

## A GIS-BASED ASSESSMENT OF RAIN-USE EFFICIENCY FACTOR AND GRAZING CAPACITY IN PREVEZA PREFECTURE, GREECE

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### ABSTRACT

This study was carried out during the period of 2006-2008 in order to assess the rain use efficiency factor and the grazing capacity of Preveza Prefecture rangelands by applying Geographical Information System (GIS) techniques and field work. Climatic data and forage production of representative range types were recorded for this study period. About 51.4 percent of total rangelands area has rain use efficiency value below 2 kg/ha/mm ranging from 0.00 to 2.00 kg/ ha/ mm. The rest 48.6 percent accounts to 2.01-4.00 kg/ha/mm. The grazing capacity value of Preveza Prefecture rangelands ranges from 0.00 to 8.80 AU/ha. The results also show that only 0.8 percent of total rangeland area is below 2.10 AU/ha and only 24.6 percent of total area is above 6.3 AU/ha. The results further show that forage production of Preveza Prefecture rangelands exhibit a high variation in relation to topography. Also, it seems that in grasslands and phrygana range types the usable forage is inadequate to meet the grazing animal requirements. However, long-term results are required to improve the accuracy of evaluations in Greek rangeland ecosystems.

**KEYWORDS:** Rangelands; rain; stocking rate; efficiency; Greece.

### INTRODUCTION

In Greece, rangelands have traditionally played an important role in the development of extensive livestock systems. Grazing livestock is the main stamina of the economic activity in mountainous and semi-mountainous areas. The assessment of rain use efficiency factor and the stocking rate

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forms a crucial management implication providing a clue for the prospect situation of range conditions and the determination of feed available to livestock.

In Preveza Prefecture, northwestern Greece, rangelands comprise about 51.3 percent of its land surface and have traditionally played an important role in the development of extensive livestock systems. These 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 (16).

This heterogeneous vegetation creates a rich spatial range mosaic, with its sustainable production depending on grazing management. Although the sustainable grazing management is a key issue of concern, many complexities are involved in the assessment of sustainable use of rangelands (13). For example, annual rainfall is significantly correlated with the rangeland production, but the magnitude and direction of that cognation varies depending on the range type (2). Although rangeland production shows a large response to rainfall, it seems that rain seasonality does not play a primary role on range productivity, on the contrary the rain use efficiency (RUE) is the main determinant of it (5, 9, 11). The RUE presents a conservative role throughout the various arid zones of the world irrespective of flora and vegetation type because it is closely related to the ecosystems and therefore affected by them but it is also very sensitive to range condition and depletion status (12).

On the other hand, long-term stocking rate determines the composition and density of the plant cover, which in turn determines biomass production under certain rainfall conditions (7, 13). Consequently, the selection of optimum stocking rate is a crucial grazing management decision with respect to rangeland sustainability and should be tenable to preserve the sustainable balance between livestock production and rangeland health (4, 24).

The assessment of RUE factor and stocking rate provides a clue on the prospect situation of range conditions and on the determination of feed available to livestock in a given area (22).

This study was conducted to determine the RUE factor and grazing capacity in the Preveza Prefecture rangelands by applying GIS techniques and field work.

## MATERIALS AND METHODS

The Preveza Prefecture basin is located in northwest of Greece (Fig. 1). It is a typical Mediterranean mountainous area, ranging from 0 to 1645 meter

