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IMPROVING THE EFFICIENCY OF THE WILDLAND FIRE PREVENTION AND SUPPRESSION SYSTEM IN GREECE

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ABSTRACT

A 3-year research project, co-funded by NATO (Science-for-Stability) and Greece (Forest Service), aimed at improving the efficiency of the wildland fire prevention and suppression system in Greece. The project involved applied research in inter-connected areas which included fire information management, wildland fuel and fire behavior modeling, fire effects assessment, and fire protection system analysis and improvement. An important task of the project had been the establishment and operation of a permanent Forest Fire Laboratory in the Forest Research Institute of Thessaloniki—essentially the first of its kind in Greece. Research was carried out at the peninsula of Halkidiki in northern Greece—a typical fire-prone forested area with high quality tourism, extensive urban development, scattered land ownership, and special scientific and ecological interests.

INTRODUCTION

This project aims at improving the efficiency of the forest fire prevention and suppression system in Greece. The objective is to optimize these systems by: a) investigating natural, socioeconomic and technological parameters of wildland fires and b) the best use of the study results.

The overall objective of the research program is pursued through the following four secondary objectives:

1. Analysis and evaluation of the past forest fire history (analysis of causes and arson phenomena), and through the development of a suitable Management Information System for the whole country of Greece through.

2. Fuel characteristics measurement and modeling

a) wildland fuel and fire behavior modeling

b) fire hazard reduction treatments

c) species composition of the forests

d) evolution of fuel biomass structure and effects of wildfire on forest succession.

3. Protection system analysis and improvement by utilization of the research results above (research items 1 and 2)

a) development of a fire data bank for real time processing of information to support decision-making for current protection activities

b) development of a linear programming model for the optimization of fire protection system

c) development of a custom-made software application that will use the above data and produce estimates with suggestions of actions to be taken

Objectives 2 and 3 concentrate on the Halkidiki peninsula. However, their application at the rest of the country high risk areas will be a repetition with slight adjustments.

4. Establishing and development of a Forest Fire Laboratory in addition to the training of personnel.

RESULTS OF STATISTICAL ANALYSIS

In order to evaluate the various causes from the viewpoint of their quantitative contribution to the problem of forest fires, we started the statistical analysis of the total of fires occurred during 1983-92 according to causes; first cause analysis explains the arsons which constitute a specific task of the project's objectives.

The analysis, in a first stage as descriptive statistics, was conducted in order to estimate the major characteristics variables of arsons phenomenon and to prepare the research of their profiles. The major results of the analysis are the following

A. Total of Fires

1. The 34.72% of fires are of unknown causes. This fact makes necessary the re-examination and the improvement of searching and investigation mechanisms to incorporate measures in the prevention system for lifting up the causes.

2. The 35.72% of fires are of possible causes. Consequently, the observation-proposal of the above paragraph is also valid here.

3. The relation between the number of fires of verified, possible, and unknown causes and the respective burned area and suppression cost is as follows:

	Causes %			TOTAL	
	Verified	Possible	Unknown	%	Absolute
Number of fires	29.56	35.72	34.72	100	13182
Area burned	21.52	42.00	36.48	100	6604492 ×1000 m^2
Suppression costs	25.06	34.04	40.90	100	1399992 × 1000 Dra

4. From the verified only causes of fires, the number of fires per cause in the first five places are in order of frequency: burning of stubbles (26.79%), arsons (17,37%), people working in the field (9.44%), lightning (8.70%) and burning of trash (8.29%). Including the possible and unknown causes as well, the five first places are occupied by unknown causes (34.72%), arsons (17.83%), pasture burning (13.67%), stubble burning (10.57%) and field workers (3.88%).

5. In order to reduce the area burned by eliminating some of the causes, the attempts should be focused to the following five social groups of verified fire causes (in parenthesis the percentage of area burned per verified causes): farmers ("burning of stubbles" 21.06), arsonists ("arsons" 19.39), persons in charge of trash management ("burning of trash" 12.54), people working in the field 8.45), people in charge of the State Electricity Company ("short-circuits" 7.60), that is 69.04% of area burned of verified causes and 14.85% of area burned of the total of fires.

Agricultural authorities able to inform efficiently the farmers, Municipality and Community authorities (responsible for the management of trash), and the State Electricity Commission (responsible for the electric network function), are also important bodies to ease off the forest fire problem.

