

A MULTICRITERIAL APPROACH TO ASSESS FOREST FIRE DEFENCE MANAGEMENT IN THE MEDITERRANEAN ENVIRONMENT: THE CASE OF SICILY

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The forest and scrub fires which break out regularly in Mediterranean countries are reputedly caused by common climatic factors, particularly with regard to rainfall, temperature and wind. Altitude, coastal exposure and orographic conformation have an effect on climate and lead to specific microclimatic conditions of the soil which may either increase or reduce fire hazard. Damage caused by the various types of forest fires is always considerable from both environmental and socio-economic points of view and justifies the financial commitment which each country must undertake in order to prevent and fight such disasters. It is a proven fact that most forest fires are started wilfully; only a few cases break out accidentally, and are hardly

ever due to natural causes such as lightning or spontaneous combustion and so on. It is therefore indispensable that anti-fire programmes should aim specifically at more effective prevention, and pay particular attention to civic education, the spread of knowledge and the

ABSTRACT

Forest fires represent a serious issue in the Countries of the Mediterranean basin, where every year large areas are severely affected by their effects. The aim of the research was to indicate some alternative ways to the management system in use in Sicily, among which to identify the most suitable one. Two multicriterial techniques were used in combination with each other, Saaty's AHP and Roy's Electre methods, which took into account both the environmental and the socio-economic aspects involved in the problem. By means of the former, weights were assigned to each criterion on the basis of expert judgements, whereas the latter allowed the rank of the alternatives to be built. The presence of private enterprises, although encouraged by financial incentives, taking the place of the regional anti forest fire service in certain areas is the main characteristics of the management system suggested by the analysis in order to reduce to a minimum the fire hazard in Sicily.

RÉSUMÉ

Les incendies de forêts représentent une menace véritable dans les Pays de la Méditerranée où chaque année de vastes espaces naturels sont dévastés par leurs effets, continuent de brûler chaque année. L'objectif de cette étude est d'indiquer d'autres systèmes de gestion et d'identifier le plus approprié entre eux. Au fin de considérer soit les aspects environnementaux que socio-économiques du problème, on a utilisé deux techniques multicritères combinées l'une avec l'autre, les méthodes AHP de Saaty et Electre de Roy. Au moyen de la première méthode on a attribué des poids à chaque critère, sur la base de jugements d'experts, tandis qu'on a utilisé la seconde méthode pour classer les alternatives obtenues. La présence d'entreprises privées, bien que encouragées par des facilitations financières publiques remplaçant le service régional contre les incendies, est la caractéristique la plus significative du système de gestion suggéré par cette analyse au fin de réduire au minimum le risque d'incendie en Sicile.

general elimination of social causes which might lead certain groups or isolated individuals to commit arson. This research specifically analyses the case of Sicily, where every year and often several times in the same year and areas, 8,000 hectares of forest and Mediterranean scrub are damaged by fire, in spite of the fact that the Regional Forestry Administration has at its disposal organisations and financial means which are far superior to those of other Mediterranean regions. The analysis adopts a multicriterial approach and aims at identifying and assessing some management alternatives to the Regional Fire Service, in order to propose changes which might lead to a more efficient use of public money, not only with regard to the reduction of the number of forest fires

but also to the damage they cause. Subsequently, if necessary, the study could be further developed according to the requirements of the Regional authorities, in order to provide more detailed information and indications, with particular regard to the socio-economic aspects of the problem.

THE EXTENT OF WOODLANDS AND FIRES IN ITALY AND IN OTHER COUNTRIES OF THE MEDITERRANEAN BASIN

Since no other reliable figures are available, the research has used the Fao data regarding woods and forest fires in the Mediterranean area, which includes European countries, North Africa and West Asia.

As to the woodland areas in the Mediterranean, 61.6% of the total is located in the West European countries of France, Greece, Italy, Portugal and Spain, East Europe and West Asia account for 27.9%, while the remaining 10.5% is in the North African countries of Algeria, Egypt, Libya, Morocco and Tunisia (**table 1**).

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The authors shared the general approach of the study, although the responsibility of each author is to be attributed as follows: S. Tudisca for the co-ordination of the research and for the introduction and the conclusion, E. Schimmenti for sections 1,2.1 and 2.2, A. Asciuto for sections 2.3.1, 2.3.2, 2.3.2.1 and 2.3.2.2, T. Cirivello for section 2.3.3.

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The same source has provided the data regarding the number of fires occurred in some of these countries during the four years from 1994 to 1997.

Most of the forest fires take place annually in Portugal: 24,905 fires, followed by Spain, with 21,085 and then Italy, with 8,849; Spain has the largest forest area damaged by fire, with 88,716 hectares (1.06% of the total national woodland), followed by Portugal with 73,053 hectares (2.54% of the total), Italy, with 37,525 hectares (0.58% of the national total) and Greece, with 30,145 hectares (0.46% of the total national woodland area). Among the Asian Mediterranean countries, Israel has the largest number of woods annually damaged by fire (1.60%).

As far as Italy is concerned, the 1996 Istat (National Italian Institute for Statistics) figures regarding woods with more than 50% of tree density and an area of at least 0.50 hectares, report 6,837,176 hectares of woodland (22.7% of the total national territory), made up of 52.9%

coppice, 43.2% tall trees and 3.9% Mediterranean scrub. According to the data provided by the State Forestry Guard, from 1978 to 1998 there were on average 11,421 forest fires, ranging from 7,377 in 1995 to 18,664 in 1985, while 53,839 hectares of the woodland areas were damaged by fire, with limits comprised between 20,324 hectares in 1996 and 116,132 hectares in 1993.

During the 21-year period the average non-woodland area undergoing fire damage was 79,941 hectares (**figure 1**).

Data split by region show that the largest area of woodland was damaged during the period 1994-1998 and was for the most part (67.0% of the national total) concentrated in the south of Italy, especially in Calabria (17.3%) and the islands of Sicily (17.0%) and Sardinia (16.3%).

