The use of biomass stability as a grazing indicator in Mediterranean areas

Patón D., Fanlo R., Toboso A., Venegas F.M.

in

Porqueddu C. (ed.), Tavares de Sousa M.M. (ed.).
Sustainable Mediterranean grasslands and their multi-functions

Zaragoza : CIHEAM / FAO / ENMP / SPPF
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 79

2008
pages 135-I-V

The use of biomass stability as a grazing indicator in Mediterranean areas

D. Patón*, R. Fanlo, A. Toboso*** and F.M. Venegas***
*Ecology Unit, Faculty of Sciences, University of Extremadura, Avda. Elvas s/n, 06071 Badajoz, Spain
**Department of Vegetable Production and Forest Science, University of Lleida,
Avda. Alcalde Rovira Roure 177, 25006 Lleida, Spain
***General Direction of Natural Park of Monfragüe, Extremadura Government,
Arroyo de Valhondos 2, 10071 Cáceres, Spain

SUMMARY – The stability of biomass has been used as a useful parameter to indicate the range of fluctuations of primary productivity in grasslands. Stability is closely related to many properties of ecosystems such as inertia, richness, disturbance level, primary productivity, etc. In this paper, we shall explore the properties of stability as a grazing indicator for an appropriate management of Red Deer (*Cervus elaphus* L.) in the Monfragüe Biosphere Reserve and National Park (SW Spain). We have found that this parameter is very useful to determine semi-quantitative scales of disturbance that could be applied to sustainable management systems of Mediterranean grasslands.

Keywords: Mediterranean Basin, stability, indicator, grazing, red deer.

RESUME – *"Utilisation de la stabilité de la biomasse comme indicateur de pâturage dans les régions méditerranéennes". La stabilité de la biomasse avait été utilisée comme un paramètre utile décrivant le niveau d'oscillation de la productivité primaire dans les pâturages. La stabilité avait été rattachée à un grand nombre de propriétés des écosystèmes comme l'inertie, la richesse spécifique, le niveau de perturbation, la productivité primaire, etc. Dans cet article, nous explorons les propriétés de stabilité comme indicateur du pâturage pour une gestion appropriée du cerf commun (*Cervus elaphus *L.) dans la Réserve de la Biosphère et Parc National de Monfragüe (SO de l'Espagne). Nous avons constaté que ce paramètre est très utile pour déterminer l'échelle semi-quantitative de perturbation qui pourrait être appliquée pour une gestion durable des pâturages méditerranéens.*

Mots-clés : *Bassin Méditerranéen, stabilité, indicateur, pâturage, cerf commun.*

Introduction

Mediterranean grasslands are characterized by marked fluctuations in botanic composition, primary productivity, nutritional value and diversity (Puerto *et al.*, 1990; Espigares and Peco, 1994; Peco *et al.*, 1998). These fluctuations are naturally caused by annual rainfall levels, the monthly distribution of precipitation, maximum temperatures and the extension of drought periods. This natural variability operates simultaneously on different human impacts, which decreases even more the predictability of Mediterranean environments. In this sense, one of the most widespread alterations on these types of grasslands is overgrazing (Alados *et al.*, 2004; Alhamad, 2006). Moreover, overgrazing has been impacting Mediterranean grasslands of the Extremadura region (SW Spain) since the Roman Period (Reale and Dirmeyer, 2000a,b). At that time in history there began a coexistence between livestock and wildlife ruminants that has continued until the present, and this has caused Mediterranean areas to become one of the most altered areas in the World (Joffre *et al.*, 1988; Perevolotsky and Seligman, 1998). On a wider landscape scale, this multipurpose management has produced a generalized mosaic of grasslands intercalated with forests of different extensions that has increased habitat diversity (Barbero *et al.*, 1990). However, on a smaller scale, the damage caused by overgrazing has produced considerable reductions in specific diversity due to an excess of consumption of the more palatable plant species. When these processes operate on a large time scale this loss of plant diversity can affect the rest of the trophic levels, thus reducing the abundance and diversity of insects, micromammals and birds (Verdú *et al.*, 2000). Therefore, it is necessary to develop good analytical methods for the early detection of overgrazing in Mediterreanean environments. In this paper we shall demonstrate how biomass stability can be used as an excellent indicator of grazing. We have tested this parameter in many ecosystems of the Monfragüe Biosphere Reserve with excellent results. After comparing areas under red deer grazing with ungrazed areas, we have determined how the biomass stability parameter enables us to separate natural climatic fluctuations from damage by overgrazing. Moreover, we have determined a semiquantitative scale of stabilities that allow us to separate different areas according to the level of overgrazing. This proposed methodology can be widely applied as an early alert system for sustainable management of Mediterranean grasslands with special emphasis as regards the Monfragüe Biosphere Reserve.