6. By lifting the causes of the first 5 categories it would be a decrease to the suppression cost of 79.93% since the suppression of these fires is responsible for about 79.93% of suppression cost of verified fires and 20.03%, of suppression cost of the total of fires.

7. The improvement of tracking down the causes will allow an even more reduction of the burned area and suppression cost by verifying the true cause for the forest fires of possible and unknown causes and attempting to lift them up.

B. Fires Caused by Arsons

1. Arsons occupy the 17.83% of the total number of fires, burning the 24.47% of the totally area burned and requiring about 28.53% of the total suppression cost. The area burned due to arsons is distributed to 82.46% in forest land and to 17.54% in agricultural land.

2. From the total number of arsons occurred during the last decade (677 cases) in only 9.30% of them the arsonists were determined. This fact makes also necessary to improve the control mechanism of fire causes.

3. Besides the above, an important role also plays the occurrence of arsons within working and non-working hours of forest authorities; because it is critical to determine the readiness level of the prevention and suppression forces at various hours of day and night in order to confront efficiently the arsons. It is noteworthy that arsons between 21.00 and 08.00 amount for 32% and burn 57% of the arsons-area whereas arsons outside these hours amount for 68% and burn 43% of the area burned due to arsons.

4. While the times between the estimated ignition and the detection of fire by arsons, and between detection and report as well, may be considered satisfactory for the greater number of arsons, the times of mobilization and attack of suppression mechanism are generally long. As a result there is a great percentage of arsons for which more than 40 minutes went by from the ignition until the attack, and due to that a very large percentage of area was burned.

DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM

Geographic Databases

The following geographic databases were prepared:

- Coastline
- Road network
- Vegetation coverage
- Contour lines showing altitude
- Digital Terrain Model (DTM)
- Location of various fire suppression characteristics

They include the location of:

- Past fires
- Fire fighting stations
- Fire fighting equipment
- Water tanks
- Fires watch towers

«*Phaethon*», a Forest Fire Information Management System

One of the objectives of the GR-FOREST FIRES project was to develop an information management system that will permit the analysis of fire incident patterns. The data on fires for years 1983-92 were analyzed statistically using SPSS. Then the information system «*Phaethon*» was developed for storing, retrieving and visualizing patterns of past fires.

«*Phaethon*» is a system that runs on PCs under the Windows '95 operating system and contains all the data of fires that occurred in Greece in years 1983-92. There are a total of about 13,000 records. The system has capabilities for storing information for subsequent years, it permits user-defined queries and visualization of the results of the queries can be done on maps and/or tabular reports.

Software Engineering

«Phaethon» was developed in order to permit forest offices staff to be able to analyze past patterns of forest fires. Hence, special emphasis was made in order to develop a software that could be used by users that did not have extensive computer expertise, it is user friendly, but also, has advanced query and visualization capabilities. It runs under the Windows '95 (and Windows 3.1) operating system and can be installed in any PC.

«Phaethon» can be considered to be a GIS system since it contains geographic data and attributes. The geographic data are the maps of Greece, the boundaries of the various prefectures, the main road network, the location of the major cities and most importantly the location (x, y) of past fires. Attribute data include various information on each fire such as day and date that it occurred, the time that it took to suppress it, the possible cause, the size of the burnt area and others. All of these are stored in various databases in an organized way.

The system was developed using Visual Basic and Visual C++. Although, the system could be implemented using any of the standard GIS/desktop mapping systems such as Arc/Info, ARCVIEW or Mapinfo it was written in VB so that it can be distributed in the various Forest offices without any additional cost. If the system was implemented using the script languages available in almost all the GIS systems, the development time would have been significantly shorter, but, in that case in order to run the system users would have to purchase a license for the GIS system as well. This would have been a significant expenditure and would have hampered the wide distribution and use of the software.

The software is multilingual. User's specify whether all the menus and options will be shown in Greek or in English. Additional language capabilities can be included once the various menus are translated in another language. This capability was embedded in the system since in the future the need might arise to implement similar systems in other countries. For the same reason, all the data are treated in separate files than the program. Thus, the software could be implemented in other countries once similar data files (maps, fire characteristics) are available.

A complete and thorough user's manual has been prepared. The manual discusses the installation and then provides step-by-step instructions on how to use it. Throughout the manual there are several actual screen pictures so that users can quickly become familiar with its operation.