The figures regarding non-woodland fires also confirm the particular vulnerability of these regions; during the five years 1994-1998, of 53,836 hectares of burnt land,

Table 1 Forest area, number of fires and area subject to fire in the countries of the Mediterranean Basin

| Countries | 1995 | | | | Average 1994-1997 | | | Burnt forest area (1994-97) / Total forest area (1995) |
|-------------------------------------|----------------------|--------------|--------------------|---------------------------|-------------------|-----------------------|------------------------|--|
| | Forest area (000 ha) | Incidence % | Land area (000 ha) | Forest area/Land area (%) | Number of fires | Total burnt area (ha) | Of which forestry (ha) | % |
| Algeria | 1,861 | 2.9 | 238,174 | 0.8 | | | | |
| Egypt | 34 | 0.1 | 99,545 | | | | | |
| Libyan Arab Jamahiriya | 400 | 0.6 | 175,954 | 0.2 | | | | |
| Morocco | 3,835 | 6.0 | 44,630 | 8.6 | | | | |
| Tunisia | 555 | 0.9 | 15,536 | 3.6 | | | | |
| North Africa | 6,685 | 10.5 | 573,839 | 1.2 | | | | |
| Cyprus | 140 | 0.2 | 924,000 | 15.2 | 25 | 133 | 133 | 0.09 |
| Jordan | 45 | 0.1 | 8,893 | 0.5 | | | | |
| Israel | 102 | 0.2 | 2,062 | 4.9 | 942 | 6,189 | 1,637 | 1.60 |
| Lebanon | 52 | 0.1 | 1,023 | 5.1 | | | | |
| Syrian Arab Republic | 219 | 0.3 | 18,378 | 1.2 | | | | |
| Turkey | 8,856 | 13.8 | 76,963 | 11.5 | 1,990 | 11,720 | 11,720 | 0.13 |
| West Asia | 9,414 | 14.7 | 108,243 | 8.7 | | | | |
| France | 15,034 | 23.6 | 55,010 | 27.3 | 6,141 | 18,758 | | |
| Greece | 6,513 | 10.2 | 12,890 | 50.5 | 1,956 | 40,698 | 30,145 | 0.46 |
| Italy | 6,496 | 10.2 | 29,406 | 22.1 | 8,849 | 59,766 | 37,525 | 0.58 |
| Malta | 0 | | 32 | 0 | | | | |
| Portugal | 2,875 | 4.5 | 9,150 | 31.4 | 24,905 | 89,012 | 73,053 | 2.54 |
| Spain | 8,388 | 13.1 | 49,944 | 16.8 | 21,085 | 182,307 | 88,716 | 1.06 |
| West Europe | 39,306 | 61.6 | 156,432 | 25.1 | | | | |
| Albania | 1,046 | 1.6 | 2,740 | 38.2 | 395 | 423 | 423 | 0.04 |
| Bosnia and Herzegovina | 2,710 | 4.2 | 5,100 | 53.1 | 135 | 776 | 776 | 0.03 |
| Croatia | 1,825 | 2.9 | 5,592 | 32.6 | 225 | 8,730 | 7,855 | 0.43 |
| Slovenia | 1,077 | 1.7 | 2,012 | 53.5 | 50 | 488 | 414 | 0.04 |
| Yugoslavia | 1,769 | 2.8 | 10,200 | 17.3 | | | | |
| East Europe | 8,427 | 13.2 | 25,644 | 32.9 | | | | |
| Total of Mediterranean Basin | 63,832 | 100.0 | 864,158 | | 7.4 | | | |
| WORLD | 3,454,382 | | 13,048,410 | | 26.5 | | | |

Source: State of the World's forests 1999, FAO; Forest Fire Statistics 1994-1997, Timber Bulletin, UN/ECE FAO.

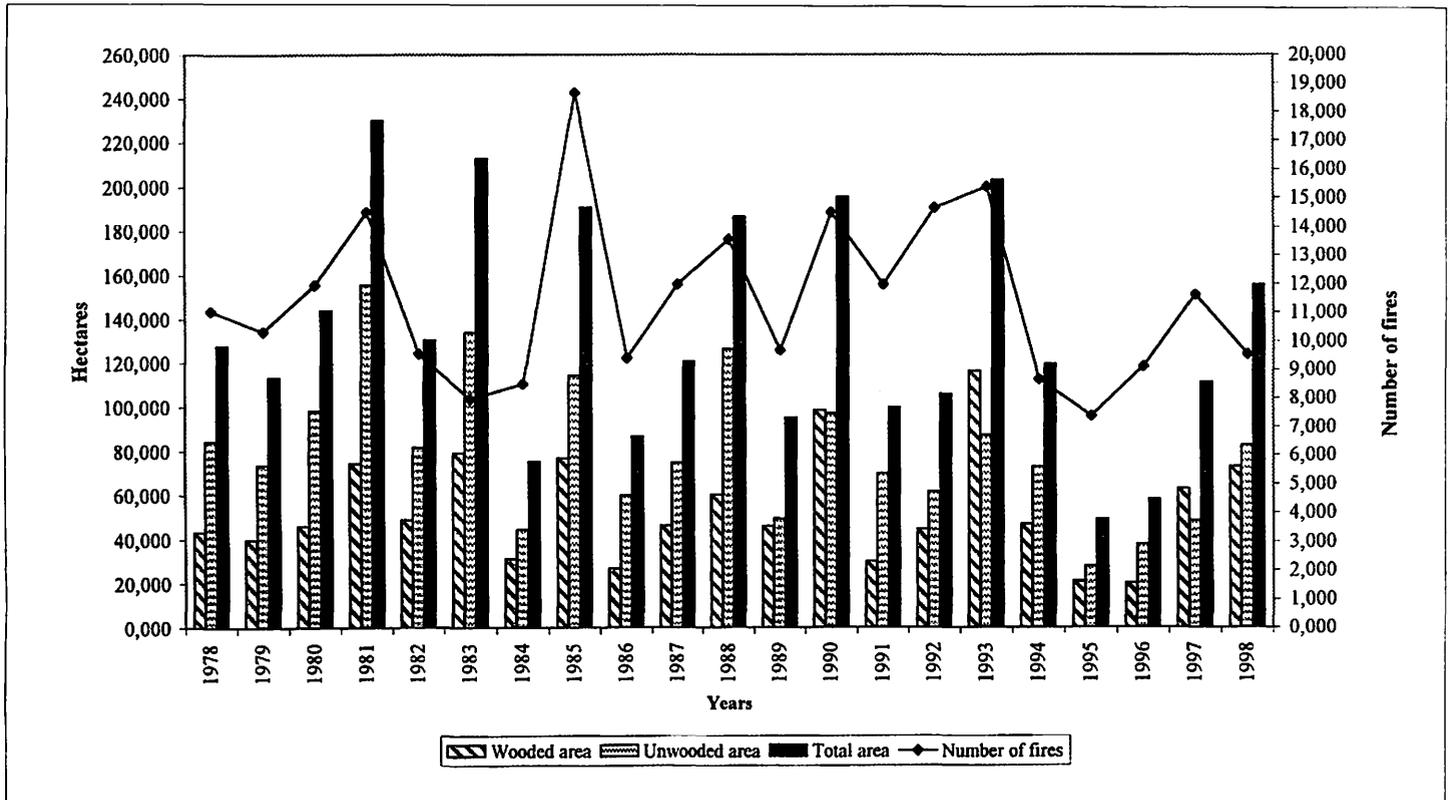


Figure 1 - The evolution of fires in Italy in 1978-1998. Source: State Forestry Guards.

25.5% was in Sardinia, 17.2% in Calabria and 15.4% in Sicily.

