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# Forest fires in Portugal: how they happen and why they happen

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Forest fires are recurrent phenomena in Southern European countries, due to the nature of Mediterranean forest and climatic characteristics. In Portugal, however, in the recent years, forest fires have become a public calamity and are now endangering the sustainability of the forest itself, as well as several derived economic activities. This paper reviews the past and current situation of forest fires in Portugal, analyses its main causes and consequences and derives recommendations to overcome this problem.

*Keywords:* Forest fires; Sustainability; Mediterranean forest

## 1. Introduction

Forest fires are part of the dynamics of planet Earth. Their occurrence derives from the interaction between biophysical factors and human land use. The environmental effect of forest fires ranges from local to planetary and can eventually affect all socio-economic and environmental categories as well as the main ecosystem reserves, which form the basis for several human activities. The integral nature of fire in growth cycles of vegetation is well evidenced in the case of the bushfires of Australia. In Portugal, such a parallel evokes the horror of the destruction, but also should encourage the authorities to study methods of fire prevention and control as practised by the rural fire services in Australia.

The forest fires that occurred in Portugal in recent years will remain long in the memory. This terrible occurrence is a typical example of how forest fires lie critically at the interface between human society and the ecological system of our planet [1].

To begin, a forest fires needs a specific ignition source, an oxygen donor and a fuel source, as in any combustion event. The specific Portuguese environment, is one of Mediterranean bush and forest dominated by species that are fire prone and that are the result of years of co-evolution in a climate seasonally wet and warm, with regular heat spells, examples of tree species include eucalyptus, pine and cork oak.

The return interval of forest fires vary from short (about 20 years) for dry to medium forests, to long (100 years) for wet forest, which are arranged in the landscape as a mosaic determined mainly by topography [2].

In Portugal, the problem of forest fires is aggravated by the existence of ancient traditional agricultural practices such as the use of fires to prepare the soil for new crops, acting also as a waste elimination procedure, and also to promote the growing of grass to be used for cattle feedstock. This practice resembles the burning-off of stubble fields in Great Britain.

In addition to these factors, there are also inadequate forest management practices such as the lack of bush and forest residue collection, insufficient economic resources to prevent, and control and fight fire. Forest fire is, indeed, one of the environmental aspects of Mediterranean forest. Yet, the environmental factors in addition to the structural, social and political aspects are significant and make Portuguese forest fires a public calamity and ecological disaster affecting considerable land area.

In Portugal, the forestry sector provides 3.2% of GDP, 12% of industrial GDP, about 11% of exports and 260 000 direct and indirect jobs [3]. Naturally, the importance of the forest goes further than the direct economic aspects of the forestry sector and is also important in terms of maintaining the hydrological regimes and cycles, protecting the soil against erosion, supporting biodiversity, carbon dioxide absorption, is a source of raw materials for local economic activities, scenic and environmental support for leisure and tourism activities.

Forest fires, apart from generating dramatic economic problems, result in severe environmental effects and almost irreversible results, such as soil recovery, loss of natural and cultural heritage, loss of human lives, increases of greenhouse gas emissions, pollution of water resources and changes to hydrological regimes [4].

## 2. Current situation

The forest fires that took place in Portugal during July and August 2005, burned more than 200 000 ha and highlighted that the strategies engaged to deal with them were insufficient (see figure 1). The main causes of forest fires are already known and persist: climatic factors, aggravated by an extreme dry spell affecting almost all of Portugal, which follows a series of several very dry years; inadequate land and forest management exhibiting very high thermal load in the vicinity of villages, which leads to the dispersion of fire fighting resources and also dispersed uncontrolled dumps containing inflammable materials abandoned to arsonists.

In July 2004, 129 540 ha of bush and forest burned in 21 870 fires [5] which took place mainly in Northern (Barcelos, Boticas, Chaves, Mirandela, National Park of Peneda-Geres, Valpaços), Central (Alverca, Mafra, Pernes, Torres Novas) and Southern Portugal (Almodovar, Loulé, Monchique, National Park of Arrábida), and the government invested about 80 million in fire fighting.

