Global Nest: the Int. J. Vol 3, No 1, pp 37-43, 2001

SETTING PRIORITIES FOR WILDFIRE SUPPRESSION POLICY IN GREECE, USING A RELATION BETWEEN YEARLY BURNED AREAS AND RECOVERY TIME

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Received: 14/10/99
Accepted: 10/04/01

ABSTRACT

In the Mediterranean region, fire is a natural factor, which contributes in the shaping of landscape and the preservation of a high degree of biodiversity. However, often repeated burning has negative impacts on the forested landscapes. When the processes of natural or artificial regeneration are efficient and the fire frequency is sufficiently low to enable the recovery of vegetation, recovery time T can be used as a tool for setting priorities for the preservation of ecological and social functions of the forested landsapes. Using a simple linear approach, we argue that their situation can be considered as acceptable, when the percentage of the yearly burned area in relation to the total forested area is much lower than 100/T (for practical purposes just lower than 10/T). This empirical rule was applied to the Greek forested landscapes. In the case of pine forests of *Pinus halepensis* and *Pinus brutia*, it was found that the condition implied by the rule was not satisfied and, therefore, a reduction of the yearly burned areas of these lowland conifer forests is necessary. However, as far as the other types of forests, as well as macchia and phrygana are concerned, the condition is satisfied.

KEY WORDS: wildfires, Mediterranean, forested landscape, burned areas, recovery time, fire suppression, *Pinus halepensis*, *Pinus brutia*.

INTRODUCTION

Mediterranean landscapes have always been subjected to fire, thus burning has become part of their dynamic natural equilibrium (Di Castri and Mooney, 1973). Fire constitutes a natural factor to which the Mediterranean ecosystems have had to adapt (Naveh, 1974). The comprehension of the actual role of fire in Mediterranean landscapes can be achieved only by recognizing its significance in the evolution of the Mediterranean flora and in the shaping of vegetation patterns (Naveh, 1994, Vazquez and Moreno, 1998). However, burning also has negative impacts on the Mediterranean landscapes, which are, in fact, commonly overstressed. The most serious of these is the effect of the combination of fire and overgrazing - a degradation factor from which the Mediterranean landscapes have suffered for many centuries (Vokou *et al.*, 1984; Yassoglou, 1986).

Yet, the effects of fire are very intricate, because of the complexity of the Mediterranean plant communities and the diversity of their responses to the type and intensity of burning. Important factors are the season and frequency of fire episodes, the interaction of burning with grazing and wood cutting, the inflammability of vegetation and the quantity of stored fuel matter, the meteorological conditions prevailing during and after burning, the biotic history of the burned areas before and after fire (Naveh, 1994).

The vegetation of the Mediterranean region withstands fire in various ways. This is the result of a long evolution during which plants have acquired mechanisms that enable them to overcome the effects of fire. This evolutionary adaptation manifests itself both by positive and negative feedback responses that enhance fire tolerance or enable the avoidance of burning. Burning is usually followed by rapid vegetative or reproductive regeneration. With increasing age, plant communities return to a state similar to that of unburned systems. The participation of the herbaceous layer, predominant during the early stages, decreases gradually with concomitant increase of the shrub and tree layers (Trabaud, 1994; Arianoutsou, 1998).

Fire history is important for understanding the relation between fire and vegetation (Vazquez and Moreno, 1998; Polakow and Dunne, 1999). Under the effect of frequent burning, plant communities become less resilient, a factor, which may lead to changes in the landscape pattern. Frequent fires in a matorral landscape can reduce species diversity (Fuentes *et al.*, 1994). Low-frequency burning of *Quercus suber* and *Quercus ilex* communities leads to greater landscape diversity, but frequent burning tends to transform these oak forests to shrublands (Trabaud and Galtie, 1996). Frequent fires may also have negative impacts on non-Mediterranean plant communities. For example, biodiversity and landscape heterogeneity of the heathlands of Brittany increase after a single fire episode, but tend to decrease as the frequency of burning increases (Morvan *et al.*, 1995). Likewise, the sensitivity of tallgrass prairies to nitrogen fertilization (Benning and Seasted, 1995) varies with fire history.