Material and methods

Study area

The study area comprised 31,500 ha inside the Monfragüe Biosphere Reserve (116,162 ha), situated in South Western Spain (Fig. 1), between 39° 43' and 39° 53 'N latitude and 5° 45' and 6°06' W longitude. The area is located at 360 m a.s.l. and is characterized by a steep and rugged terrain with slopes ranging from 20% to 50% of the territory and six types of soils: Cambisol, Alisol, Acrisol, Leptosol, Regosol and Antrosol (García and López, 2002). Monfragüe belongs to the inferior mesomediterranean bioclimatic level (It = 330) (Rivas-Martínez, 1987). During the study period (2004, 2005 and 2006) the annual average rainfall was 642.3 mm with a drought period between 3 and 5 months according to the years.

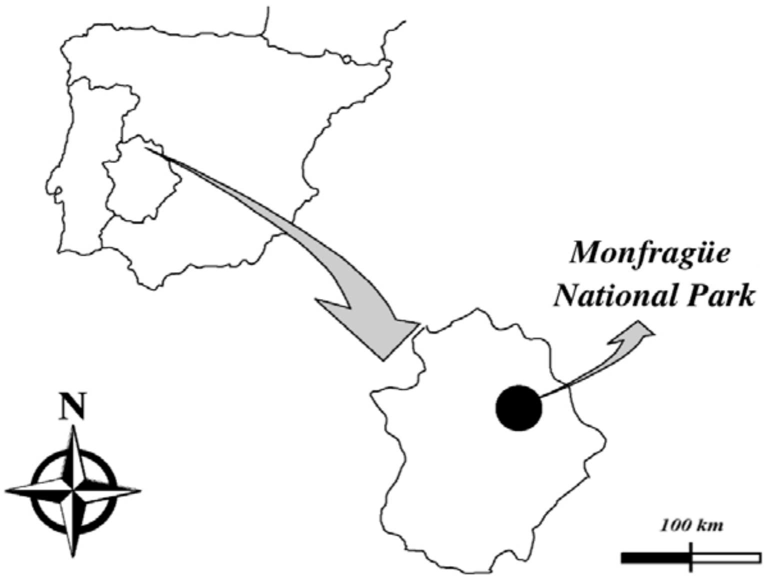

Fig. 1. Location of Monfragüe National Park in the Extremadura region (SW Spain).

The dominant vegetation is Mediterranean forest and shrublands in an advanced sucesional state (Patón *et al.*, 2002). Combining photo-interpretation (Buyolo, 1999) with TWINSPAN (*Two Way Indicator Species Analysis*) analysis (Patón *et al.*, 2004) a total of 16 ecosystems or vegetation formations were determined. The rangelands studied were located in ecosystems with a dominance of holm oak (*Quercus rotundifolia* Lam.) or cork oak (*Quercus suber* L.), which represent 10,383.21 ha (32.96%) and 5,090.81 ha (16.16%) respectively inside Monfragüe. Eight different sampling sites according to the composition of shrub species were established in both types of forests (Table 1).

