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Regional livestock grazing, human demography and fire incidence in the Portuguese landscape

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Abstract

Aim of study: Wildfire incidence in Portugal is high in comparison with other Mediterranean Europe countries. Wildfire problems have been worsened by complex interactions between land use, livestock grazing and human population during the 20th century. In this study we try to understand these interactions and relationships.

Area of study: Portugal country.

Material and methods: For the mainland Portuguese territory we present a statistical temporal analysis (1930-2001) based on the densities of livestock grazing and human inhabitants at the smallest administrative unit level, the parish. We compare these data with fire incidence descriptors (average area burned and average fire density) between 1990 and 2007.

Research highlights: We have identified clusters of parishes sharing common trends in the evolution of livestock and human inhabitant densities. A cause-effect relationship was not detected between livestock grazing density and fire incidence. However, the results point out clusters of parishes where conflicts between forest, fire and livestock grazing are important in the North, Centre and South regions of Portugal.

Key words: livestock grazing; inhabitants; forest; fire; vegetation.

Introduction

Portugal experienced the highest increase in mean annual burned area in Mediterranean Europe from 1985 to 2005 (Catry *et al.*, 2006). On average, 213,000 ha burned from 2001 to 2005, especially in the mountainous regions, which in Portugal are the poorest areas of the country from the socioeconomic point of view (Pinho, 2008). Wildfire problems tend to aggravate due to the complexity of interactions between land use, human demography and the modern changes (Mather and Pereira, 2006), in a process that has been taking place for the last one hundred years. Forest and shrubland biomass, which formerly was consumed by livestock and harvested by people for a variety of purposes, is increasing with the cease of traditional land use practices due to rural abandonment (Bland and Auclair, 1996; Moreira *et al.,* 2001; Azevedo *et al.*, 2010). As land management efforts decrease, fuel biomass builds up and generates flammable landscapes where the risk of fire spread is high. In spite of less intensive land use, traditional occupational burning to maintain pastures is still widespread in the Portuguese mountain ranges (Catry *et al.*, 2010).

Bengtsson *et al.* (2000) highlighted the need to understand natural disturbance dynamics and their relation with livestock grazing and human pressure, and mention how management practices are important to preserve biodiversity in cultural landscapes. In fact, the disturbance regimes under which European forests evolved reflect a mix of natural and anthropogenic factors. The role of humans in shaping ecosystems is particularly true for the Mediterranean Basin, and in Portugal population density and socioeconomic activities related with land use are the key drivers of fire incidence and of its regional variability (Catry *et al.*, 2010).

Agricultural decline, including of livestock grazing, has had an important role in the last decades increase in fire hazard in the Mediterranean Basin (Moreira *et al.*, 2011). Accelerated rural depopulation and abandonment of livestock grazing have occurred in Portu-

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gal like elsewhere in southern Europe (*e.g.* Lasanta-Martínez *et al*., 2005). However, the corresponding impacts on the fire regime are not well understood, and where grazing still exists its relationship with fire incidence has not been described. In this study we characterize the temporal trends (1930-2001) in livestock grazing and human population densities in Portugal. Regional variation in human inhabitants and grazing pressure is identified, categorized and then related with fire incidence descriptors.

Material and methods

We used official census data (1930-2001) on domestic herbivores (cattle, sheep and goats) and human inhabitants at the parish level, the smallest administrative unit in Portugal (see the Appendix). An urban typology (INE, 1998) was adopted to classify parishes as predominantly rural, moderately urban or urban; urban parishes were excluded from the study. The North, Centre and South regions of Portugal were individualized, using the Douro and Tagus rivers as boundaries. This partition is justified by the existence of important regional differences in land use and socioeconomic features. We used the 1934, 1955, 1972, 1989 and 1999 census for livestock, and the 1930, 1950, 1970, 1991 and 2001 census for inhabitants. The selection of census was based on Azevedo (1985) and Rosário (1998) and reflects the 20th century history of range management patterns.

For each selected period and parish we calculated the densities (n° · km^{-2}) of each livestock type (cattle, sheep, goats) and inhabitants. These variables were log transformed and used in a regional-level k-means cluster analysis (Jongman *et al.,* 1995) to identify groups of parishes with common evolution patterns.