Although, generally and in the long term, infrequent fires do not alter Mediterranean plant communities, there are several short-term negative impacts that may affect people living near burned areas. The perturbation of the hydrological regime, the increase of soil sensitivity to erosion, the loss of timber production, the decrease of wild fauna, the loss of leisure capacities and, last but not least, the unwanted changes of the landscape are among the negative impacts that lead people to push for more effective fire suppression. However, forest fire prevention and suppression policy is costly and priorities have to be adopted.

In some Mediterranean countries, an important part of the forest fires are intentional (Vazquez and Moreno, 1998). In Greece, it is estimated that more than 30% of the number of forest fires, responsible for over 60% of the annually burned area, are the result of arson (Douros, 1992) and this is a cause for anxiety among the general public, who often relates forest fires to illusory conspiracies. In fact, most of the intentional wildfires are related to pasture creation or to expected changes in land use (Lekakis, 1995). As forest fires offer a good occasion for spectacular images, passions are greatly stirred by the media which convey the impression that the country will soon be deprived of its forests. Yet, even though existing data do not confirm such a tendency (Hadjibiros, 1993), the anxiety of the public press the government to take costly measures for fire suppression and for reforestation of the burned areas.

The aim of this paper is to propose a simple model which would allow forested landscapes at great risk to be identified and fire suppression priorities to be determined, in order to facilitate a wildfire management that should be implemented in complex physical and social settings.

METHODOLOGY

In what follows, under “forested landscape” we refer to a landscape covered by natural vegetation that may include trees, bushes, spiny sub-shrubs (phrygana) or herbaceous species.

A simple linear dependence (Hadjibiros, 1993) can relate the area burned each year to the average number of years needed for the recovery of the forested landscape. The corresponding formula is:

$$f = 100 - Tg \qquad (1)$$

where:

- f is the percentage of the forested landscape (of a region or a country) which is covered by well established natural vegetation in a given year,
- g is the average percentage of the forested landscape burned each year, and
- T is the recovery time, i.e. the average number of

years after which the forested landscape fully recovers. The percentage of the area that has not fully recovered at a given moment will be Tg.

The linear formula (1) is based on the differential equation:

$$dz/dt = gf - (1 - f)/T$$

where z is the rate of change in a forested landscape. If dz/dt=0 (see condition B below), then f=1/(1+Tg) or, approximately: f=1 – Tg (taking the first two terms of the Taylor series), that is: f=100% – Tg.

The above approach is applicable to burned landscapes that recover after fire through natural or artificial processes. Landscapes that loose their natural vegetation due to reasons other than fire are not considered.

Relation (1) is not valid and consideration of recovery time is less useful, if the following conditions are not satisfied:

A. Burned areas do not burn again during the recovery period. If such burning occurs, the environmental consequences of fire are more serious and the natural landscape tends to change drastically.

B. The average surface burned each year does not exceed the average area which recovers each year through natural regeneration or reforestation. In the case of such an excess, the natural landscape would change because the vegetation cover would decrease with time.

Given the above limitations, it can be concluded from (1) that the forest cover is close to 100% if:

$$Tg << 100 \text{ or } g << 100/T \qquad (2)$$

For practical purposes, we can accept that (2) is satisfied if:

$$Tg < 10 \text{ or } g < 10/T \qquad (3)$$

It should be noted that g is always less than 100/T, since, because of the condition A, g cannot be greater than 100/(T+1).