Query Capabilities

The system has been designed so that users can search the database any way they wish. They can specify constraints to determine fires that satisfy ad-hoc imposed criteria on the attributes of the fire or its geographic location. For example, they can search the system to find out the fires that occurred on a Sunday or a Saturday in the prefecture of Herakleion, and the area burnt was more than 50 acres and the suppression time was more than 100 minutes.

User's specify the query criteria by clicking on drop-down menus. Various criteria can be linked through the keywords AND or OR. For characteristics that take numerical values users can use the < (less than), > (more than) or = (equal) signs.

Output Capabilities

«Phaethon» has capabilities for producing various tabular reports. That is the results of any query can be shown as a report on the screen, or printed in a printer. More significantly the results can be exported immediately to an XLS file that can be imported in MS-EXCELL so that users can further analyze them with that software. ASCII type of files can be also exported from the software.

An additional feature of *«Phaethon»* is that it can produce summary reports of the fires that occurred within the area covered by any local Forest Office or a region. The summary reports can be based on any of the fire attributes; two fire attributes can be specified to define a table. Criteria on fire characteristics can be imposed here as well.

Visualization Capabilities

Since it was felt that visual presentation of the results of queries can be more easily absorbed by the user population of the software special attention has been placed in integrating in «*Phaethon*» such capabilities. Extensive mapping and graph/charting features have been included in the software.

Users can specify which geographic layers they want to see and they can always zoom in or zoom out. Location of fires that satisfy the queries can be shown on the map. Additionally, users can prepare thematic maps. That is they can produce a map that shows with different colors the fires on the basis of any criterion. For example, they can show on a map all the fires that occurred in a Prefecture with different colors depending on the size of the burnt area or the day fires started or the time it took to suppress them.

Users can also view the results of their queries on graphs/charts. The graphs can be simple 2-dimensional graphs (lines, bar charts, pie charts) or even 3-dimensional. The type of graph to be produced is user selectable.

Procedures for Updating the Database

«*Phaethon*» was developed in order to serve as an easy to use system for managing the information related to forest fires. This means that in order for the system to be used it must have capabilities that permit users to add data for additional fires as the need arises.

Hence, simple to use procedures and software was prepared that permits the staff of the Ministry of Agriculture/Forest Stations to augment the database with data for other years as soon as they become available. Users must prepare simple ASCII files that contain the information and then the system reads this files and updates all internal databases without any user interference.

FUEL AND FIRE BEHAVIOR MODELING

One of the most difficult parts of developing a fire behavior prediction system is the evaluation of the physico-chemical characteristics of fuel particles for each vegetative fuel model. Especially for Mediterranean vegetation types, there are few field and laboratory experimental information concerning fuel characteristics. Knowledge of these characteristics is essential for vegetation type classification in fuel models needed for fire behavior predictions and fire suppression system improvement.

Four fuel model schemes related to characteristic vegetation types were developed in our study, to build a first approximation of a fire behavior prediction system in Greece. Every fuel model is considered a set of numerical values that describes a fuel type for the mathematical model that predicts spread rates and intensities (Rothermel 1972). Variables of a fuel model include loading, surface-to-volume ratio, heat content and moisture of extinction of the fuel particles, and fuel bed depth.

Our inventory of fuel profiles synthesized downed dead fuels along with understory vegetation, based on a combination of direct and allometric sampling methods (Brown *et al.* 1982, Kalabokidis 1993). These two elements, as the main carriers of the fire, were utilized to construct fuel models for the following characteristic vegetation cover types encountered in Greece:

1. Shrublands of evergreen/sclerophyllous plants or *maquis (Querqus coccifera, Phillyrea media, Arbutus unedo, Erica arborea, Erica manipuliflora, Quercus ilex, Pistacia lentiscus, Cistus spp.)* - [Maquis]
2. Aleppo pine (*Pinus halepensis*) forests with maquis understory - [Halepensis]
3. Stone pine (*Pinus pinea*) forests with maquis understory - [Pinea]
4. Black pine (*Pinus nigra*) forests with fern (Pteridium aquilinum) understory -[Nigra]

Results of the fuel inventory for each fuel model's live (shrub), litter, 1-h, 10-h and 100-h loadings, and shrub and dead fuel depths are tabulated and presented below:

