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ORIGINAL PAPER

Decision support system for forest fire protection in the Euro-Mediterranean region

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Abstract This paper describes the development of a decision support system (DSS) for prevention planning and emergency management of forest fire events that incorporates weather data management, a geographical data viewer, a priori danger forecasting and fire propagation modeling, automatic fire detection, and optimal resource dispatching. Collection, input, storage, management, and analysis of the information rely on advanced and automated methodologies using remote sensing, GPS, digital mapping, and geographic information systems. The results included short-term dynamic fire danger indices developed for improved and realistic prevention and pre-suppression planning. An automatic fire detection technology based on infrared video was developed and successfully tested on site. Several models for understanding fire propagation on forest fires have been proposed for practical application. Additionally, a DSS was developed with the innovation of covering wildland fire hazard management entirely, providing a complete coverage of technical and administrative activities that support decision makers in real time. The DSS was tested for high fire seasons in two different sites in South Europe.

Keywords Forest fire management · Risk management · Decision support systems · Geographic information systems · Natural disasters

Introduction

Forest fires constitute one of the most devastating natural disasters in South Europe, North America, and Australia where large areas are affected annually with very large variations in fire seasons–such as occurred from 2003 through 2008. Difficulties in confronting such natural phenomena, especially in the Euro-Mediterranean region, include assessment of biophysical causes, spatial distribution, damage inflicted and also the influence of human socioeconomic activities (e.g., González and Pukkala 2007; Sebastián-López et al. 2008). Regional civil protection agencies require the efficient combination of interdisciplinary research, technology and development of systematic risk, hazard and vulnerability assessment (Chen et al. 2003), along with prompt and reliable forecasting and

In memoriam: Forestry Professor Nikolaos I. Stamou, Greece.

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management systems (Deeming et al. 1977; Hoffmann et al. 1999; Taylor and Alexander 2006; Van Wagner 1987). New technologies of geo-informatics (e.g., global positioning systems, digital mapping, geographic information systems, and spatial decision support systems) and electronic data capture and transmission of information from remote locations (e.g., remote sensing, remote automatic weather stations, automated detection sensors, etc.) have strong potential to contribute to more effective organization for environmental protection. Benefits include prompt detection and risk assessment, methodical observation of biophysical and socioeconomic parameters, and decision support management (Bonazountas et al. 2007; Kaloudis et al. 2005; Lee et al. 2002; Morehouse et al. 2006).

The Automated Fire and Flood Hazard Protection System (*AUTO-HAZARD PRO*)–a European Union-funded research project–has been designed to improve the level of technological development on forest fire risk management in Europe and help authorities in taking appropriate action to protect the built and natural environment (Kalabokidis 2004). The main objective of our research was to integrate real-time and on-line wildland fire hazard management approaches into a geographic information system (GIS) platform. The specific evolution reported in this article is the development of a decision support system (DSS) that incorporates proactive planning, weather data management, a geographical data viewer, a priori risk forecasting and fire propagation modeling, automatic fire detection, optimal resource dispatching governed by the pertinent principles, and emergency management of real-time fire episodes (Fig. 1).

Software application, data integration, and network infrastructure

Development of the *AUTO-HAZARD PRO* (AHP) DSS prototype was conducted on two study areas in Greece and Spain, with the potential to later encompass whole regions of EU countries on an operational basis (Kalabokidis et al. 2005). One of the most important applications of the DSS, when assisting managers on duty, is to help organizing on site human and technical resources (firemen, civil protection staff, volunteers, airplanes, trucks, etc.), assigning responsibilities, and communicating to them. The AHP DSS was designed to support these communication capabilities. Central SMS sending platforms, e-mail sending and local area network (LAN) sending facilities were integrated. The MobileNetControl communications platform (MNC 2007) from Mobile Net Control Scandinavia AB was integrated within the DSS. In an advancement beyond the classical DSSs, the system included this resource managing and dispatching module as an "Alert Manager." Most of the information managed by the program was stored in a GIS-compatible format (maps and layers), using standards defined by the ArcGIS software v. 8.3 (ESRI 2007) and also used to generate, read, and display geographical information. More specifically, ArcObjects™ components were integrated into the DSS. This solution was considered as an optimum alternative instead of customizing the ArcGIS platform, since the whole DSS was built from scratch with other third parties' components also included.