As regards the fauna, the dominant herbivorous species of Monfragüe is the Iberian Red Deer (*Cervus elaphus* L. ssp. *hispanicus* Hilzheimer), very well adapted to the Mediterranean climate (Fig. 2). Red Deer are smaller in size and have a greater trophic adaptability than the North American or Central European subspecies, since its diet is based mainly on shrubs during late spring and summer (Garin *et al.*, 2001).

Table 1. Site differences in shrub species composition for *Quercus rotundifolia* (Lam.) and *Quercus suber* (L.) ecosystems

Dominant tree species	Site	Cover of woody species
Quercus rotundifolia	MER	50% *Quercus rotundifolia*, 50% *Retama sphaerocarpa*
Quercus rotundifolia	MEJ	50% *Quercus rotundifolia*, 50% *Cistus ladanifer*
Quercus rotundifolia	MEP	50% *Phillyrea angustifolia*, 50% *Quercus rotundifolia*
Quercus rotundifolia	MEA	100% *Quercus rotundifolia*
Quercus suber	MUB	40% *Quercus suber*, 40% *Cistus ladanifer*, 20% *Erica australis*
Quercus suber	MUA	40% *Quercus suber*, 20% *Cistus ladanifer*, 20% *Erica australis*, 10% *Phillyrea angustifolia*, 10% *Quercus faginea*
Quercus suber	MAM	50% *Quercus suber*, 25% *Phillyrea angustifolia*, 25% *Erica australis*
Quercus suber	MAA	100% *Quercus suber*

Fig. 2. Iberian Red Deer (*Cervus elaphus* L. ssp. *hispanicus* Hilzheimer) in a Mediterranean *Quercus rotundifolia* (Lam.) forest.

Sampling procedure

At the end of 2003, 4 permanent exclusions of 71 x 71 x 50 cm, completely closed and fixed to the ground with iron bars and wires, were situated at each site (Fig. 3). The small mesh size (50 x 50 mm) allowed only the entry of different micromammal species and therefore the grass inside these exclusions demonstrates the effect of red deer grazing. A total of 64 samples (2 measurements x 4 exclusions x 8 ecosystems) were analysed in each season, except in summer when the grass is totally dry and is not consumed by Red Deer, which only eat ligneous plants in this period. A total set of 576 samples (64 in each season x 3 seasons x 3 years) were analysed by the point-quadrat method based on 1 m lengths with 100 measurement points each cm. The contacts of each species (N_i) and the sum of total contacts (N) were registered:

$$N = \Sigma_{i=1}^{i=n} N_i$$

In a subset of 256 point-quadrats, the grass was harvested in 50 x 50 cm squares and dried in a SELECTA forced-air stove for 72 h at 65℃ and weighed on an OHAUS Scout-Pro electronic scales with ± 0.01 g precision. The biomass production (B) of a subset of 256 point-quadrats was compared to total contacts (N) using several regression models (linear, exponential, logarithmic…) that were tested in an R^2, ANOVA test, homoscedasticity based on the Breusch-Pagan test and residual normality tested by the Shapiro-Wilk procedure. The selected model was used as a fast method of biomass determination (Patón *et al.*, 2002).

Fig. 3. Permanent exclosures (71 x 71 x 50 cm) used in the present study showing the grazing impact of red deer on Mediterranean grasslands.

Data analysis

The temporal ecosystem stability of biomass (SB) is defined as the ratio between the mean abundance of each i-esimum point quadrat (X_i) and its standard deviation (S_i^2) throughout successive temporal samplings (Tilman, 1996).

$$SB = \frac{X_i}{S_i^2}$$

In our case, we did only calculated simple SB, since we had only three years of sampling which is too short time to register any ecological succession. An ANOVA test (Analysis of Variance) was carried out for the following independent factors and their interactions of order 2 and 3:

(i) Ecosystem was defined as the plant formation with dominance of *Q.rotundifolia* or *Q.suber.*

(ii) Site or Vegetation Unit according to Table 1.