FUEL MODEL	SHRUBS (kg/m²)	LITTER (kg/m²)	1-H (kg/m²)	10-H (kg/m²)	100-H (kg/m²)	SDEPTH (cm)	FDEPTH (cm)
Maquis	1.35	0.30	0.06	0.07	0.00	149.00	2.86
Halepensis	0.77	0.32	0.09	0.11	0.03	145.20	5.00
Pinea	0.63	0.68	0.09	0.11	0.02	117.50	6.95
Nigra	0.00	0.72	0.02	0.10	0.02	0.00	5.69

Other physico-chemical characteristics were added to the fuel models, representing the Mediterranean-type of vegetation in this zone. These characteristics were surface-area-to-volume ratio (S/V), heat content, and moisture of extinction; values were derived from sampling and the pertinent literature, with attention given in publications which consider characteristics of the species above and result from studies of the Mediterranean region (Daligault 1991, Doat and Valette 1981, Guijarro *et al.* 1997, Hernando *et al.* 1995, Pereira *et al.* 1995, Szczygier *et al.* 1992, Trabaud 1989). A summary of these physico-chemical fuel characteristics of the four fuel models in our study follows:

FUEL MODEL	HEAT CONTENT (J/g)	EXTINCTION MOISTURE (%)	1-H S/V RATIO (cm^{-1})	LIVE WOODY S/V RATIO (cm^{-1})
Maquis	20000	30	80	70
Halepensis	20000	30	90	70
Pinea	20000	30	70	70
Nigra	20000	30	75	--

Fuel Loading vs. Depth Relationship

Direct sampling for fuel loading estimation is considered a cumbersome and difficult procedure to be conducted by forest managers in pine/evergreen shrub cover types. To facilitate this task, a number of allometric equations was attempted to regress downed dead fuel loadings on fuelbed depths; besides using a considerable number of linear, nonlinear, and logarithmic equations, it was not possible to succeed in explaining more than 19% of the variance between the two previous variables. This difficulty has been also found by other investigators outside Greece, and it can be attributed to other factors affecting the fuel accumulation and decay rates (e.g., site quality, productivity, age, moisture).

A major implication of this development leaves managers in the area with two alternatives—besides direct actual sampling that we believe it is impossible for them to do: i) fuel models accompanied by corresponding photos and/or ii) indirect sampling methods (e.g., planar intersect technique which is difficult—but not impossible—to apply, especially in shrub fields).

Fire Behavior Prediction

Wildland fuel characteristics, converted to fire behavior outputs through the FUEL subsystem of BEHAVE (Burgan and Rothermel 1984), resulted in fire behavior potential shown in Figure 1 for each of the 4 site-specific fuel models. Fire behavior related variables (e.g., rate of spread and flame length) were predicted for fuel moisture and weather conditions representing typical summer situations in Greece.

Aleppo pine and stone pine forests show a similarly extreme fire behavior potential with almost 3 to 4 times higher spread rates and flame lengths compared to the maquis shrublands. This is mainly due to the lower compactness (ratio of fuel quantity to depth) and the favorable vertical and horizontal fuel arrangement (both live and dead fuel) of the forest cover types. In addition, the live fuel moisture distribution of the understory layers (as the main carrier of the fire) is a determining factor in the fire propagation. The black pine forest types have low fire potential in relation to windspeeds ranging from 0 to 5 on the Beaufort scale (BF).