In 2003, in just two weeks of August and September, compounded by exceptional and extreme meteorological conditions (high temperatures, very low relative humidity and unstable winds) the situation evolved to a public calamity: 18 people were killed, about 100 houses were destroyed and 423 950 ha were burned. Of these 280 747 ha were forest and 143,203 ha were bush [6]. This former number is four times more than the yearly average for the 1990s and two times worst than in 1991, as shown in figure 2. Also, the number of fires resulting in a burned area of more than 1 ha that took place in 2003 was about 60% of the average for the period ranging from 1998 to 2002. The most affected regions were Beira, in the east and Alentejo in the south and represented, respectively, 37 and 24% of the total burned area. It is estimated that more than 25% of the larger forested pine (*pinus pinaster*) area in Europe was burned [6].



Figure 1. Lisbon at dusk surrounded by smoke of nearby forest fires, 25 July 2005.

According to data released by the ICN, the National Conservation Institute [6], more than 28 000 ha were burned during 2003 in Protected Areas, which largely exceeds the average value of 11 000 ha for the period 1998–2002. Although the number of fires decreased by 13%, in comparison to 2002, the burned area increased about 2.5 times, as shown in figure 3.

In fact, for the period ranging from 1980 and 2002, the average yearly burned area reached 93 000 ha; in 1998–2002 it was 120 000 ha/year, whereas in 1980–1984 was only of 55 000 ha/year [6].

The fires in 2003 (and those that are happening again in 2005) took lives and villages, the smoke affected the air quality in several cities and the media, both newspapers and television, showed terrible images of this disaster and this aroused the general public and created a wide discussion about the causes, consequences and possible solutions to overcome these recurrent disasters.

The average annual fire fighting cost is €25 million totalling up to €80 million invested in human and equipment resources. The Department of Forests estimated the direct losses as more than €1000 million in 2003 [8]. This same Department has not yet completed the estimates for 2004 and 2005, but one could anticipate €323 million for 2004 and more than €500 million for 2005, based on the corresponding proportion of burned area.

A recent estimate [8] produced the data presented in table 1, corresponding to the 400 000 ha burned in 2003. These values account for one third of the annual allowed emission of greenhouse gases for Portugal, authorized by the Kyoto Protocol (60 Mton/year) and 13% more than the thermal power produced without any energy recuperation. For 2004 and 2005 these values were also attained.

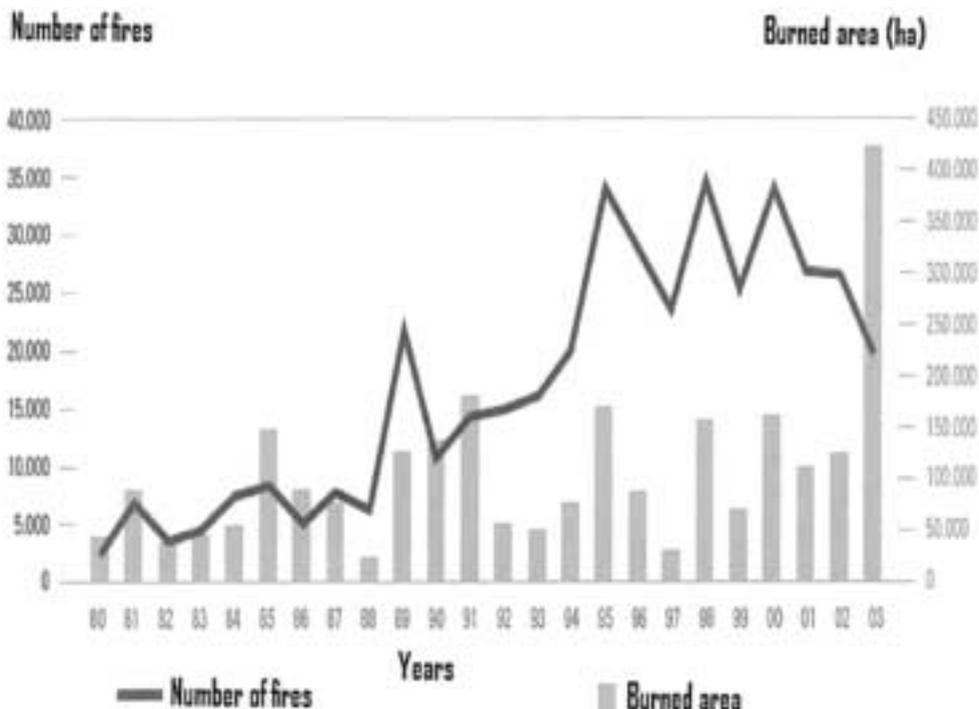


Figure 2. Number of forest fires and burned area from 1980 to 2003 (IA, 2005).