Recovery time T is not the same for different categories of natural vegetation. In the case of Greek forested landscapes, at least four different categories should be considered:

1. Phrygana and grasslands, which are mainly consisted of low spiny or aromatic species. Common in them are *Sarcopoterium spinosum*, *Thymus capitatus*, *Phlomis fruticosa*, *Euphorbia acanthothamnos*, *Cistus spp.* etc. These communities, which cover about 11% of the land surface, are found in coastal as well as in mountain areas. They often burn, partially because of traditional fires set by shepherds, but they are well adapted to fire. Post-fire regeneration occurs by resprouting, as well as by seed germination. Their recovery does not last more than 7 years (Papanastasis, 1977; Arianoutsou, 1984; Trabaud, 1994). On the basis of this information, the value T=7 years has been adopted for the recovery time of the Phrygana/grassland landscapes.
2. Shrublands (Mediterranean macchia) dominated by evergreen sclerophyllous species, like *Pistacia lentiscus*, *Quercus coccifera*, *Quercus ilex*, *Arbutus unedo*, etc. They cover about 24% of the land surface and are found in coastal as well as in mountain areas. They burn frequently, partially because shepherds use fire as a traditional means of pasture improvement. These ecosystems are adapted to fire and their post-fire regeneration takes place mainly by resprouting (Trabaud, 1994). Trabaud (1992) studied a community of *Quercus coccifera* and found that a 6-year fire frequency causes the least change in the vegetation composition. According to the same author, the burned macchia recovers generally in 10 years. On the basis of this information, a value for the recovery time T=10 years has been adopted.
3. Forests dominated by *Pinus halepensis* or by *Pinus brutia*. These forests cover about 4% of the land surface and are found mainly at low altitudes, often near coastal areas and on islands. They are highly flammable and are often subjected to arson, with the aim of changing the land use (Douros, 1992), mainly in areas where land prices are high. The pyrophile characteristics of these forested landscapes and the post fire natural regeneration of *P. halepensis* (Abbas *et al.*, 1984; Thanos *et al.*, 1996; Herranz *et al.*, 1997) and of *P. brutia* (Thanos and Marcou, 1991) have been well studied. Regeneration is generally abundant, but not always successful, being strongly dependent upon factors such as the meteorological conditions after fire, the condition and the slope of the soil ground, seed and seedling predation,

competition etc. However, these forests are often reforested if natural regeneration is not satisfactory, since they often occur in peri-urban and in coastal landscapes. The recovery time is very irregular. Some years after fire, a young forest has generally been established, but a proportion of young pines remain short for a period of several years, forming a sampling bank and waiting for favourable environmental conditions (Thanos and Marcou, 1991). The age when 50% of the population is reproductive may be in the range of 7-15 years for *P. halepensis* and of 10-20 years for *P. brutia*. Consequently, an even-aged Mediterranean pine forest will reach reproductive maturity at an age of 15-30 years, depending on environmental conditions and site quality (Thanos and Daskalakou, 2000). The assumption of a value T=25 years is considered to correspond to a point of minimal resilience, although a safe estimation would require a higher value.

4. Montane conifer and deciduous forests. They are dominated by *Abies cephalonica*, *Abies borisii-regis*, *Pinus nigra*, *Pinus heldreichii* or by deciduous trees, like *Fagus sylvatica*, *Quercus spp* etc. All these various types of forests cover about 21% of the land surface. They have very different characteristics, they are not generally adapted to fire and they do not burn frequently (Kailidis, 1990). These forests differ considerably in their recovery speed, but it is not necessary to consider them in separate groups for the purpose of this study. The value T=70 years, which has been adopted, is not thought to be an underestimation, given that even in boreal forests with slow development, the mean time between two big fires has been estimated at 69 years (Larsen and MacDonald, 1998).

RESULTS AND DISCUSSION

The application of relation (3) to the case of Greek forested landscapes presupposes that conditions A and B are satisfied. Analytical data on the different forested areas that burn each year and on those which recover through reforestation or natural regeneration are lacking. Nevertheless, the fact that the surface of forested landscapes has increased in Greece during the last decades (Ministry of Agriculture, 1992) can be used as an indication that, at a country level, no important deforestation took place, despite previous estimations (Margaropoulos, 1979). Therefore, despite the non-negligible percentage of burned areas that do not recover, because of grazing or unfavourable natural conditions, it will be assumed that conditions A and B are approximately satisfied.