THE CASE OF SICILY

Current situation of the forestry sector and fires

The survey conducted by the Sicilian Regional Forestry Administration in preparation for the "New Regional Plan for the Defence of Woodlands and Areas Protected Against Fire-Hazard", published in 1996, reports 283,080 hectares of woodland, that is, 11.0% of the overall regional territory; 66,293 hectares of which are classified as "deteriorated". Trees cover 220,033 hectares of the area (including all the deteriorated zones), part of which has already been reforested as part of the future policy to be followed, while the remaining 63,047 hectares are made up of simple or compound coppice. The woods containing tall trees, with the exception of the deteriorated areas, are made up of 48,140 hectares of broadleaves, 45,326 hectares of conifers and 60,274 hectares of coniferous and broadleaves trees together. The majority of Sicilian woods, 137,680 hectares or 48.6% (1) of the regional total, belong to the Sicilian Region; 98,660 hectares (34.9%) are private or the property of public bodies, while the local councils own 46,740 hectares (16.5%). During the last fifty years woodland areas have been increased by 230%, from 85,643 hectares in 1947 to the current 283,080 hectares, as a result of a slow but continuous reforestation policy aiming at the conservation,

mainly for public purposes, of the land in the mountain basins and of water courses, which has also proved to be of great social value due to the high number of jobs created in the primary sector. In 1991 only 74,000 out of the 240,000 hectares of paranatural and artificially reforested woodland showed a certain potential productivity (G. Ascianto, 1992a) compared with the current 107,000 hectares of forests with predominant productive function recently estimated. Statistical research with regard to forest fires in Sicily is based on the data provided by the Anti-Forest-Fire Service (S.A.B.) of the Sicilian Regional Forestry Guard. This public body operates all over the regional territory, by means of both direct observation, with the use of fixed watch towers containing specific apparatus situated at strategic check-points for the control of vast woodland areas, and a mobile observation service performed by the Forestry Guard Patrols. These observation groups are also linked up to the Radio Service, which at once transmits the alarm to the various operative centres which will then immediately send out the emergency squads. An examination has been made of the statistics concerning twenty-one years from 1978 to 1998 to get a better idea of the number of fires occurring and the areas involved. For more detailed information about the

(1) Since during the period 1996-1998 further areas have been sold to private buyers, the present extent of State-owned woodland is 53.0% of the overall area, whereas privately-owned areas account for 30.5%.

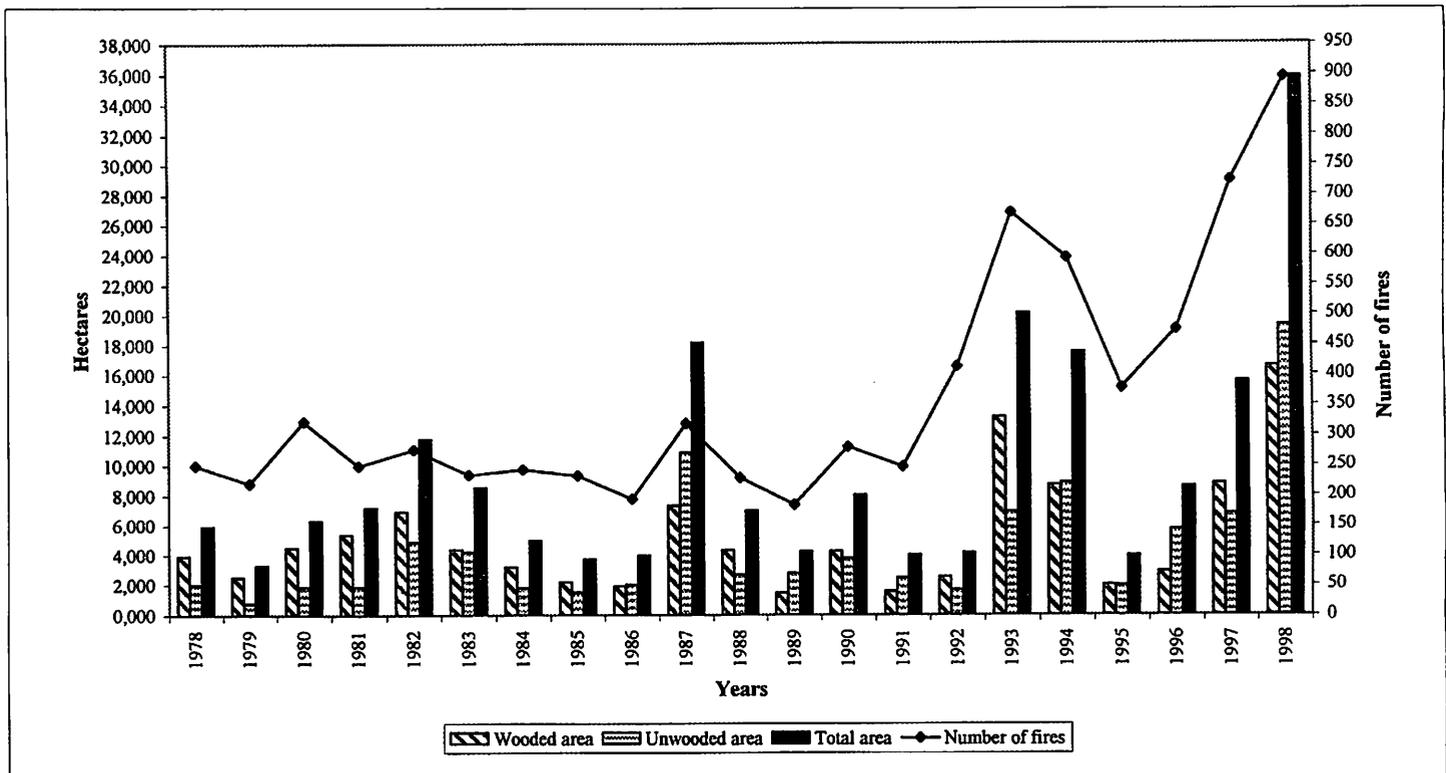


Figure 2 - The evolution of fires in Sicily in 1978-1998. Source: Agriculture and Forestry Department - Regional Forestry Guard - Anti-Forest-Fire Service.

causes of the fires, the amount of damage and the type of woodland, use has been made of the 1994-1998 data. It should, however, be borne in mind that the Forestry Guard only collects data on forest fires or those occurring near woodland areas or in protected zones and that these figures are divided up according to the type of land involved and not to the number of fires.

The number of fires occurred in Sicily from 1978 to 1998 varied considerably from one year to another without any apparent cyclical regularity. The annual average is 363 fires, ranging from 184 in 1989 to 894 in 1998 (figure 2). It must be emphasised, however, that

apart from 1980 and 1987, till the end of the 1980's there were never more than 300 fires a year, whereas during the 1990's there has been a considerable and worrying rise; on the whole, 54.4% of the fires in the 21-year period took place in the period 1992-1998.