Thus, if Portugal was obliged to pay for these CO<sub>2</sub> emissions at the current market value of €20/ton, the fire losses, due to the emissions, could then be estimated in €392 million for 2003, €127 million in 2004 and more than €180 million in 2005. These values added to the direct losses previously indicated result in unbearable costs.

The current civil protection, prevention and fire fighting systems do not seem to provide an adequate response to this problem. In fact, international experts evaluated the situation [9,10] and concluded that fire brigades, forest wardens and private companies do have an initial efficient capacity for fire fighting which is, however, hindered by the absence of an effective and unified command structure and communication means, which tends to be critical when several brigades are involved. Thus, the initial fire fighting efforts are aggressive and effective, but if a fire affects large areas or lasts for several days, limitations start to become evident in respect of planning capacity, containment strategies and logistics. These limitations are frequently aggravated by an adverse topography occurring in interior and remote areas of the country.

### 3. Causes of forest fires

The causes of forest fires in Portugal are multiple and structural:

- (1) Portuguese forest is mainly based on a monoculture of pine and eucalyptus, which are highly combustible species, due to their essential oils. This type of forest is more fire

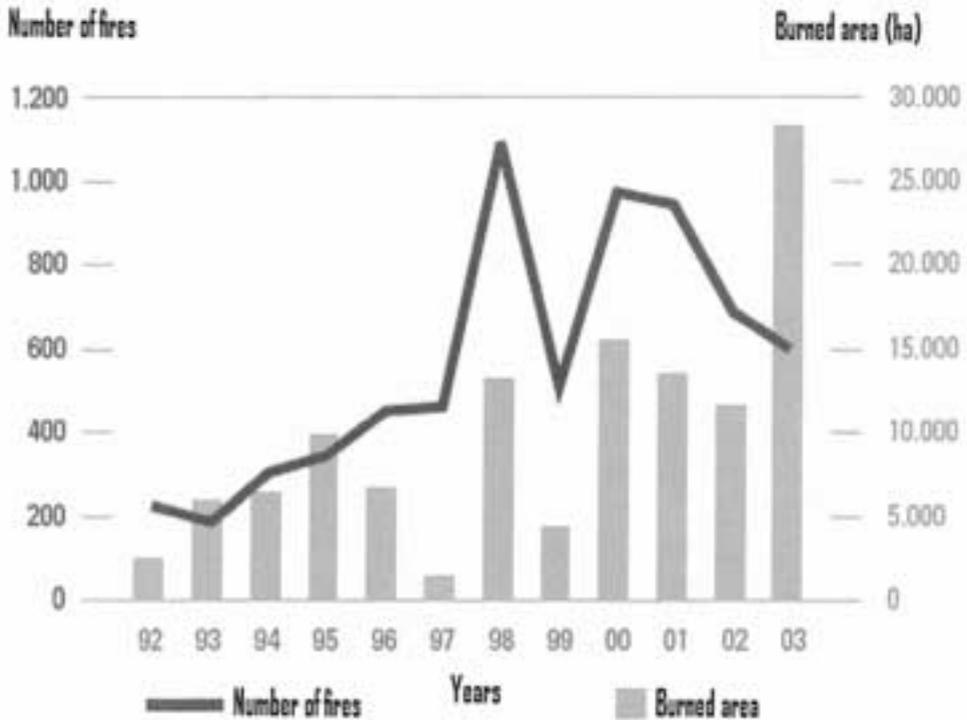


Figure 3. Number of forest fires and burned area in protected areas from 1992 to 2003 (IA, 2005).

prone than the autochthonous species composed mainly of oak (*quercus*), cork oak (*quercus suber*) and holm oak (*quercus ilex*).

- (2) Currently, in Portugal, rural and forest areas are, considerably deserted due to population migrations from these areas to the main cities, which began in the 1950s. As a consequence, rural villages are old and deserted and the rural development policies undertaken will not reverse this trend. This has led to three effects, which contribute to an increased vulnerability to fire: (a) a considerable amount of land used traditionally for non-intensive agriculture is now occupied by bush and dense forest; (b) bush and forest residues

Table 1. Estimates of emissions and energy corresponding to 400 000 ha burned in 2003 [8].