Data on burned forested areas of Greece are available for the period 1957-1999 (Ministry of Agriculture, 2000). The percentages of the different burned areas (g) were calculated from data on the forested landscapes of Greece (Ministry of Agriculture, 1992), using the approaches of Kailidis (1990) and Hadjibiros (1993). Their mean values for the whole period 1957-1999 and for the sub-periods 1960-1969, 1970-1979, 1980-1989 and 1990-1999 are given in Table 1. The recovery times (T) estimated for the 4 categories of forested landscapes, as well as the products (Tg) are also presented in the same Table. In combination with the relation (3) they lead to the following results:

1. Relation (3) does not hold for forests of *P. halepensis* and *P. brutia* neither for the whole period 1957-1999, nor for any of the sub-periods. During the 80's and the 90's the situation is similar, but much more serious than the situation during the previous sub-periods.
2. Relation (3) holds for all the other categories of Greek forested landscapes for the whole period 1957-1999 as well as for all sub-periods. There is a considerably increasing impact of wildfires during the 80's which remains almost the same during the 90's. This increase is less important for phrygana/grasslands landscapes. Nevertheless, for all types of forested landscapes, except for *P. halepensis* and *P. brutia* forests, the overall percentage of yearly burned area is still relatively low.

Generally, the examination of the product (Tg), which gives an estimation of the importance of the percentage of burned areas in relation to the recovery time, shows that there is a serious threat for the forests of *P. halepensis* and *P. brutia*. The situation seems to be alarming, given that the value T=25 could be in fact an underestimation. As far as the rest of the forested landscapes are concerned, it seems that the present situation is not alarming.

The percentage of burned areas of *P. halepensis* and *P. brutia*, already high during the 60's and the 70's, has become much higher during the 80's and the 90's. As a result, even if these forests fully recover after fire and even if they are not subjec-

Table 1. Recovery time of forested landscapes (T) and average percentage of burned areas (g) from 1957 to 1999 in Greece

Forested landscapes	**T Years**	**g (%)**					**Tg (%)**				
		1957-1999	60's	70's	80's	90's	1957-1999	60's	70's	80's	90's
Phrygana/ Grasslands	7	0.47	0.28	0.44	0.59	0.71	3.29	1.96	3.08	4.13	4.97
Mediterranean macchia	10	0.43	0.24	0.20	0.75	0.61	4.30	2.40	2.00	7.50	6.10
P.halepensis/ P.brutia	25	1.85	0.56	1.18	3.03	3.00	46.2	14.0	29.5	75.7	75.0
Other forests	70	0.09	0.03	0.06	0.14	0.14	6.3	2.1	4.2	9.8	9.8

ted to further burning or grazing, an important proportion of them will exist in an immature form. Mature forms of forest cover will remain significantly less than the potential maximum and, consequently, the role of these forested landscapes as recreation areas for humans will be degraded and their economic value diminished. They may also be less efficient in protecting the soil, in regulating the hydrological cycle or in offering habitat to the fauna. Therefore, these forests may not be able to fulfil their role and the functions that society and particularly city dwellers expect from them.

Most if not all ecological systems undergo cycles of disturbance and recovery that involve characteristic scales of space and time (Naveh, 1994). This is particularly true in the case of the relation of pine forests to fire. In the Mediterranean region, people living in rural areas are accustomed to coexisting with low-altitude pine forests, as well as with problems related to them. However, if the frequency of fire episodes or the proportion of burned areas are too high, then corrective intervention is needed, although (Naveh, 1994) fire should not be considered as a wholly condemnable element that has to be prevented at all costs and at all times. Given that fire is an unavoidable natural phenomenon, corrective intervention should focus on measures for the prevention of man-induced wildfires and on the restoration of burned forested landscape. This last objective can be achieved mainly by the protection of natural regeneration after burning and, in cases where it is considered necessary, by artificial reforestation.

Greater efforts to suppress fires are necessary in cases in which the average burned areas are larger than an acceptable level. Its magnitude could be defined on the basis of relation (3), with the restrictions that burned areas fully recover by natural regeneration or artificial reforestation, and that no further burning occurs during the recovery period. In these cases, the recovery time is an important parameter for determining policy priorities.