The average extent of woodland annually involved in fires equals 5,147 hectares (about 2.0% of the regional forest area), with a minimum of 1,451 hectares in 1989 and a maximum of 16,543 hectares in 1998. An annual average of about 4,493 hectares of non-woodland areas, including grassland, non-cultivated zones and agricultural land near woodland or protected areas, are also

Table 2 Forest area subject to fire by type of wood in Sicily in 1994-1998 (hectares)

| Years | Coniferous high forest | Broad-leaves high forest | Mixed trees high forest | Total high fores | Simple coppice and coppice with standards | Compound coppice | Coppice strongly degraded | Total coppice | Mediterranean scrub | Total forest area |
|---------|------------------------|--------------------------|-------------------------|------------------|---|------------------|---------------------------|---------------|---------------------|-------------------|
| 1994 | 984.67 | 2,780.55 | 1,754.55 | 5,519.77 | 677.91 | 51.00 | 728.91 | 2,419.99 | 8,668.67 | |
| 1995 | 231.55 | 522.80 | 233.30 | 987.65 | 257.85 | 79.50 | 337.35 | 654.94 | 1,979.94 | |
| 1996 | 281.76 | 506.12 | 190.74 | 978.62 | 195.70 | 139.50 | 335.20 | 1,558.88 | 2,872.70 | |
| 1997 | 2,858.64 | 1,396.95 | 1,477.40 | 5,732.99 | 776.68 | 106.35 | 883.03 | 2,169.56 | 8,785.58 | |
| 1998 | 5,112.15 | 3,852.32 | 2,775.60 | 11,740.07 | 921.20 | 34.90 | 1,059.40 | 3,743.05 | 16,542.52 | |
| Average | 1,893.75 | 1,811.75 | 1,286.32 | 4,991.82 | 565.87 | 82.25 | 668.78 | 2,109.28 | 7,769.88 | |
| % | 24.4 | 23.3 | 16.6 | 64.3 | 7.3 | 1.0 | 8.6 | 27.1 | 100.0 | |

Source: Agriculture and Forestry Department - Regional Forestry Guard - Anti-Forest-Fire Service.

involved in fires, with a minimum of 769 hectares in 1979 and a maximum of 19,243 in 1998. In the period from 1992 to 1998 50.4% and 54.1% respectively of all the damage caused by fire in woodland and non-woodland areas in the period under observation took place. From 1994 to 1998, the most serious fire damage occurred in tall tree areas (coniferous, broadleaves and mixed trees), with a mean annual extent of 4,992 hectares (64.3% of the total), and in the Mediterranean scrub (27.1%); the coppiced areas have proved to be less vulnerable (8.6%) (**table 2**).

Most of the fires occurred in privately-owned woods (47.7%) and in those belonging to the Sicilian Region (44.1%).

The Istat and the S.A.B. have classified the causes of forest fires as follows:

natural: having nothing to do with either wilful or accidental human acts (such as lightning);

accidental: resulting from facts or circumstances linked to human acts, but without intention, such as recreational, forestry, agricultural and industrial activities, or the burning of rubbish or cigarettes, and so on (unpremeditated fires);

wilful: resulting from facts or circumstances with the wilful intention of producing a fire (arson);

uncertain (or unclassifiable): causes which can not be attributed, even presumably, to the above reasons.

A careful examination of the fires registered in Sicily shows a clear prevalence of wilful arson, accounting for an average 77.6% of the total during the period from 1994 to 1998 (**table 3**), although various institutions, experts and public opinion are in disagreement about the causes; there are two much smaller groups of fires of uncertain (11.2%) and accidental (10.7%) origin, whereas there is a negligible number of those of natural origin (0.5%). The majority of the damage, both in woodland (84.6%) and non-woodland (80.6%) areas, is the result of wilful arson committed during the summer season, when high temperatures, dry grass, dried-up soil, wind and reduced humidity all facilitate the spread of fire. In the five years examined, in fact, most of fires occurred in July (36.2% of the total) and August (28.2%), followed by June (17.1%) and September (11.8%), while only 6.7% of all the annual fires occurred in the remaining months.

It is extremely difficult to assess the economic damage resulting from forest fires; the Regional Forestry Administration adopts various methods depending upon the different aims of the estimates, but in no case does it take into consideration the environmental aspects compromising the non-market functions of woodland areas, such as hydrogeological defence, conservation of natural habitats, tourist and recreational activities, oxygen production, and so on.

According to the method used by the S.A.B., the mean direct damage resulting from forest fires in the 1994-

1998 period is 70.9 billion lire per year, with values ranging considerably from 4.4 billion lire in 1996 to 162.4 billion lire in 1994.

Regional legislation on forest fires

The Regional Law 88/75 sanctions the application of the rules for the defence of woodland against fire as laid down by the Law 47/75, since these are to be considered compatible with regional legislation regarding this subject.

This Law provides for the institution of the S.A.B. by the Regional Forestry Guard, which is responsible for co-ordinating the activities of forest fires prevention and repression in the various operative centres of the Forestry Inspection Departments and for the drawing up of the Regional Plan for the defence of woodland against fire, as laid down in the Law 47/75.

The subsequent Regional Law 52/84 authorises the regional Administration to extend its prevention and extinguishment interventions to nature reserves and parks as laid down by the Regional Law 98/91.

The Regional Law 11/89 updated the Regional Plan with which the Regional Laws 88/75 and 2/96 approve the New Regional Plan for the defence of woodlands and areas protected from fire and provides for the co-ordination to be organised by the Administrative office of the Parks Department between the different activities of the various bodies, each within its own territory, in charge for the prevention and fighting of forest fires.

This Regional Law also requires that reforestation of regionally-owned woodlands, destroyed or damaged by fire, should only be performed after monitoring to determine and remove any fire-hazards linked to possible structural deficiencies; it also provides for the establishment of a forest fire register and authorises the Agricultural and Forestry Department to supply helicopters to be used by the permanent staff of the Regional Forestry Guard. In the case of any delay in the special training to be given to the latter, the Agricultural and Forestry Department may apply to private bodies, following the contractual procedure laid down by the current regulations.