Burned cellulose	12 Mton
O <sub>2</sub> needed for combustion	14.2 Mton
Released CO <sub>2</sub>	19.6 Mton
Released H <sub>2</sub> O	6.7 Mton
Released energy	53 633 GW
Released energy (expressed as equivalent oil)	3.6 Mton

Note: this estimate considered 30 ton of wood burned per ha, and the following chemical reaction:  $C_6H_{10}O_5 + 6O_2 \rightarrow 6CO_2 + 5H_2O$ . Then, the mass balance is: 162g (C<sub>6</sub>H<sub>10</sub>O<sub>5</sub>) + 192g (O<sub>2</sub>) → 264g (CO<sub>2</sub>) + 90g (5H<sub>2</sub>O). Referring to energy data, it was assumed an heating value of 19 090 kJ/kg for cellulose, and 3.6 kJ/GW and 0.301 kJ/GW to convert, respectively, cellulose and cellulose based wood into equivalent oil ton.

- are no longer used as wood for heating purposes; (c) the initial line of prevention, which was formed by village inhabitants, no longer exists and has not been replaced by efficient resources which could be active in prevention, monitoring and quick intervention.
- (3) The state owns only around 3% of the Portuguese forest, and 12% of the area has no proprietor and thus are not subjected to any management system. Furthermore, 85% belong to about half-million proprietors and have an average dimension of 5 ha (in more vulnerable interior regions, this average dimension could even be smaller). This enormous area is usually fragmented into smaller parcels. Also the current register of land owners is far from up-to-date and thus proprietors are frequently dead or unidentified. This situation obviously hinders any coherent and effective management practice. This could be overcome by the mechanism of a forest association; but this is somewhat contrary to Portuguese rural culture, mainly in the northern areas of the country.
  - (4) The number of professional foresters, dedicated to the forest, is rather limited and the State Departments in charge suffer from a chronic lack of resources, both human and material; especially for planning and coordination. Also, a unified command structure does not exist, or communication channels and common means shared between the fire brigade systems. This obviously leads to limitations in terms of fire containment and effective logistics, especially for fires lasting for more than one day.
  - (5) The current Portuguese legislation prescribes the clean-up of forest and bush residues, by proprietors, to a minimum distance of 50 m around houses and 100 m around industrial facilities and urban agglomerations. Thus, this legislation, which is seldom enforced, dilutes the responsibility among a multitude of bodies both public and private. The resulting impunity in terms of fire is now considered to be an aggravated risk factor.
  - (6) The state policy has been directed towards increasing fire fighting capacity instead of prevention, educational programmes and reduction of the use of fuels in forest practices.
  - (7) There is a general lack of formation in fire fighting. Important know-how has been acquired in recent years, some derived from foreign experiences, but the technology transfer to those people really involved in fire fighting has not taken place.
  - (8) Arson is common but is very seldom penalized. Arson has two main origins: by pyromaniacs, who became excited by the emotional attention given by media to forest fires; and, for personal and economic gain.
  - (9) Negligence is also infrequently penalized. Several fires originated by uncontrolled fires started to prepare land for coming crops, non-extinguished matches, cigarettes and domestic fires. Also the existence of small dumps containing waste such as electric apparatus, used vehicles, chemical products, tyres, dead animals, etc, greatly increases fire risks.

Apart from these structural factors, other situational aspects occurred in 2003 and are bound to be recurrent:

- (1) Spring brought heavy rain, which increased the thermal load of the bush, especially herbaceous vegetation that grows as a result and which fuels forest fires.
- (2) A very dry and hot summer, especially in interior regions of the country, having two heat waves, in August and September, where air temperatures surpassed 30–40°C (the largest number of fires took place in those periods, in interior areas). The dryness index (DI), which is an indicator of risk severity, reached very high values during 2003 in Coimbra region (in Central Portugal), very near the highest registered value reached in 1995 (see figures 4 and 5).



Figure 4. Night of 24 August 2005, flames near Coimbra, the third largest Portuguese town, Central Portugal.

- (3) Adverse topography fires located in favourable places; creating 'stack effects' and the subsequent fire spread.
- (4) A new scheme for the coordination of prevention and fire fighting which was not tested sufficiently and failed at critical moments.

Most of all these structural and situational causes have continued since 2003 and have been present in 2005. This has been an exceptionally dry year, extreme dryness has been observed in all territories, air temperatures have been extremely high and thus, an extremely high risk of fire exists, even though a considerable area was burned in the previous years. Figure 6 shows the classification of risk hazard in Portugal, areas by area.