Regarding the forest policy in Greece, it can be argued that copious and costly efforts dedicated to forest fire suppression are not excessive in the case of the forests of *P. halepensis* and *P. brutia*. In fact, they must be intensified, because even full recovery is not sufficient. More effective action is needed in the domain of fire prevention and suppression, so that the proportion of *P. halepensis* and *P. brutia* forests burned yearly can become significantly reduced.

Conversely, for the rest of the forests, the macchia and the phrygana/grassland of Greece, the situation is considered generally as not threatening. The present figures suggest that, if fire frequency remains low and if regeneration is adequate, the aspirations of modern society regarding forest landscape quality could be fulfilled at an acceptable level. Therefore, policy priorities should focus on prevention of frequent fires and on regeneration of burned areas.

Finally, it should be noted that these conclusions are based on a simple linear approach and should be validated and expanded by additional work. A more precise estimation of the recovery time, the use of vegetation types defined in more detail as well as the consideration of spatial heterogeneity within each vegetation type could contribute in developing a more complete approach, which would, eventually, lead to more specific guidelines on wildfire management.

AKNOWLEDGEMENTS

The author wishes to thank all persons and especially anonymous referees who have read and commented earlier versions of this paper. A part of this work was carried out in the "Laboratoire d' Évolution des Systèmes Naturels et Modifiés" of the "Museum National d' Histoire Naturelle" in Paris. I wish to thank Professor J. C. Lefeuvre and its personnel for their kind hospitality.

REFERENCES

Abbas H., Barbero, M. and Loisel, R. (1984), Réflexions sur le dynamisme actuel de la regénération naturelle du pin d'Alep dans les pinèdes incendiées en Provence calcaire (de 1973 à 1979), *Ecologia Mediterranea*, **10**, 85-104.

Arianoutsou, M. (1984), Post-fire successional recovery of a phryganic (east Mediterranean) ecosystem, *Acta Oecologica Plantarum*, **5**, 387-394.

Arianoutsou, M. (1998), Aspects of demography in post-fire Mediterranean plant communities of Greece, In: *Landscape Disturbance and Biodiversity in Mediterranean-type Ecosystems*, Rundel, P.W., Montenegro, G. and Jaksic, F.M. (eds), pp. 273-295, Spinger, Berlin.

Benning, T.L. and Seasted, T.R. (1995), Landscape-level interactions between topoedaphic features and nitrogen limitation in tallgrass prairie, *Landscape Ecology*, **10**, 337-348.

Di Castri, F. and Mooney, H. (1973), Mediterranean Climate Ecosystems. Origin and Structure, Springer, Berlin.

Douros, G. (1992), The causes of fires in the Greek forests, *Nea Oikologia*, **92**, 24-26 (in Greek).

Fuentes E., Segura, A.M. and Holgren, M. (1994), Are the responses of matorral shrubs different from those in a ecosystem with a reputed fire history?, In: *The role of fire in Mediterranean-type ecosystems*, Moreno, J.M. and Oechel, W.C. (eds), *Ecological Studies*, **107**, 16-23, Springer-Verlag.

Hadjibiros, K. (1993), The forested area destroyed by fire and the importance of its rehabilitation time, In: *Proceedings of the 3rd Conference on Environmental Science and Technology*, volume A, University of the Aegean, Lesvos, pp. 664-671 (in Greek).

Herranz J.M., Martinez-Sanchez, J.J., Marin, A. and Ferrandis, P. (1997), Post-fire regeneration of *Pinus halepensis* Miller in a semi-arid area in Albacete province (Southeastern Spain), *Ecoscience*, **4**, 86-90.

Kailidis, D. (1990), Forest Fires, Giachoudi-Giapouli, Thessaloniki, (in Greek).

Larsen, C.P.S. and MacDonald, G.M. (1998), An 840 year record of fire and vegetation in a boreal white spruce forest, *Ecology*, **79**, 106-118.

Lekakis, J.N. (1995), Social and Ecological Correlates of Rural Fires in Greece, *Journal of Environmental Management*, **43**, 41-47.