Methodological approach for the assessment of alternative proposals in anti-fire defence

Overview

In order to face the problem of natural resources management, it is necessary first of all to rationalise the choices linked to political actions which may be particularly important for a specific territory, in order to assess the effects they may have on the natural resources. The evaluation of the relevant plans has thus assumed an extremely important role in the socio-economic analysis, since the traditional economic analysis, leading to an extreme simplification of the decisional

Table 3 Number of fires, area subject to fire and relative damage according to the causes in Sicily in 1994-1998

| Years | NATURAL | | | | ACCIDENTAL | | | | WILFUL | | | |
|---------|----------------------|--------|------------|-----------------|----------------------|-----------|------------|-----------------|----------------------|----------|------------|-----------------|
| | Area subject to fire | | | | Area subject to fire | | | | Area subject to fire | | | |
| | Number of fires | Forest | Non forest | Damage 000 lire | Number of fires | Forest | Non forest | Damage 000 lire | Number of fires | Forest | Non forest | Damage 000 lire |
| | | Ha | Ha | | | Ha | Ha | | | Ha | Ha | |
| 1994 | 3 | 8.50 | 21.50 | 18 | 480 | 7,083.72 | 6,230.83 | 103,010,123 | 61 | 954.25 | 1,680.35 | 4,512,891 |
| 1995 | 3 | 9.50 | 1.00 | 3,783 | 286 | 1,561.74 | 1,459.13 | 5,281,141 | 34 | 151.80 | 183.20 | 1,218,970 |
| 1996 | 2 | 2.05 | 1.50 | 0 | 374 | 2,528.39 | 5,101.00 | 3,813,111 | 58 | 173.14 | 423.05 | 282,869 |
| 1997 | 1 | 0.15 | 0.00 | 0 | 606 | 7,640.82 | 5,443.75 | 25,540,155 | 61 | 652.30 | 733.15 | 725,929 |
| 1998 | 5 | 16.50 | 53.00 | 47,000 | 634 | 14,070.52 | 16,035.06 | 138,213,973 | 115 | 1,407.55 | 1,235.07 | 5,855,461 |
| Average | 2.8 | 7.34 | 15.40 | 10,160 | 476.0 | 6,577.03 | 6,853.96 | 55,171,701 | 65.8 | 667.81 | 850.96 | 2,519,224 |
| % | 0.5 | 0.1 | 0.2 | .. | 77.6 | 84.6 | 80.6 | 77.8 | 10.7 | 8.6 | 10.0 | 3.6 |

Source: Agriculture and Forestry Department - Regional Forestry Guard - Anti-Forest-Fire Service.

process into economic terms, is not able to assess the value of the non-marketed benefits provided by forest areas.

From the end of the 1970's, therefore, there has been a widespread diffusion of multicriterial analysis (M.C.A.) techniques, which study the effects of the various actions in order to assist decision-makers in the choice of the "best" alternative by combining economic, mathematical, statistical and psychological procedures.

Two separate matrices, the assessment and the priority matrix, are essential to the decisional process. The former reports all the effects produced by each alternative, with their respective measurement units, estimated according to each single criterion. The latter makes it possible to give each criterion its recognised importance, according to the specific situation, and then to establish a range of values for each one in order to accept or reject preference for one to another according to a pre-established, pondered judgement.

It is therefore imperative to weigh up the various criteria with great care, either in a vectorial or matricial form, so that they may be arranged in their order of importance.

The priorities assigned to each criterion may form a linear or non-linear scheme of ponderation; in such cases it is a good idea to verify the reliability of the results by analysing their sensitivity to different scenarios.

The final result of the multicriterial assessment is nothing more than the estimate of the value for each of the alternatives, depending on factors which have been considered and analysed and that should be interpreted as elements necessary for structuring the problem rather than for providing a solution to it. The decision-

maker will therefore have at his or her disposal the results of the analysis, which may be used together with other information in order to make a final decision without expressing any "a priori" judgement.

Such basic knowledge, which may be the starting point for the verification of the value of one alternative rather than another, should therefore be a guideline behind any form of activity to identify new procedures aiming to put together proposals for intervention and for the safeguard of particular environmental conditions.

A multicriterial analysis for an integrated management in the defence of wood and protected areas against fire

Multicriterial methods, which take into consideration a wide range of factors to help identify the best alternative, are considered as a valid support in the organisation of a management which is not only capable of protecting woodland, but also of reducing the defence costs.

The possibility offered by this type of analysis, that is to assign the correct importance to each criterion, makes it possible to obtain a vast choice of different solutions according to the specific scale of priorities of the various aspects considered; there is a significant innate advantage in the method, since it provides a reclassification of all the alternative plans under consideration, and indicates the best or the worst road to follow in order to reach the main aim of environmental protection, while at the same time paying attention to the economic and social constraints which the general analysis has shown to be of basic importance. The method might well represent a useful tool for helping in the decisional

| UNCERTAIN | | | | TOTAL | | | |
|----------------------|----------|------------|-----------------|----------------------|-----------|------------|-----------------|
| Area subject to fire | | | | Area subject to fire | | | |
| Number of fires | Forest | Non forest | Damage 000 lire | Number of fires | Forest | Non forest | Damage 000 lire |
| | Ha | Ha | | | Ha | Ha | |
| 50 | 622.20 | 884.75 | 54,837,946 | 594 | 8,668.67 | 8,817.43 | 162,360,978 |
| 55 | 256.90 | 322.30 | 789,389 | 378 | 1,979.94 | 1,965.63 | 7,293,283 |
| 41 | 169.12 | 190.53 | 269,507 | 475 | 2,872.70 | 5,716.08 | 4,365,487 |
| 56 | 492.31 | 595.73 | 3,458,711 | 724 | 8,785.58 | 6,772.63 | 29,724,795 |
| 140 | 1,047.95 | 1,919.85 | 6,539,522 | 894 | 16,542.52 | 19,242.98 | 150,655,956 |
| 68.4 | 517.70 | 782.63 | 13,179,015 | 613.0 | 7,769.88 | 8,502.95 | 70,880,100 |
| 11.2 | 6.7 | 9.2 | 18.6 | 100.0 | 100.0 | 100.0 | 100.0 |

processes of a modern, integrated management of the environment or of a specific aspect such as the protection of woodland areas against fire hazard.

As in all cases when this method is applied, the following basic steps should be followed for its use in the protection and defence against fire hazard.

Definition of the planned alternatives. Three alternatives have been identified for the analysis on forest fires in woodland and protected areas in Sicily.

The first alternative is the present situation of the anti-forest fire service, where 100% of woodland and protected areas are covered by the S.A.B., by means of temporary manpower for fire observation and extinguishment.

In 1998 its cost (with the exclusion of established personnel) accounted for 150 billion lire for about 700,000 working days.

The increase in the "efficiency" of the service, in terms of reduction both in the number of fires and in the damage is, however, secondary to the actions and interventions aimed at reorganising the different phases of prevention and extinguishment of forest fires and reforestation, as follows.

- Improvement in the systems used for fire-sighting by means of electronic sensors or other modern techniques, although limited to high-risk areas.

- The sensitisation of local populations towards the issue of forest fires, through the diffusion of knowledge and civic education. The creation, within municipal areas of extended woodland, of centres providing information on fire hazards during the dry season and on preventative techniques; rewards to be offered for the identification of persons committing arson.

- The assignment of priorities, within the public interventions of the forestry department, to projects of thicket-removal and thinning-out to favour the creation of artificial conifer woods and the gradual planting of broadleaves which will over time take the place of the coniferous plants.

- An increase in the amount of ground destined as firebreaks (at present created mostly along the outside perimeter) so as to create a network of protective strips of at least 20 metres wide and to allow the passage of off-road vehicles, thus reducing the risk of fire spreading from one place to another and permitting a more rapid intervention from the ground.