Implementation, calibration, and validation of data sets, algorithms, and software were carried out. Validation was

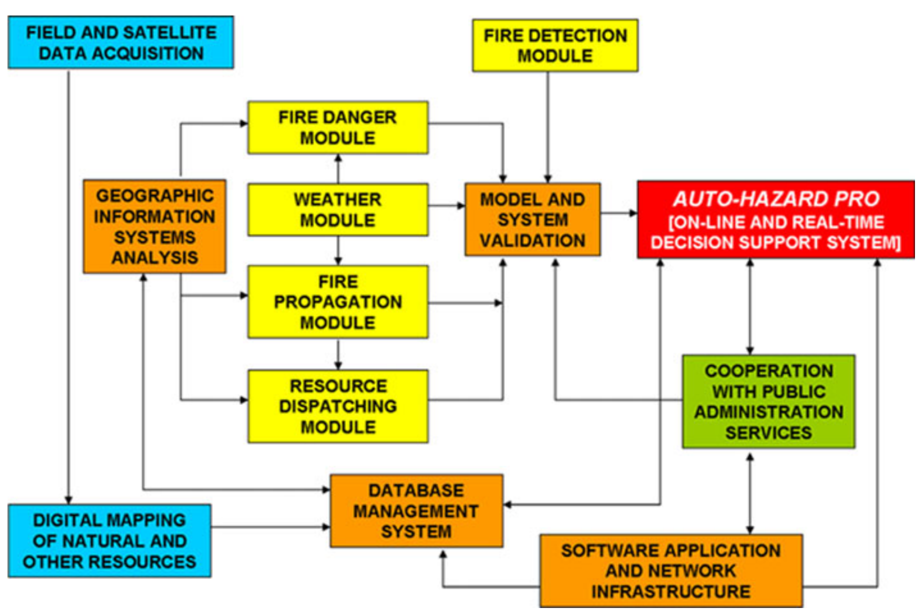

Fig. 1 Graphical presentation of the *AUTO-HAZARD PRO* DSS's components

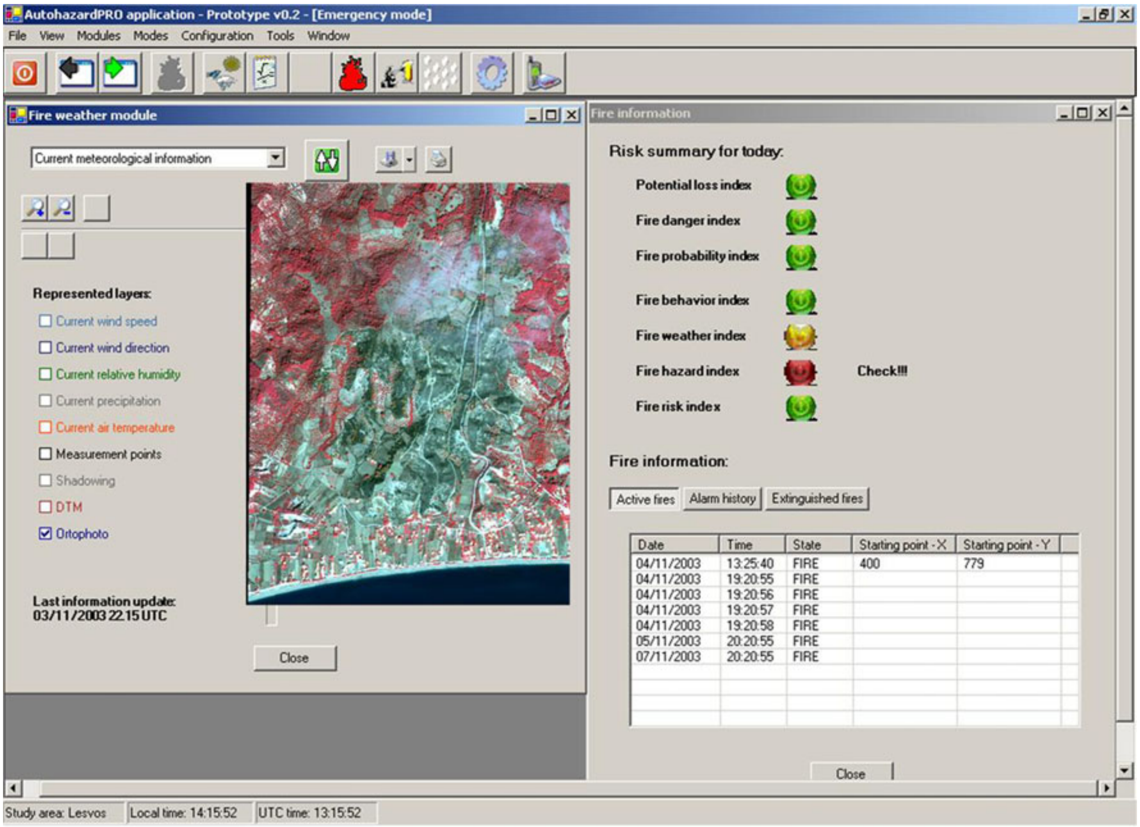

Fig. 2 A snapshot of the *AUTO-HAZARD PRO* DSS

accomplished by selecting a combination of existing, proven models, data sets and algorithms for comparison; testing of new algorithms and meteorological operational activities; and systematic data gathering of real data about different elements throughout the running of field campaigns, including:

- field sampling for digital maps acquired through remote sensing;
- actual atmospheric and weather data gathering (historical records);
- actual data of forest fire detection (experimentation); and
- actual data of forest fires (historical, real, and experimental burning).

Forest fire protection requires the use of large volumes of data that change continuously over time and space, creating both the need and the opportunity to automate the tasks. Within the DSS, satellite and ground technologies were integrated and applied using advanced geo-informatics tools and models for the inventory, mapping and monitoring of geomorphology, land cover and uses, fire occurrence, atmospheric and physical processes, and anthropogenic influences. Multi-spectral QuickBird satellite images (2.5-m resolution) for the whole island of Lesvos, Greece, and for the forest area within the Province of Madrid, Spain, were used to extract useful geographical information to study and monitor forest fires (e.g., vegetation and fuel types, topography, fire history, road networks, land-use boundaries). A database was developed and integrated into the DSS. The database was also used as input to various simulation models and for mapping purposes.

The philosophy followed within the AHP project was to create a DSS system that supports effectively its end-users throughout the fire management process by means of a fast and easy to use interface (Fig. 2). The interface takes advantage of the capabilities of the diverse technologies, models, and systems it integrates (i.e., GIS, communication software, automatic fire detection, and fire risk index generation). This user-friendly and efficiently designed application allows the user to view the meteorological conditions, check the fire risk for different time horizons, simulate the propagation of a fire or send messages to fire-fighting resources through different communication technologies (SMS, e-mail, and network sending). The applied methodology followed the standard software development guidelines that divide the software process into analysis, design, implementation, and testing phases, establishing different links and “tunnels” between them.

Analysis

The goal was to collect and analyze the minimum requirements necessary to be able to start designing an application. For achieving this goal, different techniques were used:

- personal interviews with the users/partners (person-to-person, by phone, or by e-mail);
- documentation of requirements sent to the users/partners to be completed and returned to the computer scientists.