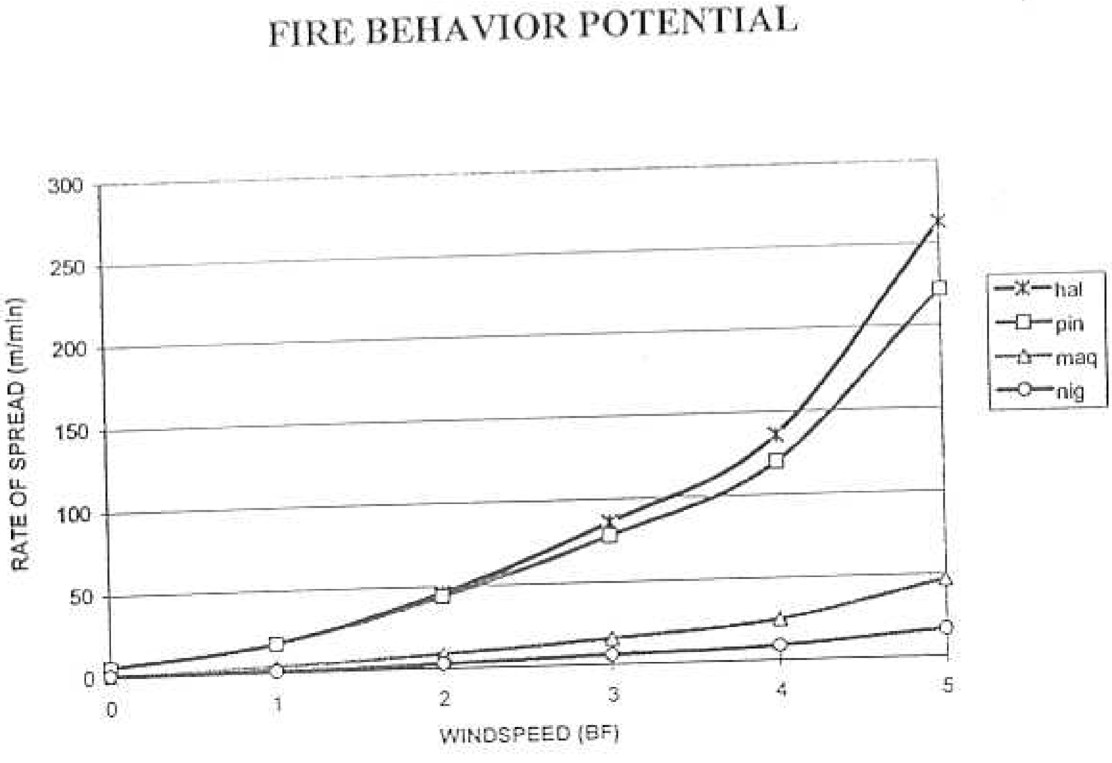

Figure 1.Fire behavior potential of the 4 fuel models developed for Greece.

Addition of local meteorological data (i.e., fuel moisture contents and wind profiles) during the fire season enabled us to produce some additional real-time management tools for the fire suppression personnel. Two-way input tables and graphics were developed with the important fire behavior parameters to be used as decision-aid tools in prevention and presuppression planning (e.g., fuels management, fuelbreak construction in appropriate areas, allocation of detection resources) as well as in actual suppression operations (e.g., strategic placement of human and mechanical resources, prediction of fire growth development, selection of direct versus indirect attack methods).

The purpose of all the above fire behavior models, graphs and tables is to provide for valuable "tools" and aid in timely and correct decision-making from experienced and well-trained fire management personnel. Thus, the role of fire managers is not replaced, but to the contrary, it is strengthened with justified and quantified decisions and actions.

Adaptation of the BEHAVE Fire Behavior Model

The objective of the work carried out in the project was to make the appropriate changes in the BEHAVE system, so that it can be used in Greece. To accomplish this objective the following tasks were performed:

- Translation of all user input and the output of the program in Greek so that the average user in Greece could use it without any difficulty.
- Adaptation of the various parameters and units of the fuel models so that they conform to situation in Greece (different vegetation, different units, etc.).

The code of BEHAVE is written in FORTRAN. Both the USDA Forest Service version and the Spanish version of the code were used to develop the «Greek» version. The Spanish version was used since some conversions on the units were done on that version already. As part of the translation, all the formats of the READ, WRITE, and PRINT statements were changed and are now in Greek. Minor changes were done on the code to make it compatible with the Microsoft FORTRAN™ compiler that was used to compile the program. To adapt the various parameters to the forest conditions in Greece (fuel types), some changes were done on the input files that contain these parameters.

The complete system was tested with Greek Forest Service personnel to determine its usability and ease of use. As a result of the input received some changes were made in the input screens to facilitate its use. The Greek version of BEHAVE is now available and runs on PCs under DOS and Windows; a short user's manual has been also prepared.

FIRE HAZARD REDUCTION

Within the frame of this project, we initiated fuel treatments to reduce fire hazard potential, quantify and compare alternatives, and monitor the effects of the treatments on a permanent basis. The study has been conducted in the Halkidiki peninsula of Greece, where a 2-ha permanent study area has been selected and bound. Fire behavior and fuel characteristics were implicated into effects on fire hazard reduction. The following treatments have been considered appropriate for testing, not only for hazard reduction but also in terms of feasibility and local practices: i) shrub removal, ii) shrub removal and tree thinning, and iii) shrub single-stemming and tree thinning.