(iii) Grazing. The different effect comparing inside (without grazing) and outside (pasturing) the exclosures was defined.

For all the statistical tests we used an R program (R Development Core Team, 2003) under a Debian GNU Linux system.

Results and discussion

A log-log model was selected due to its significant coefficient of determination ($R^2 = 0.987$; $p < 0.001$), ANOVA test ($F = 1.66E+4$; $p < 0.001$), homoscedasticity ($BP = 0.057$; $p > 0.05$) and residual normality ($W = 0.994$; $p = 0.407$). Only 6.64% of outliers were extracted and the log-log model was recalculated giving this function:

log(B(kg/ha)) = 1.345*log(contacts)

This equation was used for the determination of biomass for the total set of 576 point-quadrats. Afterwards an ANOVA test (Table 2) has demonstrated that only stability is significantly modified by grazing. This demonstrates that only non-natural disturbances such as grazing can structurally modify the changes in grasslands throughout a period of time. In fact, grazing completely alters the spatial distribution of plant species causing gaps where an intense colonization of new species and competence between them is produced. Therefore, the natural differences between sites or ecosystems do not modify the stability of grasslands, and the only differences are in botanic composition or nutritive value. In conclusion, Mediterranean grasslands operate in a similar manner in terms of temporal stability and only non-natural disturbances considerably modify this characteristic. In other words, stability remains within certain margins of variation typical of Mediterranean grasslands; nevertheless, disturbances alter these margins causing stronger fluctuations in productivity. Finally, we designed a semiquantitative scale of stabilities (Fig. 4) from 0 to 4 which demonstrates that grazed areas usually come under stability level 2 whereas ungrazed areas usually surpass this value. Thus this semiquantiative scale could be used as a good indicator of disturbances caused by grazing.

Table 2. Effect of different environmental factors (F-test of ANOVA) for stability of biomass (SB) in the three sampling years (2004-2006)

Factors	SB
Ecosystem	0.05ns
Site	1.79ns
Grazing	5.18*
Ecosystem*Site	0.18ns
Ecosystem*Grazing	0.05ns
Site*Grazing	0.01ns
Ecosystem*Site*Grazing	0.47ns
Residual standard error	0.63

*p < 0.05; ns: non-significant differences.

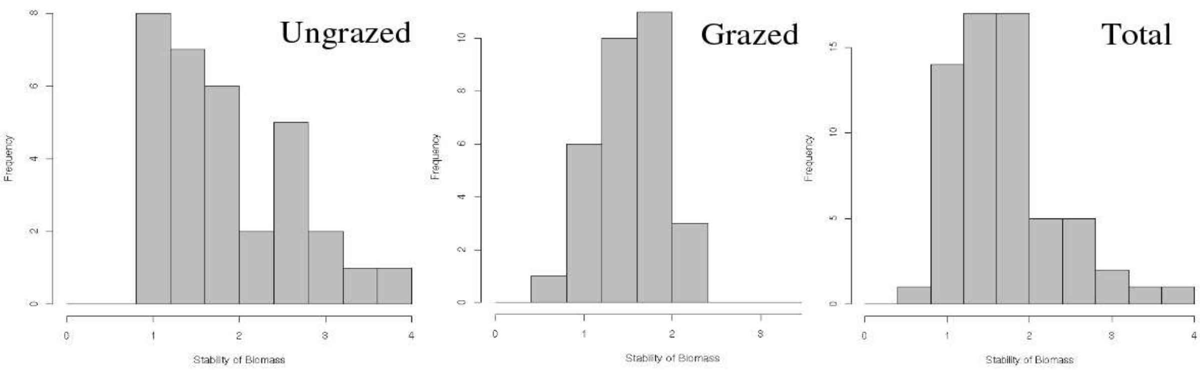

Fig. 4. Stabilities in ungrazed, grazed and total grasslands from Monfragüe Biosphere Reserve.