- In woods owned by the Sicilian Region or local councils, made up of non-indigenous or exotic species unable to reproduce naturally, per-

mission for grazing should only be given on condition that the area be kept under strict supervision. Drinking troughs, roofing, fencing, etc. should be provided so that the animals may also graze on the land during summer. In areas of natural or paranatural woods, excluding those within protected zones, a similar type of permission may be given by rotations of at least five-year periods for each woodland area, in order to avoid damage to natural plant-renewal. In protected areas, except for those in integral nature reserves, the regulations governing thicket-removal, grazing and creation of firebreaks should be relaxed, but steps should be taken to assure artificial renewal and the introduction of woodland species of high naturalistic value.

- Facilitate the use, only under supervision, of artificial, natural and paranatural woodland for recreational, cultural and productive activities, with the help of youth associations and co-operatives in order to revitalise such areas where these activities are forbidden at present. With this aim in mind, the Regional Forestry Administration and local bodies should organise the recovery of cultural and historical sites and old rural buildings existing within the woodland area.

- The formation of a specialised body for the extinguishment interventions, the "Forestry Fire Brigade", selected exclusively from established personnel of the Regional Forestry Administration in order to reduce the perverse habit of taking on temporary workers for anti-forest fire defence to a minimum.

- Increase in the number of ground vehicles available for emergencies in order to stop the spread of fire while awaiting help from the air and the use of aircraft only in cases where it is impossible to reach the fire by other

means. Helicopters should be mainly used to observe the progress of fire and to transport specialised personnel to strategic points in order to apply specific fire-fighting techniques.

According to the Alternative 2, the responsibility of the Agriculture and Forestry Department would be limited to regional woodlands, nature reserves and private and public land administered by the Regional Forestry Commission (comprising 70% of the present area, that is about 210,000 hectares).

As to prevention, the same proposals as Alternative 1 apply, concentrating technical and financial means within a reduced area for a higher expenditure efficiency. For privately and municipally-owned woodland, incentives could be provided for the organisation of preventative measures, especially with regard to the creation of fire-breaks, woodland and agricultural enterprises which would also co-operate in anti-forest fire control, agritourist undertakings and those economic activities linked to the conservation and improvement of the forest patrimony.

The issue of legislative measures to guarantee that such obligations are complied with and the possible expropriation or temporary occupation where their failure might be partially responsible for irreversible damage to the woodlands.

The organisation of fire-fighting training courses for private citizens and municipal employees, co-operatives or associations which can be entrusted by the local councils to help in the prevention of and defence against forest fires.

As to extinguishment, regionally-owned woods and protected areas administered by the Regional Forestry Department would be involved.

In the woodland areas belonging to or managed by the Regional Forestry Administration, the proposals are similar to those in Alternative 1.

In private woods, once the basic rules for prevention have been observed, the presence of woodland and agricultural or agritourist enterprises during the critical periods, together with adequate controls, would facilitate intervention for extinguishing fires and might dispense with the need for more expensive technical equipment.

In any case, such enterprises should be given particular incentives in order to encourage them to acquire vehicles and equipment for ground interventions.

As to the 3rd alternative, the use of the regional fire-fighting service should be limited to natural and paranatural woodlands and to artificial forests mostly used for soil conservation and not for timber production because of their particular morphology or slope.

With regard to the present situation, involving over 300,000 hectares of natural and artificial woodland and protected scrub areas of naturalistic importance, about 50% of this land would be subject to anti-fire control,

made up as follows:

- Natural and paranatural woods, and scrub formations, about 125,000 hectares, including those in protected areas.

- Artificial woods planted with conifers and broadleaves (eucalyptus, acacias, robinias) which have a protective but not a timber production or a grazing function, about 25,000 hectares.

The above do not include scrub and timber-producing forests having a productive and/or recreational function in which woodland, agricultural, agritourist or sporting enterprises might be undertaken.

Where these areas are regional, whether or not they are intended for soil conservation, since these can be assimilated within the timber-producing areas, they should be administered as forest enterprises either directly by the regional administration or entrusted to forestry public or private companies, so as to organise cultural activities and reduce fire hazard to a minimum (agricultural care, mowing, thinning-out etc.) together with regular timber-cutting and related activities.

Financial liability for the prevention and extinguishment of fire should be borne by the management concerned, although there should also be public funding so that positive results might be achieved.

Definition of the judgement criteria. Some criteria have been selected to assess the various alternatives from both the economic and environmental aspects.

The non-economic criteria have been chosen so as to take into consideration not only such specifically environmental elements such as ecosystem protection, soil conservation and so on, but also social and aesthetic elements.

Defence costs, income from timber and non-timber activities and loss of income from timber production are the indicators identified in the analysis within the economic criterion.

Defence costs include those for fire prevention and extinguishment, expressed in lire per hectare of woodland and non-woodland areas, under responsibility of the Regional Forestry Administration.

The assessment of surveillance operations, together with the monitoring and management of woods and protected areas, are necessary in order to reduce both accidental and wilful fires to a minimum. This indicator is expressed by the actual costs for the interventions required for prevention and extinguishment, as previously described, and their incidence in the overall costs of the alternatives under consideration.

These costs also include public incentives for rationalising woodland management on private or municipal property and for the provision of the necessary fire-fighting equipment.

Recovery costs are those involved in the recovery of a wooded area subsequent to a forest fire and are linked to the level of environmental quality that it is meant to

be achieved by recreating the woodland and shrub vegetation.

The second indicator assesses the positive economic effects linked to both large and small interventions aiming at fire prevention and environmental safeguard of woods and protected areas. It comprises the possible income deriving from the sale of tickets to have access to woods in protected areas and also from money spent by visitors, plus the income descending from grazing rents and farm products.

Loss of income resulting from fire damage is not easy to estimate, since regional, municipal and private woods all earn their main income as grazing grounds, while the amount of money deriving from the sale of wood products is almost negligible due to the lack of forestry industries on the island and also to the regulations in force regarding land within protected areas.

For research purposes, estimates have been made of the present annual loss of grazing income, discounted for ten years, which is the period fixed by law for the recovery of grazing land after fire damage, while income loss involving scrub has been determined by applying the mean sales price to the estimated quantity of firewood damaged.

Among the non-economic criteria, social, aesthetic and environmental components were included in the analysis.

As to the social component, two indicators have been taken into consideration which are linked to the presence of woodland of varying quality.

Exploitation of leisure time regards the positive effect of the existence of woods on the local populations, who can spend their leisure time there pleasantly relaxing or in various pastimes.

Employment is a quantitative indicator expressed by the number of working days, both with regard to woodland management of preventative, extinguishment or reconstitution measures and to the activities linked to these.

The aesthetic and visual component is represented by a single index, termed beauty of landscape, expressed by

a scale from 1 to 10 indicating, in a decreasing order, the improved visual compatibility of the wood within the environment.

The environmental components have been sorted out in such a way that they should be able to identify the impact produced by forest fires.