The database was completed with parish-level fire incidence descriptors for the dynamics between 1990 and 2007, by using official Forest Services data: the average percent of burned area (APAB) and the average fire density (AFD) (fires 1,000 ha^{-1} year^{-1}). We used analysis of variance (ANOVA) to compare the fire regime descriptors among clusters of each region. Percentage values went through an angular transformation $y = \arcsin\sqrt{(x)}$ prior to the ANOVA (Sokal and Rohlf, 1995).

SPSS 13.0 (SPSS Inc, 2006) was used to carry out the statistical analysis. Statistical significance adopted the level of 5% ($p < 0.05$).

Results

The regional cluster analysis resulted in thirteen clusters of parishes for the Portuguese mainland (Fig. 1). The difference between each cluster's average is significant ($p < 0.001$) for both livestock grazing or inhabitant variables. Geographical continuity in relation to this study main goal was restricted to the coastal clusters in the North and the Centre regions. We could hypothesize the existence of continuity between *Noroeste Interior* and *Beira* clusters, located respectively in the North and Centre regions, but in fact their landscape structure is different (Torres-Manso, 2004).

Table 1 displays the mean fire incidence descriptors for each cluster, which helps in identifying clusters where extensive forest plantations and conflicts between competing land uses, *i.e.* livestock grazing and forestry, are more likely to result in high fire incidence: *Noroeste-Interior* and *Cordilheira Minhoto-Du-*

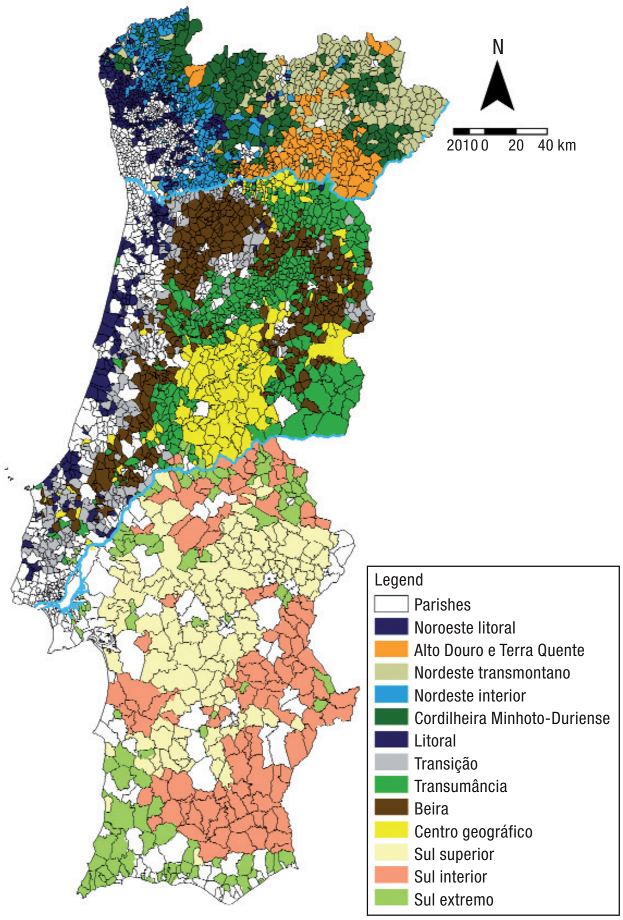

Figure 1. Spatial distribution of the parishes clusters in Portugal.

Table 1. Fire incidence descriptors (mean ± standard deviation) per cluster. *p*-values refer to the existence of significant differences between clusters within each region

Region	Clusters	No	APAB (%)	$p > F$	AFD (n° fires/1,000/ha)	$p > F$
Norte	Nor. Litoral	327	3.09 ± 5.17	0.000	13.98 ± 11.11	0.000
	Nor. Int.	367	4.15 ± 8.46		12.52 ± 8.94	
	C.Min-Dur.	217	3.01 ± 6.06		3.22 ± 3.18	
	N.Transm.	223	2.04 ± 7.24		2.00 ± 2.00	
	A.D. & T.Q.	153	1.94 ± 2.90		3.35 ± 3.84	
Centro	Litoral	121	1.02 ± 2.50	0.000	3.40 ± 5.21	0.81
	Trans.	263	1.68 ± 3.52		3.69 ± 6.22	
	Beira	399	2.75 ± 4.07		3.42 ± 3.73	
	Transum.	422	2.64 ± 4.32		3.28 ± 4.10	
	Ct. Geog.	172	4.04 ± 9.11		3.23 ± 4.21	
Sul	Sul Superior	127	0.11 ± 0.31	0.000	0.09 ± 0.33	0.000
	Sul Interior	116	0.74 ± 2.41		0.08 ± 0.30	
	Sul Extremo	116	0.74 ± 1.75		1.11 ± 1.91	