Overall, shrub removal associated with three different treatments has shown to be an effective means for reducing fire spread, resistance-to-control, and ecological losses (by limiting fire intensities). Modeled surface fire behavior was brought within limits of direct suppression techniques, and potential damages were mitigated as a result of these alternative fuel treatments. Tree thinning (accomplished in two treatments) provided an extra level of fuel modification with mixed results, due to the crown openings of the forest that generally promote faster re-growth of understory vegetation; excessive fine slash was also produced from the thinning operations, which was impractical and impossible to be completely removed from the study site. At any rate, thinning with no slash disposal treatment is an inappropriate option because more fuel becomes available for combustion and, thus, contributes to extreme fire outcomes (e.g., crowning and erratic fire behavior).

DEVELOPMENT OF A DSS AND OPTIMIZATION MODEL FOR IMPROVEMENT OF THE FOREST FIRES PREVENTION AND SUPPRESSION SYSTEM

One of the major objectives of the research project is to produce tools that they will be able to support the Forest Service in the difficult task of the decision making in regard with the forest fires prevention and suppression system. We have approached this objectives by the development of two different models. The first is a Decision Support System (DSS) aiming at the best information of the persons-in-charge of the Interagency Commanding Office located in the Central Headquarters. The second is a goal programming model aiming in the optimum allocation of the different suppression means during the summer months.

The DSS

The system intends to confront the situations of simultaneous claim for sending out airplanes and firefighters to various regions of Greece. During summer months it is often observed the phenomenon of many fire incidents occurring at the same time (or almost at same time) throughout the country. The persons-in-charge of forest offices in the areas of fire incidents are reporting to the Commanding Center and claim for sending out airplanes. In the case which the available airplanes are adequate to handle all fires (a fact not often observed) the Commanding Center Officer may satisfy all claims as long as he considers that the mission of airplanes is necessary. However, when available airplanes are not enough the Commander faces the dilemma: **where and how many airplanes to be sent.**

The proposed Decision Support System (DSS) aims at adding one more estimation which will be based on the statistical analysis of historical data collected from the forest fires and which will be expressing the possibility for a fire to develop within specific size classes.

The DSS will be taking into account the data which are immediately estimable by the person who will report the fire to the Commanding Center (usually the Forest Officer or his deputy) and who claims for airplanes. The DSS based on the data will calculate the possibility for a fire incident to take specific dimensions.

The proposed system is theoretically supported by the methodology of discriminant analysis and is described by the next model.

By applying discriminant analysis and using a sum of independent variables we try to forecast to which size class the fire belongs to. The size classes may be shown either with arithmetic data (e.g. 1-100 stremmata, 101-500 stremmata etc.) or with a descriptive way (e.g. very small area, small, medium, big, very big). The descriptive way suits better in the case we want to differentiate the classes depending on the specific forest office.

The linear discriminant equation takes the following form

$$D = \sum_{i=1}^{n} B_i X_i$$

where i = the number of independent variables

B = the estimated parameters and

X = the independent variables

By the discriminant analysis it is tried to find a transformation which will produce the maximum ratio expressed by the known formula

$$\max \frac{\text{between}-\text{groups sum of square}}{\text{within - groups sum of squares}}$$

The independent variables in order to classify a fire, are correlated based on the similarities of their distributions.

The prediction in respect to which class belongs a fire, is done by applying the Bayes rule:

$$P(C_j \mid D) = \frac{P(D \mid C_j)P(C_j)}{\sum_{j=1}^{k} P(D \mid C_j)P(C_j)}$$

which provide us with the **possibility of a fire of which the price of discriminant equation is D, to belong to the class j**.

At this point we have to stress out that the proposed DSS aims at providing only a new information to the person-in-charge of the Commanding Center and **not to suggest a specific decision to be made.**

The Optimization Model (Methodology)

There are i = 1,2, ... n candidate stationing locations on which specific vehicle-surveillance crew type j= 1,2 .... m can park. Each vehicle type bears a specific (given) number of vehicles Kj. (The number of vehicles will be positioned within the particular range for which various solutions will be given).

Every candidate location is expressed as X_i^j, in other words it expresses the stationing of the vehicle type j in location i. Every candidate stationing location covers a specific responsibility area (the candidate locations are set out after a joint meeting of the research team with the various Forest Offices). As long as responsibility areas are outlined upon the map each one will be divided into subsections of about 100 stremmata each. For each responsibility area the following are calculated:

1. The rate of fire distribution according to the fire map which is available for each area. So, for each location and vehicle type it will result a coverage rate β_i, where the coverage rate equals to the number of fires from the under surveillance area location i towards the total of fires of the under study area multiplied by 100

(the β_i may need a weighing for each vehicle type j and so coefficients β_i^j will come up).