It should be noted that the majority of climate models used for previewing the future climate, both for medium- and long-term prediction, indicate a tendency for the occurrence of this type of extreme conditions, in spite of the associated uncertainty. Therefore, some conclusions can be extracted from what has happened in the last three years:

- Forest fires cannot be prevented and/or fought at the level of individual property.
- Land use must be regulated in response to what is known about fire progression.
- Forests have a determinant role in reducing global warming and thus, there is an increased reason for protecting forests.
- The experience of other Mediterranean countries, which are well organized to deal with this problem and have done so effectively, should be utilized.



Figure 5. Satellite image of Coimbra where smoke can easily be seen, 25 August 2005.

#### 4. Consequences of forest fires

The consequences of large-scale forest fires are, in fact, very serious. The more dramatic ones are, indeed, the loss of human lives, houses and other material assets, as well the economic value derived from the forest itself such as wood, honeycombs, and also the landscape and tourism related values. The loss of ecological value is also to be considered, although it should be noted that the regions with greater ecological value are, usually, less vulnerable to fire.

Another important aspect is the disruption to the hydrologic cycle, which can result in erosion phenomena, silting of water lines, flow increase of superficial water lines and thus affect both the frequency and dimension of flood; reduction of aquifer resources, which will also contribute to the occurrence of dry spells; chemical erosion of soil as the soil becomes very hydrophobic rejecting water and increase of superficial water flows. Soils also become very alkaline due to the presence of ash compounds.

Forest fires result in considerable gas emissions, which include greenhouse gases and which form an important part of the permissible national emissions of greenhouse gases, as discussed above.

Therefore, the economic losses, both direct and indirect, due to fire fighting (logistic resources, aerial and terrestrial means) and also due to the loss of burned wood, loss of production capacity, cost of opportunity for rural tourism and ecotourism, are currently accumulating and increase year by year. This endangers the economic survival of several interior regions of Portugal, which were already depressed areas before these occurrences.