No: n° of parishes. Nor. Litoral: noroeste litoral. Nor. Int.: noroeste interior. C. Min-Dur.: cordilheira Minhoto-Duriense. N. Transm.: nordeste Transmontano. A.D.& T.Q.: Alto Douro e Terra Quente. Trans.: transição. Transum.: transumância. Ct. geog.: centro geográfico.

riense in the North, and *Beira, Transumância* and *Centro Geográfico* in the Centre. Our description and analysis will mainly focus on the aforementioned clusters. Fire incidence in the South of Portugal is substantially lower than in the North and the Centre.

The *Noroeste-Interior* cluster corresponds roughly to parishes that occupy low elevation areas dominated by forest and shrubland in northwestern Portugal. Higher elevations in a more inland position – the mountain ranges of *Peneda, Soajo, Gerês, Cabreira, Larouco, Barroso, Alvão, Marão and Padrela* – as well as *Nogueira, Bornes* and *Mogadouro* in northeastern Portugal correspond to the *Cordilheira Minhoto-Duriense* cluster.

Fig. 2a shows the temporal trends of livestock and inhabitants in the North region. Decreasing density trends for both grazing animals and people prevail in the *Noroeste Interior* and *Cordilheira Minhoto-Duriense* clusters, especially after 1955.

The ANOVA indicates significant differences ($p < 0.001$) in fire incidence among the five clusters (Table 1). The highest average fire density (AFD) occurred in the *Noroeste Litoral* cluster (14.0 1,000 ha^{-1} $year^{-1}$), probably in relation with population density, which is the highest and increased continuously during the study period. Fire density is also very high in the Noroeste Interior cluster (12.5 1,000 ha^{-1} $year^{-1}$), which has the highest average percent of burned area (APAB) (4.2%). AFD is substantially lower in *Cordilheira Minhoto-Duriense* (3.2 $1{,}000^{-1}$ ha $year^{-1}$) but its APAB is still high (3.0%) in the national context.

The *Beira* cluster in central Portugal is a rough match to the complex of mountains extending from *Montejunto* to *Montemuro* ranges, also including the ranges of *Leomil* and *Marofa*. Landscape and vegetation cover types are highly heterogeneous within this cluster, comprehending pine and eucalipt forests as well as oak woodland, shrubland and grasslands. Most *Beira* parishes encircle the *Serra da Estrela* mountain range, which is part of the *Transumância* cluster that includes other ancient transhumance areas such as northeastern central Portugal and the lands of *Idanha*. The *Centro Geográfico* cluster occupies the geographic centre of Portugal and its main feature is the prevalence of continuous stands of pines and eucalypts.

Sheep and goat livestock and inhabitants densities, which are more likely to affect fire incidence, have all been decreasing since 1950 in the three clusters, *Beira, Transumância* and *Centro Geográfico* (Fig. 2b).

Significant differences ($p < 0.001$) exist between the APAB among central Portugal clusters, but not between ignition densities (Table 1). Judging from our indicators, socioeconomic changes were more dramatic in *Centro Geográfico*, which is consistent with its 4.0% APB that stands out in the region and approaches the *Noroeste Interior* value.

Forest density in southern Portugal is generally lower than in the north and centre regions. Cork and holm