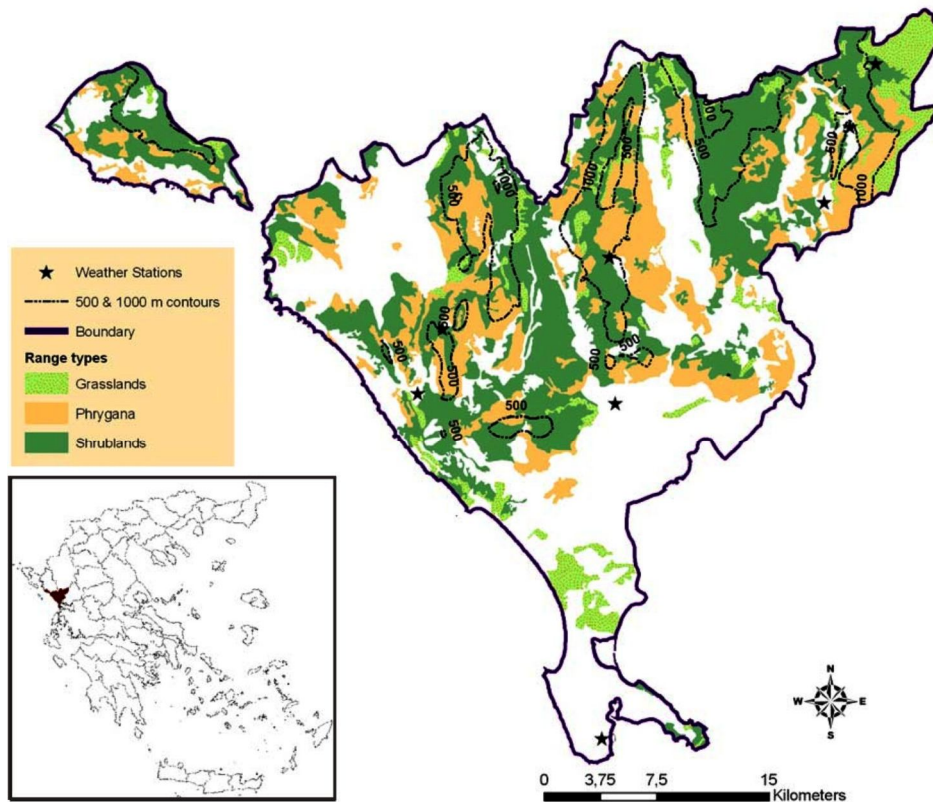


Fig. 1 Location of the study area.

above sea level with great variation in topography, soil and climatic conditions. Vegetation belongs to the eumediterranean zone of *Quercetalia ilicis*, class *Quecion ilicis* (3, 8) and ranges from typical Mediterranean (macchie, phrygana) in the lower areas to sub-alpine in the more humid and higher areas. These rangelands are representative of Epirus region. Although these are extended from lowlands to uplands, yet most of them have suffered a high stocking rate (19).

Long term records of the climate of study area were obtained from Soulis (21). Accordingly, the climate is typical Mediterranean, characterized by rainy cold winters and dry warm summers; with a mean monthly temperature ranging between 8.7 and 26.4°C in January and July, respectively, and a mean annual rainfall reaching upto 1.344,9 mm (SD = ± 286.6) for the period of 1951-1991. The annual rainfall of the basin shows a high variation which ranges from 890 mm in the southern and flat part to 1400mm in the north-eastern and higher part of the basin.

### Rainfall data

Annual rainfall data was obtained from eight local automatic weather stations (Onset HOBO weather station) placed in Preveza Prefecture (Fig. 1) during the month of September 2006 gathering data of three consecutive years 2006 to 2008. Geographical information (latitude, longitude, altitude above sea level) was determined using a handheld GPS mobile mapping device (Promark3, Thales Navigation). The altitude above sea level was related with differences in rainfall conditions. Lastly, the data obtained from the eight weather stations were combined to get three-year mean values which were used for regression analysis (Fig. 1).

### Forage production determination

To determine the maximum annual production of rangelands in the study area, 93 sites were selected for sampling (Table 1), each one presenting different environmental and site characteristics (aspect, slope percentage, altitude above sea level and soil). At these sites, three main range types were recognized according to Papanastasis and Noitsakis (16): grasslands, phrygana and kermes-oak dominated shrublands. One 20 m<sup>2</sup> plot in each site was fenced to avoid grazing during the experimental period.