2. The average access time of each vehicle type on the total of its responsibility area. This time will be a function of the maximum access speed to each sub-region and the distance from the stationing location. Therefore, for each area i and vehicle type j it will arise the average attack of the vehicle α_i^j.

The optimization problem based on the above lies on the following:

$$\min \sum_{i=1,\, j=1}^{n,m} a_i^j X_i^j$$

$$\max \sum_{i=1,\, j=1}^{n,m} \beta_i^j X_i^j \ .$$

s.t

$$\sum_{i=1}^{n} X_i^j = K_j \,, \forall\, j = 1,2,\ldots.m$$

$$\sum_{j=1}^{m} X_i^j \leq 1 \,, \forall\, i = 1,2,\ldots.n$$

$$X_i^j \in \{0,1\}$$

The above problem is of an integral goal programming one which consists of 2 goal functions and of limitations the total of which equals to the sum of candidate stationing locations and the vehicle types. Therefore, for 25 candidate locations and 3 vehicle types we have 28 limitations.

The first limitation group requires that the used vehicles to be within the range which we have set out whereas the second limitation group does not allow the stationing in one location of more than one vehicles.

The solution of the above system will provide for those locations which will cover the greater possible area on one hand and on the other will minimize the average attack time in each area.

The above model is possible to be applied for each forest office as long as the required data along with the necessary digitized maps, are estimated first. Its advantage lies on the potential that two goal functions can be used each time. The model was solved by the Institute of Technology and Research (ITR) for the Kassandra peninsula based on real data.

POST-FIRE SPROUT DEVELOPMENT OF MEDITERRANEAN SHRUBS

Permanent experimental plots have been established in a burned forest area near the town of Metamorphose, Halkidiki, Greece, for investigating the development of sprouts and the growth rate of new plants following a wildfire. The climate is typical Mediterranean-type, with an extended dry and hot summer period followed by mild and rainy winters; the mean annual precipitation is around 470 mm. The geological substrate in the study area is acid granite, characterized by few rocks on the earth surface; the soil is acidic (pH = 4.5 - 5.0), shallow, and poor in nutrients and stone compartments.

Before burning, the study area was covered by Aleppo pine (*Pinus halepensis*) in the overstory, with an understory of various sclerophyllous/evergreen shrubs (*Arbutus unedo, Erica manipuliflora, Pistacia lentiscus, Olea europea, Quercus coccifera, Cistus spp.*). The plots were classified by the method of Braun-Blanquet into a single plant community (*Oleo-lentiscetum*). Low regeneration of all species was the common characteristic of the plant community before burning, due to the extreme ecological conditions of the ecosystems.

Cistus spp. (C. incanus, C. salviefolius, C. monspeliensis) were the most abundant species found after the fire. They usually cover over 40% of the burned area within 2 years of the fire. The increasing presence of this genus is due to small size seeds, which are hidden into cracks of the ground where they retain their growing capacity for more than three years and activate under high temperatures of the fire. There is also another speculation that the dynamic presence of *Cistus spp.* is due to the fact that light seeds are transferred easily in great distances from close-by unburned areas.

Erica manipuliflora was dominant in plant communities before burning; it is a very competitive species for *Pinus halepensis* seedlings. However, *E. manipuliflora* disappeared from the *Oleo-lentiscetum* plant community the first two years after the fire. The other shrubs grew normally and expanded to cover the previously unburned area.

Numerical tags were placed on burned sprouts, where the height and diameter of the dominant individuals was measured periodically. The purpose of these measurements was to find a relation between maternal burned plant and dynamic growth of the sprouts. As a result, the first sprouts were noticed immediately after the wildfire. There have been low increase of sprouts in height during the first autumn and winter (1994-1995). Maximum growth occurred during the first vegetative period, where the sprouts acquired almost 70% of the initial maternal height. This growth stopped during the second autumn and winter (1995-1996). A very small growth marked the second vegetative period. These observations show that Mediterranean shrubs sprout and grow mainly during the first vegetative period following a wildfire, as these shrubs use nutrients that the maternal plant has stored underground in the roots.

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