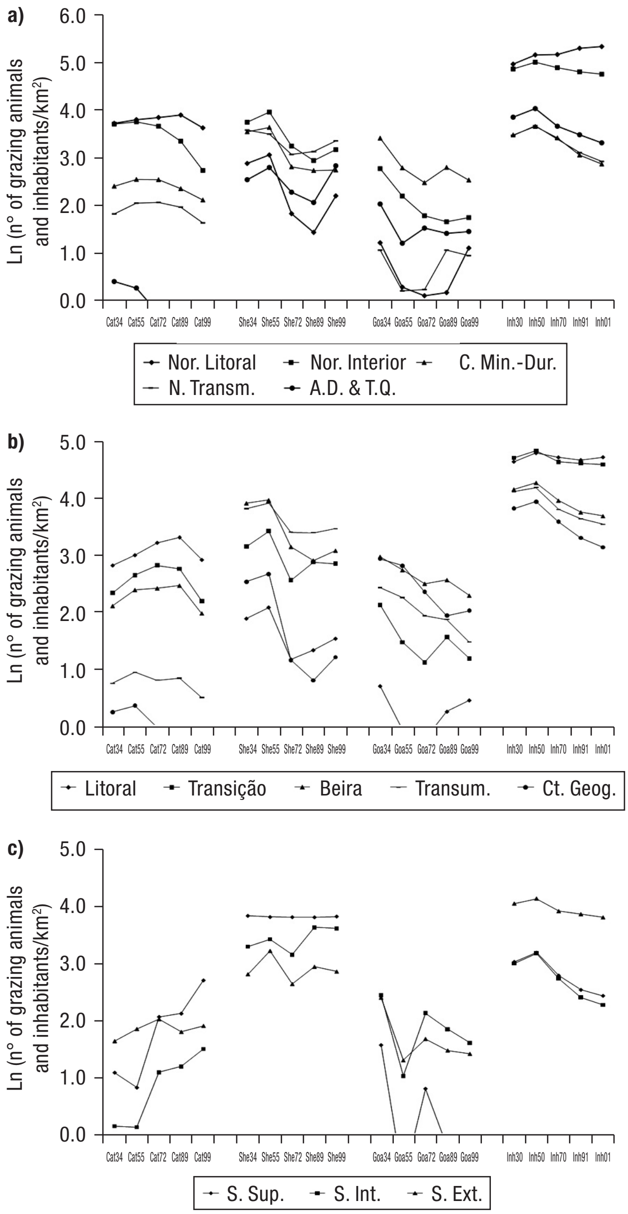

Figure 2. a) Livestock grazing dynamics (1934-1999) and inhabitants (1930-2001) densities in the five northern Portugal clusters. Cat.: cattle; She.: sheep; Goa: goats; inh: inhabitants. Nor. Litoral: noroeste litoral; Nor. Int.: noroeste interior; C. Min-Dur.: cordilheira Minhoto-Duriense; N. Transm: nordeste transmontano; A.D.& T.Q.: alto Douro e Terra Quente. b) Livestock grazing dynamics (1934-1999) and inhabitants (1930-2001) densities in the five central Portugal clusters. Transum.: transumância; Ct. Geog.: centro geográfico. c) Livestock grazing dynamics (1934-1999) and inhabitants (1930-2001) densities in the three southern Portugal clusters. S. Sup.: sul superior; S. Int.: sul interior; S. Extr.: sul extremo.

oak woodland associated to wheat, grassland or shrubland dominate the landscape in clusters *Sul Superior* and *Sul Interior*. The *Sul Extremo* includes higher-elevation areas with more diverse forest and shrubland types.

Fig. 2c shows the temporal trends of livestock and inhabitants in the southern Portugal. The South is much less fire-prone than the North and Centre regions. Nevertheless, fire incidence differences exist within the South clusters ($p < 0.001$, Table 1). The only striking difference is the AFD (1.1 1,000 ha^{-1} year^{-1}) in *Sul Extremo*, which is higher by one order of magnitude in relation to the other southern clusters.

Discussion

This study results exposed the regional variability in grazing livestock and human inhabitants densities in the form of clusters of parishes. Such variation is likely to explain fire incidence to some extent. Some clusters had at the same time the highest levels of small ruminant densities and the highest fire densities or burned area percentages. Hence, an increase in burn probability can result from grazing activities. The higher likelihood of fire is an outcome of management-ignited burns to maintain or create pastures, as well as of land-use conflicts. The clusters that conform to this pattern are *Noroeste Interior* and *Cordilheira Minhoto-Duriense* in northern Portugal, and *Beira* and *Transumância* in central Portugal, and coincide with mountains or plateaus. In Portugal, elevation has a positive influence on ignition occurrence, in relation with periodic burning required by traditional land use (Catry *et al.*, 2010).