The value to be assigned to an indicator for each alternative should be calculated a priori since it is already itself derivative and complex, correlated to different parameters and therefore expressed in qualitative terms by means of a synthetic reference index.

Furthermore, since the indicators express the level of impact induced by the alternative according to the criterion, they have been expressed on a scale of values from 1 to 10 where the index derives from the consideration of the complement of the alternative to 100%, subdivided by 10. As an exemplification, in the 70% alternative the index value will be 3 since this is 1/10 of 30, complement of 70 to 100; for the alternative to 50% the index value will be 5.

Three specific indicators were considered, that is hydrogeological problems, ecosystem and fire risk index. The former indicates, in qualitative terms, the environmental components which mainly depend on the stability of the general slope of the land, which is in turn strongly correlated to the various levels of woodland. It is generally accepted that on the whole, wooded slopes tend to give major land stability and a better structure of soil which is less exposed to such high summer temperatures.

Ecosystem describes the qualitative level of the main environmental factors, each of which would have deserved a specific analysis of its own. Among the elements to be taken into account, flora, fauna, water system, air and water quality and so on, but since this is a research study at general level, just indicative values were attributed to the alternatives in the form of synthetic judgements formulated by external consultants.

These two indices range from 1 to 10, where the lower values, related to higher negative impacts, were as-

Table 4 Assessment matrix

| Criteria | Economic | | | Social | | Aesthetic and visual | Environmental | | |
|----------------------------------|------------------------------|-----------------------|-------------------------------|------------------------------------|----------------------------------|---------------------------|------------------------------------|-----------------|-----------------|
| | Defence costs (Billion lire) | Income (Billion lire) | Loss of income (Billion lire) | Exploitation of leisure time index | Employment (no. of working days) | Beauty of landscape index | Hydrogeological difficulties index | Ecosystem index | Fire risk index |
| Total prevention (Alternative 1) | 150 | 3 | 123 | 10 | 700,000 | 10 | 1 | 1 | 0.66 |
| 70% prevention (Alternative 2) | 115 | 3.5 | 100 | 7 | 650,000 | 7 | 3 | 3 | 0.60 |
| 50% prevention (Alternative 3) | 85 | 4 | 60 | 5 | 550,000 | 5 | 5 | 5 | 0.55 |

Source: Expert estimates.

signed to the alternatives of partial defence (50% and 70%).

A fire risk index has been deduced from the Regional Plan for the defence of woodland and areas protected against fire, which, on the basis of a large number of cases, has established indices correlated to the type of woods involved, varying from 0.33 (broadleaves woods) to 1 (coniferous or deteriorated woods), with both mixed coniferous and broadleaves woods and non-woodland protected areas being at 0.66 and a weighted average value for all woodland and protected non-woodland areas equal to 0.66.

Although these criteria might also be assessed in a different form, since the aim of this study was to test the applicability of the described method, it is essential that the basic scheme of the methodological application be expressed as clearly as possible. It goes without saying, therefore, that if this research showed the method to be adequate, the rather simplistic assessment of these values might be improved by means of a further specific and more detailed study to answer these special needs.

Current application and results

The current application of the multi-

criteria analysis for the assessment of interventions aiming at the protection of woodland and at fire prevention was performed according to the traditional steps, the first of which regarded the assessment of the above alternatives. The correlation of these ones to the criteria taken into consideration produces a double-entry matrix for the insertion of all the associated assessments at each cell where a criterion and an alternative cross. The resulting table (table 4) provides the data necessary to proceed with the application of the Electre II (°) method. It is obvious that different criteria may be included, but for the illustrative purpose of this study the indicators already considered are deemed to be sufficient. After completion of the assessment matrix, each single descriptor is pondered and a weight is attributed to each of the criteria considered, taking into account both the needs and the aims from a more "private" point of view. This fundamental operation was performed by means of Saaty's Analytic Hierarchy Process (AHP), based on the decomposition of the environmental system at various hierarchical levels (the subdivision of a complex problem into its elementary parts); this

(°) The Electre methods (Roy B., 1971) are based on concordance and discordance for the determination of a value of the alternatives for a given point of view to achieve a final order by means of the comparison between the alternatives, or, even better, comparing the various alternatives considered and observing to what extent one single alternative totally prevails over all the others. The comparison should be made for each pair of alternatives and an analysis should be performed of the number of criteria disposed towards the alternative under consideration compared with the others (concordance analysis) plus a calculation of the separation effect, that is, to what extent each single criterion is discriminant for the alternative in question compared with all the others (discordance analysis).

Table 5 Saaty "Fundamental Scale"

| Intensity of importance | Definition | Explanation |
|-------------------------|---|---|
| 1 | Equal importance | Two activities equally contribute to the aim |
| 3 | Moderate importance | Experience and judgement favour the first option |
| 5 | Considerable importance | |
| 7 | Great importance | Its predominance is demonstrated |
| 9 | Extreme importance | Strongest evidence in favour of one option |
| 2,4,6,8 | Intermediate values between two judgements | A compromise may be necessary |
| Reciprocal values | If one of the above numbers is assigned to "j", when this is compared with "i", "i" has a reciprocal value (and vice versa) | |
| Rational numbers | The ratios are derived from the scale | If it has been necessary to force the consistency in order to obtain the values |

Source: Saaty T.L., 1980.

Table 6 Criteria indicators weights matrix

| Indicators of Criteria | Defence costs | Income | Loss of income | Exploitation of leisure time | Employment | Aesthetic and visual component | Hydrogeological difficulties | Eco-system | Fire risk | WEIGHTS R.C. = 7.1% | |
|--------------------------------|---------------|--------|----------------|------------------------------|------------|--------------------------------|------------------------------|------------|-----------|----------------------------------|--------|
| | | | | | | | | | | Ranking | Scores |
| Defence costs | 1 | 5 | 1 | 5 | 4 | 3 | 2 | 2 | 1/3 | 1 Fire risk | 0.282 |
| Income | 1/5 | 1 | 1/5 | 1/2 | 1/5 | 1/4 | 1/5 | 1/5 | 1/5 | 2 Defence costs | 0.157 |
| Loss of income | 1 | 5 | 1 | 5 | 4 | 3 | 2 | 2 | 1/3 | 3 Loss of income | 0.157 |
| Exploitation of leisure time | 1/5 | 2 | 1/5 | 1 | 1/4 | 1/3 | 1/6 | 1/6 | 1/6 | 4 Ecosystem | 0.113 |
| Employment | 1/4 | 5 | 1/4 | 4 | 1 | 1/5 | 1/4 | 1/4 | 1/5 | 5 Hydrogeological difficulties | 0.110 |
| Aesthetic and visual component | 1/3 | 4 | 1/3 | 3 | 5 | 1 | 1/2 | 1/2 | 1/3 | 6 Aesthetic and visual component | 0.082 |
| Hydrogeological difficulties | 1/2 | 5 | 1/2 | 6 | 4 | 2 | 1 | 1 | 1/3 | 7 Employment | 0.049 |
| Ecosystem | 1/2 | 5 | 1/2 | 6 | 4 | 2 | 1 | 1 | 1/3 | 8 Exploitation of leisure time | 0.026 |
| Fire risk | 3 | 5 | 3 | 6 | 5 | 3 | 3 | 3 | 1 | 9 Income | 0.023 |

Source: Our survey with key respondents with regard to the paired comparisons and Saaty's AHP method as to the weights ranking.