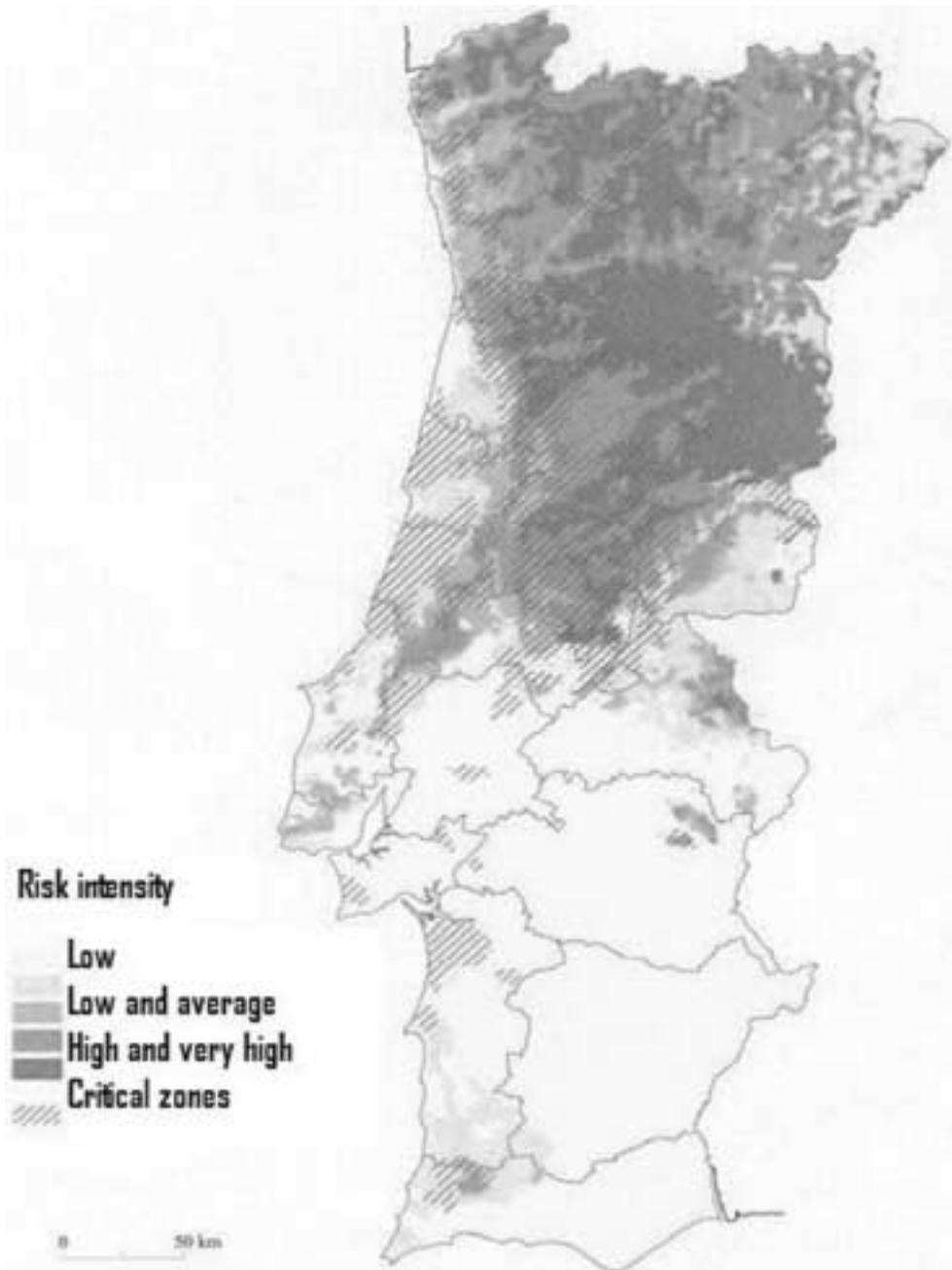


Figure 6. Intensity of fire risk in Portugal. *Source:* DGF (2002), in DGOTDU (2005).

## 5. How to deal with this problem

The most important measure seems to be the establishment of a strategy for sustainable development of the Portuguese forest: the model for this forest, in the future, has to be well

defined, considered as a national strategic value and planned from that basis of understanding. Such would require significant political imagination and political negotiation with the electorate, so that economic resources may be found, and applied to the problem.

Another important measure would be to consider the use, on a large scale, of forest residues as a source of energy. Following the example of the Scandinavian countries, which have demonstrated that it is possible to clean up forests, thus preventing forest fires, and even using biomass excess for bio-ethanol production. Such bio-ethanol can be mixed with gasoline and diesel for transportation vehicles; thus reducing fuel costs as well as emissions to the atmosphere.

It is also important to invest in the development of autochthonous species, such as oak, chestnut, pine and cherry trees [14] and in efficient forest management. In fact, these species will result, in the long term, in greater yield per ha, especially for furniture and lumber production. These indigenous species are the ones more compatible with the multiple uses of forest (e.g. extensive pastures, honey production, ecological and game tourism); are less vulnerable to fire; are better for soil conservation and hydrological cycle regulation, and are even better carbon dioxide absorbers.

It is important to promote the diversity of forest species, clean-up fields and bushes, build access routes to forest areas, even in adverse topographic conditions; protect valleys and water lines; protect mountain ridges with human occupation and dense covert species. On slopes in excess of 45° fire resistant species should be grown, as well as in ridges facing east and south. Further, species grown for production should be protected with access routes and surrounded by fire resistant species. When planning tree occupation of land, factors such as flammability, heating value, passive and active resistance, density control, must be taken into account.

One basic measure would be the promotion of the idea of a forest association. As the majority of Portuguese forest belongs to 'micro-proprietors', a forest association should be made a legally necessary for all proprietors, to get an effective forest management in every partial aspect: strategic approach, conservation of resources, economic rationality, productivity, certification of forest products and, finally, fire prevention.

This measure could be linked to the need to promote public participation in the process. In fact, the involvement of rural communities is indispensable for defining and enforcing the measures to fight desertification and to promote sustainable agriculture and forest development.

The role of the state cannot be disregarded. The state must enforce and further develop the current legislation so that a long-term forest management policy may be derived, comprising the important aspects of nature conservation, scientific research, strategic economic resource, as well as the creation of a national forest service controlled by the Minister of Environment; instead of the Minister of Agriculture as is the current situation. The state should decisively invest in preventive actions; instead of reactive ones, during the whole year and not only during summer where most forest fires occur. The vesting of ownership of small blocks (parcels) of forest in a National Forestry Commission may be one option to be considered, so that standard methods are followed and economies of scale are gained.

Another very important aspect is the need for unified coordination of fire fighting bodies, which has also to be complemented in efficient training of professionals and preparation for emergencies. The fire service could be improved by replicating the approaches of the rural fire services in Australia.

In conclusion, it can be noted that the main solutions to forest fires in Portugal are not easy, but have been already studied and quantified for some time. Therefore, what is really needed is the political will and courage to promote their enforcement.

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