**Table 1. Preveza sites: general characteristics.**

Range type	Dominant species	Sites selected
Grassland	<i>Bromus squarosus</i> L. - <i>Hordeum bulbosum</i> L. - <i>Anthyllis vulneraria</i> L. - <i>Trifolium repens</i> L.	16
Grassland	<i>Festuca ovina</i> L. - <i>Lotus corniculatus</i> L - <i>Stipa pulcherrima</i> K. Koch	11
Phrygana	<i>Phlomis fruticosa</i> L. - <i>Dactylis glomerata</i> L. - <i>Avena sterilis</i> L.	30
Shrublan	<i>Quercus coccifera</i> L. - <i>Phillyrea media</i> L. - <i>Arbutus unedo</i> L.	36

Throughout the experimental period (2006-2008), hand-clipped samples were collected from each plot at the stage of blooming. Sampling was done by cutting vegetation in eight randomly selected quadrants of 0.25 m<sup>2</sup> 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 the 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 hours at 60°C and weighed to determine the dry matter production on gram per square meter basis.

### Regression analysis

Linear estimation regression models were used to determine the type of regression that best describes the relation, in each range type, between measured variables (altitude, aspect and slope percentage) of the experimental plots and dry matter production. The equations for each range type were selected based on the coefficient of determination, as given below:

Equation	Adj. R <sup>2</sup>	S.E.
Grassland production = 358,7 – 0,069 Altitude – 1,928 Slope	0.663	31.2 (Eq. 1)
Phrygana production = 196,8 – 0,056 Altitude – 1,119 Slope	0.617	16.4 (Eq. 2)
Shrubland production = 355,7 – 0,140 Altitude – 1,827 Slope	0.728	30.2 (Eq. 3)

Annual rainfall was obtained from eight climatic stations of Preveza Prefecture for the period 2006 – 2008 and was used in the analysis. Further, the relationship between annual rainfall and altitude above sea level was tested using linear regression over three-year mean values of annual rainfall and altitude above sea level (Eq. 4).

$$\text{Rainfall} = 929,96 + 0,436 \text{ Altitude} \quad \text{Adj. R}^2 = 0.750 \quad \text{S.E. } 103.7 \quad (\text{Eq. 4})$$

### Calculations

The rain-use efficiency (RUE) was determined as the amount of dry matter (DM) produced in a given area over a given period of time per unit of rain, and usually expressed in kg dry matter/ha/mm. The estimation of grazing capacity in the present study was based on the assumptions: i.e (a) the animal unit (AU) was defined as one 50-kg ewe and lamb, or with its equivalent (1 beef cattle = 6.67 ewes) (14); (b) forage intake by a ewe was 1.0 kg DM per 50 kg of liveweight (1); (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) proper use factors were 50 percent for the grasslands and phrygana and 70 percent for the shrublands; and (e) 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.

### **Geographical information system**

After the computation of annual rainfall and production of each range type, grid layers were generated by performing a spatial analysis using the raster calculator of spatial analyst tool of ArcMap software. A digital elevation model based on 50 m contours for the region was available generated for 30 m resolution. Other basic data layers were available from Technological Education Institute of Epirus (15) (Prefecture borders, lakes, range type areas, etc.) The cell size resolution of all interpolated layers was 50 m. The GIS platform used was ArcGIS version 9.3.

## **RESULTS AND DISCUSSION**

### **Rain use efficiency**

The analysis of RUE in Preveza Prefecture was taken as the ratio of annual forage production and mean annual rainfall of the area. Based on the analysis the RUE value ranges from 0.00 to 4.00 kg/ ha/ mm (Fig. 2; Table 2). About half (51.4%) of the total studied area has RUE value below 2 kg DM/mm/year. The rest 48.6 percent accounts to 2-4 kg DM/ha/mm. The phrygana range type gave RUE values ranging from 0.45 to 2.11 kg DM/ha/mm with an average RUE value upto 1.46 (S.D.=0.35) which was the

lower one compared to those given for shrublands ( $2.40 \pm 0.66$ ) and grasslands ( $2.60 \pm 0.87$ ) (Table 2; Fig. 2).

**Table 2. Forage production, rain use efficiency factor and grazing capacity in Preveza Prefecture rangelands.**

Range Type	Area (ha)	Forage production* (kg DM/ha)	Usable forage (kg DM/ ha)	Rain Use efficiency (kg/ ha/mm)	Grazing capacity	
					AU/ha	AU
Grasslands	8,174	2,905	1,453	2.60	6.92	56,535
Phrygana	19,131	1,554	777	1.46	3.70	70,786
Shrublands	33,173	2,573	1,287	2.40	5.85	129,322
Total	60,478					256,643
Weighted mean		2,296	1,148	2.13	5.31	

\*Based on the average annual forage production over 2 years of study.