Pastoral burning is responsible for 20% of all wildfires in Portugal, accounting for just 11% of the total surface burned, of which 78% is non-forested land; in contrast the remaining fires burn more forest (56%) than shrubland (37%) (Catry and Rego, 2008). Torres-Manso (2004) reported that parishes with the highest burned areas in *Noroeste Interior* and *Cordilheira Minhoto-Duriense* did not coincide with those parishes with the highest goat density, and the parishes with the highest average burned area closely matched those with large pine forest expanses and sometimes went through great decreases in goat density.

Land abandonment, fire occurrence and fire hazard are interconnected. Agriculture-related variables play an important role on the occurrence of fire ignitions in Europe, depending on the socio-economic context (Ganteaume *et al.*, in press). Extensive livestock grazing potentially decreases fire hazard through biomass consumption (Valderrábano and Torrano, 2000; Ruiz-Mirazo and Robles, 2012; Mancilla-Leytón *et al.*, 2013), even if landscape-level impacts are largely unknown (Bartolomé *et al.*, 2000). Conversely, grazing management is directly implicated in higher ignition density (Martínez *et al.*, 2009) in relation with the spatial arrangement of rangelands (Ruiz-Mirazo *et al.*, 2012), especially where land abandonment is less expressive (Martínez-Fernández *et al.*, 2013). Nonetheless, fires caused by shepherds or grazing activities are irrelevant to fire incidence when compared with the factors that have changed landscape management (Moreno *et al.*, 1998). Landscape-scale fuel accumulation (Loepfe *et al*., 2010) and homogeneity in vegetation cover favours wildfire spread (*e.g.* Viedma *et al.*, 2009), and a marked preference of fire for shrubland in relation to forest has been pointed out (Nunes *et al.,* 2005; Moreira *et al*., 2009). However, maximum fire size in Portuguese shrubland increases with time since fire, which implies that short rotation burning by shepherds constrains the spread of fire in the landscape (Fernandes, 2010).

Moreira *et al.* (2001) found that the landscape changes in northwestern Portugal between 1958 and 1995 were mainly described by decreases in the surfaces occupied by agriculture and low shrubland and an increase in tall shrubland, which parallels our findings on the temporal trends of livestock and human inhabitants. Consequently, depopulation and abandonment of rural activities in the impoverished inland regions, generate biomass accumulation and potentially increase the extent of burned surfaces. Almeida and Moura (1992) and, more recently, Mather and Pereira (2006), had already noticed these dependencies, and related the increase in fire incidence with losses in human population due to emigration. A self-sufficient system has been replaced by a system that integrates Mediterranean traditional highlands into wider and more dynamic territorial and economic spaces. Also, the fire problem can be perceived as an indicator of socioeconomic differences between areas and their respective levels of development (Lasanta-Martínez *et al.*, 2005; Vélez, 2009).

A sociological survey is needed in the more critical and contentious regions in order to characterize ancestral practices and knowledge, trying to conciliate traditional knowledge with informed landscape management. Empowering stakeholders and increasing active public participation are crucial for this process to succeed. According to Vélez (2006), environmental education is clearly deficient and is essential to both urban and rural communities. Learning processes related to the rational use of fire by rural populations and the mitigation of human-caused wildfires can effectively contribute to decrease fire incidence by managing social conflicts and developing new cooperation opportunities. Governments should define and implement the corresponding legal frameworks and platforms to make public participation in fire management possible and effective.

A duality creates conflicts in Mediterranean grazing systems (Poux *et al.*, 2009): by opening the vegetation cover, grazing can prevent fires and increase biodiversity, but the use of fire by shepherds can increase the risk of wildfire. An evaluation of the different types of grazing systems practices and of their environmental impacts must be done, namely the knowledge of daily grazing paths and their rangeland conditions, animal load and fire management practices. Shepherds with good practices and who promote positive environmental impacts could benefit from this assessment.

The development of programs to enhance the social value of shepherds and grazing activities is also very important. Grazing could be marketed in regards to fire hazard mitigation, promotion of land surveillance or integration with nature tourism. The joint implementation of these interventions in the landscape and interactive pasture management actions between the different stakeholders and agencies would be essential in this context (Moore and Smith, 2006). Effective fire prevention policies are needed to address the root causes of forest fires, actively involving all stakeholders relevant to land use planning and land management. Also, adequate landscape level planning policies should integrate forest fire risk assessment in all development plans related to the different economic sectors operating in a rural area, and integrated sustainable rural development should be promoted as part of preventive measures.

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Appendix: statistical data sources

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