Margaropoulos, P. (1979), Forest Communities, In: *Proceedings of Conference on the Protection of the Flora, Fauna and Biotopes in Greece*, Hellenic Society for the Protection of Nature, Athens, pp. 49-69 (in Greek).

Ministry of Agriculture (1992), Results of the First National Survey of Forests, Forest Service, Athens (in Greek).

Ministry of Agriculture (2000), Report of Activities of Forest Service for 1999, Forest Service, Athens (in Greek).

Morvan, N., Burel, F., Baudry, J., Trehen, P., Bellido, A., Delettre, Y.R. and Cluzeau, D. (1995), Landscape and fire in Brittany heathlands, *Landscape and Urban Planning*, **31**, 81-88.

Naveh, Z. (1974), Effects of fire in the Mediterranean region, In: *Fire and Ecosystems*, T.T. Kozlowski and C.E. Ahlgren (eds), pp. 401-434, Academic Press.

Naveh, Z. (1994), The role of fire and its management in the conservation of Mediterranean ecosystems and landscapes, In: *The role of fire in Mediterranean-type Ecosystems*, J.M. Moreno and W.C. Oechel (eds), *Ecological Studies*, **107**, 163-185, Springer-Verlag.

Papanastasis, V.P. (1977), Fire ecology and management of phrygana communities in Greece, In: *Proceedings of Symposium on the Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems*, Palo Alto, California, USDA Forest Service, Washington DC, General Technical Report WO-3, pp 476-482.

Polakow, D.A. and Dunne, T.T. (1999), Modelling fire-return interval T: stochasticity and censoring in the two-parameter Weibull model, *Ecological Modelling*, **121**, 79-102.

Thanos, C.A. and Marcou, S. (1991), Post-fire regeneration in Pinus brutia forest ecosystems of Samos island (Greece): 6 years after, *Acta Oecologica*, **12**, 633-642.

Thanos, C.A., Daskalacou, E.N. and Nikolaidou, S. (1996), Early post-fire regeneration of a Pinus halepensis forest on Mount Parnis, Greece, *Journal of Vegetation Science*, **7**, 273-280.

Thanos, C.A. and Daskalacou, E.N. (2000), Reproduction in *Pinus halepensis* and *P. brutia*, In: *Ecology, Biogeography and Management of Pinus halepensis and P. brutia Forest Ecosystems in the Mediterranean Basin*, Ne'eman, G. and Trabaud, L. (eds), Backhuys Publishers, Leiden, The Nederlands (in press).

Trabaud, L. (1992), Influence du régime des feux sur les modifications à court terme et la stabilité à long terme de la flore d'une garrigue de *Quercus coccifera, Revue Écologie* (*Terre et Vie*), **47**, 209-230.

Trabaud, L. (1994), Post-fire Plant Community Dynamics in the Mediterranean Basin, In: *The role of fire in Mediterranean-type ecosystems*, J.M. Moreno and W.C. Oechel (eds), *Ecological Studies*, **107**, 1-15, Springer-Verlag.

Trabaud, L. and Galtie, J.F. (1996), Effects of fire frequency on plant communities and landscape pattern in the Massif des Aspres (Southern France), *Landscape Ecology*, **11**, 215-224.

Vazquez, A. and Moreno, J.M. (1998), Fire frequency and fire rotation period in areas with different potential vegetation type in peninsular Spain, In: *Fire Management and Landscape Ecology*, Trabaud L. (ed), pp. 305-314, International Association of Wildland Fire, USA.

Vokou, D., Diamantopoulos, J., Mardiris, T.A. and Margaris, N.S. (1984), Desertification in Northwestern Greece; The case of Kella, In: *Desertification in Europe*, R. Fantechi and N.S. Margaris (eds), pp. 155-160, Reidel.

Yassoglou, N. (1986), The production potential of soils: part II- Sensitivity of the soil systems in Southern Europe to degrading influxes, In: *Scientific basis for soil protection in the European Community*, H. Barthe and P. L' Hermite (eds), pp. 87-122, Elsevier.