References

Alados, C.L., El Aich, A., Papanastasis, V.P., Ozbek, H., Navarro, T., Freitas, H., Mihalis, V., Larrosi, D. and Cabezudo, B. (2004). Change in plant spatial patterns and diversity along the successional gradient of Mediterranean grazing ecosystems. *Ecol. Model.*, 180: 523-535.

Alhamad, M.N. (2006). Ecological and species diversity of arid Mediterranean grazing land vegetation. *J. Arid Environ.*, 66: 698-715.

Barbero, M., Bonin, G., Loisel, R. and Quézel, P.C. (1990). Changes and disturbances of forest ecosystems caused by human activities in the western part of the mediterranean basin. *Plant Ecol*., 87(2): 151-173.

Buyolo, T. (1999). *Procesos evolutivos del paisaje y complejos ambientales del actual Parque Natural de Monfragüe*. PhD Thesis, Univ. de Extremadura, Badajoz, Spain.

Espigares, T. and Peco, B. (1994). Floristic fluctuations in annual pastures: The role of competition at the regeneration stage. *J. Veg. Sci.*, 5: 457-462.

García, A. and López, A. (2002). *Mapa de suelos de la provincia de Cáceres. Escala 1:300.000.* Universidad de Extremadura, Cáceres, Spain.

Garin, I., Aldezabal, A., García, R. and Aihartza, J.R. (2001). Plant composition and quality of the red deer (*Cervus elaphus* L.) diet in the Northern Iberian Peninsula. *Anim. Biodiv. Conserv.*, 24: 53-63.

Joffre, R., Rambal, S. and Ratte, J.P. (1988). The dehesa system of Southern Spain and Portugal as a natural ecosystem mimic. *Agro. Sys.*, 45(1-3): 57-69.

Patón, D., Buyolo, T., Fernández, L. and Cabezas, J. (2004). Determinación de las unidades de vegetación mediante el programa TWINSPAN en áreas cinegéticas de Extremadura. In: *44º Scientific Meeting of the Spanish Society for the Study of Grasslands, SEEP, Grasslands and Extensive Livestock*, Salamanca, Spain, 10-14 May 2004.

Patón, D., Núñez, J., Bao, D. and Muñoz, A. (2002). Forage biomass of 22 shrub species from Monfragüe Natural Park (SW Spain) assessed by log-log regression models. *J. Arid Environ.*, 52: 223-231.

Peco, B., Espigares, T. and Levassor, C. (1998). Trends and fluctuations in species abundance and richness. *Appl. Veg. Sci.*, 1: 21-28.

Perevolotsky, A. and Seligman, N.G. (1998). Role of grazing in Mediterranean rangeland ecosystems. *Bio. Sci.*, 48(12): 1007-1017.

Puerto, A., Rico, M., Matías, M.D. and García, J.A. (1990). Variation in structure and diversity in Mediterranean grasslands related to trophic status and grazing intensity. *J. Veg. Sci.*, 1(4): 445-452.

R Development Core Team (2003). *R installation and administration*. GNU Free Software Foundation.

Reale, O. and Dirmeyer, P. (2000a). Modeling the effects of vegetation on Mediterranean climate during the Roman Classical Period. Part I. Climate history and model sensitivity. *Glo. Planet Change*, 25(3-4): 163-184.

Reale, O. and Dirmeyer, P. (2000b). Modeling the effects of vegetation on Mediterranean climate during the Roman Classical Period. Part II. Model simulation. *Glo. Planet Change*, 25(3-4): 185-214.

Rivas-Martínez, S. (1987). *Mapa de series de vegetación de España 1: 400.000*. ICONA, Ministerio de Agricultura, Madrid, Spain.

Tilman, D. (1996). Biodiversity: Population versus ecosystem stability. *Ecology*, 75: 2-16.

Verdú, J.R., Crespo, M.B. and Galante, E. (2000). Conservation strategy of a nature reserve in Mediterranean ecosystems: The effects of protection from grazing on biodiversity. *Biol. Cons.*, 9(12): 1707-1721.