$) higher than in the other altitudinal zones as result of the better climatic conditions and the longer duration of the growing season [10,11]. Second, in northwestern Greece, the lower and middle zones are dominated by C_4 plants, in contrast to the upper zone, where C_4-C_3 plant mixtures are characterized as dominant depending on the climatic conditions [3]. There is some physiological compensation due to the fact that C_4 plants are photosynthetically more efficient and they tend to exhibit higher dry-matter accumulations compared to C_3 plants [24].

Table 2: Results of two-way ANOVA showing the significance of the effects of altitudinal zone, range type and factor interaction on Rain-Use Efficiency factor and Grazing Capacity

Source of variation	d.f.	Mean Square	F	Sig.
Rain Use Efficiency				
Zone	2	21.597	1509.510	0.000
Range type	2	19.700	1376.881	0.000
Zone × Range type	4	2.207	154.245	0.000
Grazing Capacity				
Zone	2	128.448	381.046	0.000
Range type	2	495.503	1469.932	0.000
Zone × Range type	4	24.110	71.523	0.000

Table 3: Rainfall, forage production and grazing capacity in Preveza Prefecture rangelands

	Area (ha)				Production (kg DM ha^{-1})			Usable forage * (kg DM ha^{-1})		Grazing capacity ha AU^{-1}		Grazing capacity AU	
Zone	Grasslands	Phrygana	Shrublands	Mean annual rainfall (mm)	Grasslands	Phrygana	Shrublands	Grasslands and Phrygana	Shrublands	Grasslands and Phrygana	Shrublands	Grasslands and Phrygana	Shrublands
Lower	1.261	10.861	9.069	1.017	3.646	1.745	3.505	971	2.629	4,6	10,6	56.073	28.899
Middle	2.452	8.115	9.217	1.170	2.715	1.538	3.412	906	2.559	4,3	10,3	45.567	28.593
Upper	6.135	1.118	2.263	1.440	2.697	1.304	1.955	1.241	1.466	6,9	10,9	50.008	7.374
Total	9.848	20.094	20.549									151.648	64.866
Weighted mean				1.209	3.019	1.529	2.958	1.039	2.218	5,3	10,6		

*: Average value of usable forage in grasslands and phrygana range type is based on the relative proportion of these range types to their sum for each altitudinal zone

The average RUE values across all altitudinal zones for each range type were 2.60 kg ha^{-1} mm^{-1} for grasslands, 1.33 for phrygana and 2.62 for shrublands. These values are comparable to those obtained by Guevara *et al*. [25, 16] for the temperate – warm climate of Argentina varying between 0.67 and 2.76 kg ha^{-1}mm^{-1}.

It is important to underline that in our study water loss through evaporation, surface runoff; erosion factors and deep drainage were not taken into consideration, likely leading to a RUE underestimation.

Grazing Capacity: It was observed that there were significant ($P < 0.05$) differences in grazing capacity among altitudinal zones and range types (Figure 3) and it also varied significantly ($P < 0.001$) with the altitudinal zone and the range type (Tables 2 and 3) with the average in all altitudinal zones ranging from 3.6 to 7.2 AU ha^{-1} for phrygana and grasslands, respectively (Figure 3).

In terms of animal units, grasslands and phrygana range types were grazed by 219,802 sheep and cattle, while shrublands are grazed by 56,706 goats. Consequently, the grazing-livestock population was about 44.9% over the estimated grazing capacity of grasslands and phrygana range types (Table 3), while in oak-dominated shrublands, the grazing capacity was about 14.4% higher than the existing goat population. Because of the fact that livestock data were provided by the local self-organized authorities (municipalities), they can be considered reliable. Thus, it is evident that grasslands and phrygana are overgrazed compared to the under-grazed oak-dominated shrublands. This fact leads to the degradation of rangelands and contributes to poor range conditions, especially in phrygana range type.

CONCLUSIONS

From the results of this study, we concluded that grazing capacity and rain-use efficiency were independent of rainfall fluctuations across all range types and altitudinal zones, with both following similar trends. The RUE factor is a useful indicator of the prevalent range conditions and can be utilized in grazing management. Therefore, it is evident that long-term results are required to improve the accuracy of the evaluation and also to better understand the interactions among these two factors with the altitudinal zones and the range types in Greece.

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