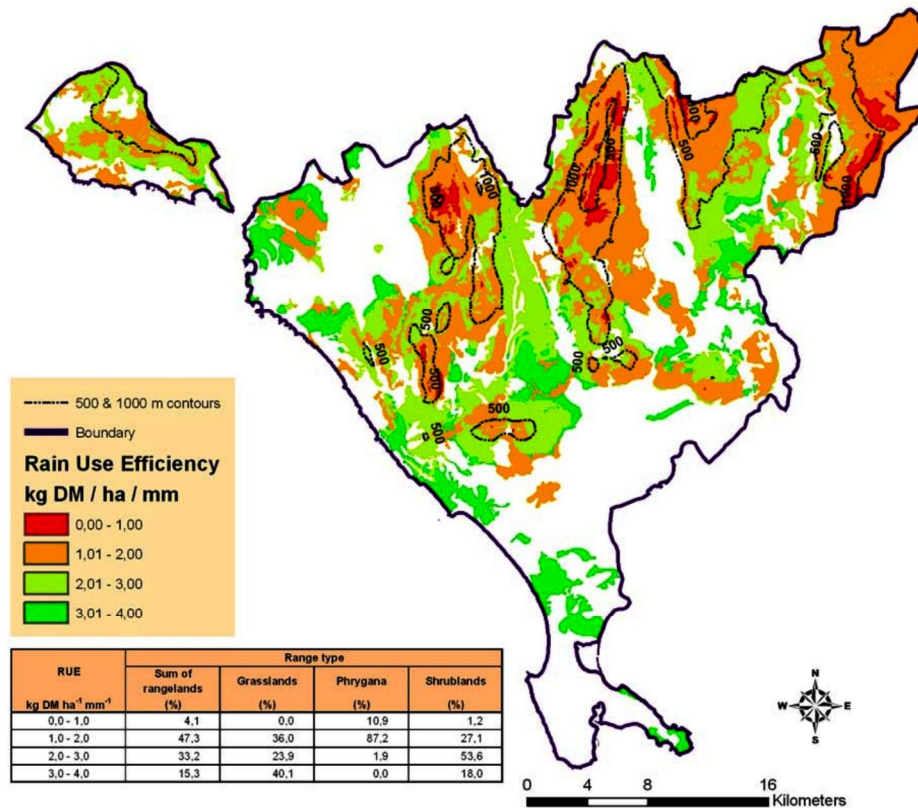


Fig. 2 Rain-use efficiency in Preveza Prefecture rangelands.

In general, RUE values found in all range types were very low despite the significant annual rainfall. Due to increase of annual rainfall with the altitude above sea level, one would expect higher RUE values in the uplands than in lowlands. However, such an assumption is not justified because the forage production in lowlands is higher than in uplands as a result of better climatic conditions and the longer duration of growing season (17, 20, 23).

Also, the spatial distribution of RUE in the basin indicates the highest RUE values found in the area where there is high rainfall and low degree of slope. Such low values provide evidence that these rangelands are overgrazed and so, they are in an unfavorable condition (11). Low RUE values could be due to various factors, including topography, soil's physical and chemical properties, the vegetation type and management regimes (18). The RUE is known to be substantially lower in degraded ecosystems and considerably higher in pristine conditions (6, 10, 18).

It is important to underline that in this study water losses 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 grazing capacity of Preveza Prefecture rangelands ranges from 0.47 to 8.54 AU/ha (Fig. 3; Table 2). The results also show that only 0.8 percent of the total rangeland area is below 2.10 AU/ha. The grasslands range type gave an average grazing capacity of 6.92 (S.D. =1.19) which was higher than shrublands ( $5.85\pm 1.20$ ) and phrygana ( $3.70\pm 0.62$ ) (Fig.3).