Table 7 Preference matrix with the standardized data, weights assigned to the criteria and the concordance and discordance threshold values adopted

| Criteria | Economic | | | Social | | Aesthetic and visual | Environmental | | |
|--|---------------|--------|----------------|------------------------------|------------|----------------------|------------------------------|-----------|-----------|
| | Defence costs | Income | Loss of income | Exploitation of leisure time | Employment | Beauty of landscape | Hydrogeological difficulties | Ecosystem | Fire risk |
| Total prevention (Alternative 1) | -1.00 | 0.29 | -1.00 | 0.33 | 1.00 | 0.33 | 1.00 | 1.00 | 0.33 |
| 70% prevention (Alternative 2) | -0.77 | 0.33 | -0.81 | 0.67 | 0.93 | 0.67 | 0.67 | 0.67 | 0.67 |
| 50% prevention (Alternative 3) | -0.57 | 0.38 | -0.49 | 1.00 | 0.79 | 1.00 | 0.33 | 0.33 | 1.00 |
| Weights | 0.157 | 0.023 | 0.157 | 0.026 | 0.049 | 0.082 | 0.110 | 0.113 | 0.282 |
| Discordance index $D_1 = 0.40$; $D_2 = 0.50$ Concordance index $C_1 = 0.60$; $C_2 = 0.50$ | | | | | | | | | |
| Source: Our elaboration on the data from previous tables. | | | | | | | | | |

method is generally recognised as a valid instrument for the attribution of "values/weights" to the different levels and to the elements present in these ones (Saaty T.L., 1980). In this study the AHP was only adopted in the first hierarchical level, relating therefore the nine criteria under consideration with the aim of the research, the prevention of forest fires, since the analysis will subsequently be carried out by the application of the Electre method. The ponderation of the criteria implies a whole series of multiple paired comparisons which are organised in a matrix and resolved and verified according to an index, the "consistency ratio", which evaluates the consistency of the judgements. A square matrix is therefore defined, of the order $n \times n$, made up of criteria compared with reference to the main aim. Comparisons are performed in pairs in order to identify the relevance to the aim for each criterion considered. Since the components of the level considered are not based on the same units of measurement, each pair examined is given a real positive number corresponding to a judgement value expressed by a group of experts on a scale of 9 points, known as the "fundamental scale" (table 5). It indicates the relative importance of an alternative with another one with regard to their contribution to the aim of the project, where low numbers mean slight differences in importance and higher numbers **stronger and stronger** significant predominance of an activity over the other one in the pair. From the matrix built up by means of the scores assigned according to the basic scale, therefore, a calculation was made of the maximum autovalue and the relative autovectors, then normalised. The search for the autovalues was performed by means of the decisional analysis programme "Definite" (³), which was also adopted to solve the assessment matrix and achieve the final order of the planned alternatives. After weight attribution (table 6), the next phase involves the concordance analysis based on the standardised assessment matrix of

Table 8 Concordance and Discordance Matrix

| Concordance Matrix | | | |
|--|------|------|------|
| Alternatives | 1 | 2 | 3 |
| 1 | - | 0.27 | 0.27 |
| 2 | 0.73 | - | 0.27 |
| 3 | 0.73 | 0.73 | - |
| Discordance Matrix | | | |
| Alternatives | 1 | 2 | 3 |
| 1 | - | 0.33 | 0.67 |
| 2 | 0.33 | - | 0.33 |
| 3 | 0.67 | 0.33 | - |
| Source: Output from Electre II method. | | | |

the impacts completed by the value of the weights of the criteria and by the assignation of the two pairs of concordance and discordance thresholds (table 7).

As above mentioned, the Electre methods, and especially version no. II, fix two concordance thresholds (weak and strong) and two discordance thresholds (weak and strong). As for the discordance thresholds, it was decided to assign values of 0.50 for the weak one (D_1) and 0.40 (D_2) for the strong one. For the concordance thresholds, however, we used the values obtained from the literature regarding the use of the Electre methods in the environmental field, which are 0.50 (C_1) for the weak threshold and 0.60 (C_2) for the strong one. Once the matrices of concordance and discordance have been obtained (table 8), it is possible to see if one solution proves to be more important than another (in our own case Alternative 1 against 2 and 3). The application of the multicriterial method provides a

(³) *Definite*: A system to support decisions on a finite set of alternatives. Developed by Ron Janssen and Marjan van Herwijnen, Institute for Environmental Studies, Free University Amsterdam, The Netherlands. Kluwer Academic Publishers, Dordrecht, The Netherlands, 1992.

classification of the considered alternatives, by virtue of the assessments assigned to them according to each criterion, on the basis of the weights attributed to the indicators and of the values assigned to the concordance and discordance thresholds. From the formulated and subsequently processed matrix, Alternative 3 (50% prevention) outclassed Alternatives 2 (70% prevention) and 1 (total prevention) and was therefore considered the best among the proposals considered.

CONCLUSIONS

This research has shown that in the Mediterranean countries, where every year vast areas of woodland and other types of vegetation of great natural interest are destroyed by forest fires, there is a pressing need to increase the efficiency of the management methods regarding prevention, extinguishment and reforestation, both in terms of public spending and damage monitoring. Sicily was taken as an example, since it is a typical Mediterranean region at high fire risk due to specific physical and socio-economic factors. Here every year, in spite of vast public spending for the organisation of the anti-forest fire services, 8,000 hectares of woodland and Mediterranean scrub are seriously damaged or destroyed. Apart from the mere improvement of the present management system (Alternative 1), two other alternatives have been proposed – public management on 70% (Alternative 2) and on 50% (Alternative 3) of the present land involved. The woods (30%) and protected areas (50%) excluded are to be entrusted to woodland, agritourist, agritourist-hunting enterprises and so on, which, encouraged by financial incentives, are required to create suitable facilities able to guarantee adequate services of prevention and active fire defence. The multicriterial analysis was conducted with the use of the programme Electre II, which suggested that alternative 3 is by far the preferred option, followed by alternative 2 and finally by alternative 1. Although the study was conducted with a limited number of indicators, the results obtained suggest that public money could be spent more efficiently only if the anti-fire services were concentrated in forests and protected areas of particular naturalistic interest, and if incentives were offered for the creation of new management to be included in anti-fire defence programmes in the context of economically viable private enterprises. Therefore it seems possible that the most effective prevention and defence from fire can be achieved where woods and protected areas are of interest to the community, not only in virtue of their environmental characteristics but also for their socio-economic effects. ●

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