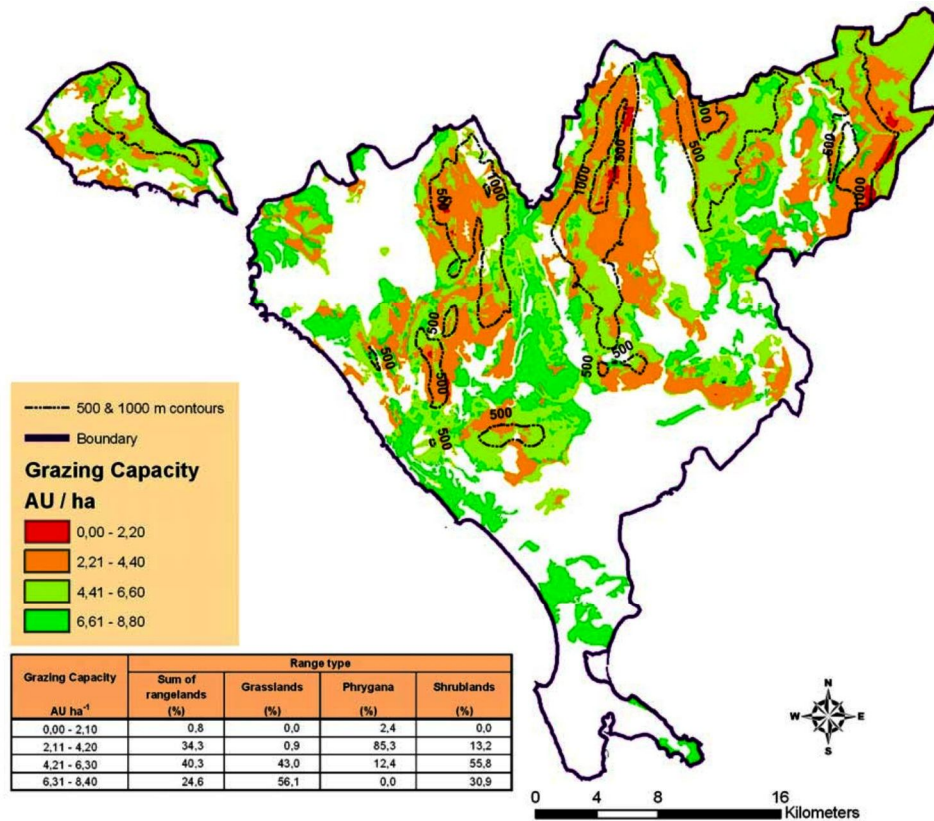


Fig. 3 Grazing capacity in Preveza Prefecture rangelands.

In terms of animal units, grasslands and phrygana range types were grazed by 219,802 sheep and cattle, while shrublands are grazed only 56,706 goats. Also, it was assumed that 50 percent of overall area of the shrublands was grazed by the goats due to their very high density avoiding by this way its utilization. Consequently, grazing-livestock population was about 72.6 percent over the estimated grazing capacity of grasslands and phrygana range types (Table 2), while in oak-dominated shrublands, the grazing capacity was about 14 percent higher than the existing goat population. Due to the fact that livestock data were provided by the local self-organized authorities (municipalities), it can be considered reliable. Thus, it is evident that grasslands and phrygana are overgrazed compared to the under-grazed oak-dominated shrublands leading to the degradation of rangelands and contributing to poor range conditions, especially in phrygana range type.

## CONCLUSION

This paper describes how we applied GIS techniques and field work to determine the rain use efficiency factor and grazing capacity in Mediterranean mountainous areas with great variation in landscape. This methodology can be used to any same rangeland environment of interest, given adequate field data.

The study concludes that forage production of Preveza Prefecture rangelands has high variation in relation to topography (altitude above sea level and degree of slope) which contributes to the variation of RUE factor and grazing capacity. The results also show that in grasslands and phrygana range types the usable forage is inadequate to meet the grazing animal requirements. Since grazing livestock is the main stamina of the economic activity in mountainous and semi-mountainous areas of Greece, enhancing the forage production by proper management practices the application could be economically more productive and environmentally beneficial.

It is further noted that since 3-year mean values for forage production and annual precipitation were used in this study, different results would be expected with a long-term data. Therefore, long-term results need to improve the accuracy of evaluations in Greece rangeland ecosystems.

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