The result of this stage within the AHP DSS application was a set of more than 120 requirements that the system should comply with.

Design

Once sufficient and consistent requirements had been identified, collected, and understood, a design was generated prior to the implementation. The design was then optimized and checked for possible failures or flaws in the analysis (that could lead back to the analysis phase). A set of models containing the design of the application was generated in UML–a standard object-oriented and multipurpose modeling language (UML 2007).

Implementation

Based on the design, the implementation or coding was performed at different stages. First, prototypes were generated to be evaluated by the users. In AHP, the prototypes were empty (without functionality) graphical user interfaces. These prototypes lead again to the analysis of requirements and, in some cases, to the design phase. After the users had validated the prototypes, the implementation began using them as starting point. In large applications like AHP, the program is divided into modules for the application of one or a combination of development techniques to each module in turn. A mixture between cascade (one module is done entirely, then the next one) and incremental (modules are completed incrementally, flowing several times from the first to the last one, and improving them in every iteration) procedures were used during the coding of the application. If there was a test phase after the implementation, working of modules was evaluated and significant failures or flaws were detected and corrected at this stage.

Testing

After the designed application was coded, different tests were performed as follows:

- individual module tests;
- inter-module tests;
- working mode tests;
- communication with devices tests;
- graphical user interface tests; and
- overall application working tests.

The AHP DSS can be run in *emergency* and *training* modes that are focused on dealing with real-fire cases and training the end-users, respectively. The system was designed in such a way that the two modes cannot be the origin of any conflict or information inconsistency for they work with separate sets of data. There is no overlap that might confuse "false" with "real" alarms. Functioning of the system has been designed to switch automatically from training mode to emergency mode when an alert happens. The software application offers functionalities to cover different aspects of both pre-fire and fire event management stages as follows:

- In the pre-fire stage, it is possible to obtain and/or generate actual and predicted meteorological information and fire danger indices.
- For the fire event stage, there is the automatic reception of fire alarm information, the possibility of simulating the evolution of a fire, getting particular dispatching advice for each alarm, and sending messages to other electronic devices (computers and mobile phones) through different communication technologies.

AHP: a DSS for forest fire protection

The AHP DSS is divided into five main modules that represent to the user different kinds of information and perform different tasks providing support during the whole fire management process. These modules are the: fire weather module, fire detection module, fire danger rating module, fire propagation simulation module, and resource dispatching module. The final application provides capabilities of simultaneous visualization of different information (fire danger indices, available resources, and active fires), fire alarm information management, and resource information management.

Weather module

The weather module is based on a high-resolution limited area weather forecasting system. Within this module, both current and predicted meteorological maps can be created. These maps can be displayed by clicking on the corresponding link at the meteorological information tab of the DSS. The source data for current meteorological maps can be obtained either from FTP servers (2-D meteorological fields) and/or remote automatic weather stations (RAWS)–that continuously record and transmit in situ weather data. Alternatively, data can be supplied manually through an appropriate interface. In the current application, the predicted meteorological maps are generated from data downloaded from the FTP server of the operational center of the Atmospheric Modeling and Weather Forecasting Group of the University of Athens. The weather predictions are made with the use of a high-resolution non-hydrostatic modeling system called SKIRON (http://forecast.uoa.gr). The forecasting horizon is 5 days.

Figure 3 shows an example of the 72nd-hour SKIRON forecasted wind field over Greece, together with the meteograms (time plots of predicted variables: wind speed and direction, temperature, relative humidity, atmospheric pressure, and accumulated precipitation) for our study areas. For example, the model has predicted high wind speeds over the Aegean Sea reaching 12 and 16 m/s in Lesvos Island (Fig. 3). Such wind conditions are often related to severe forest fire intensity and spread (Pyne et al. 1996). Accurate predictions of forest fire behavior depend on the spatiotemporal accuracy of wind and precipitation forecasts provided by numerical weather prediction models such as the SKIRON. Sensitivity analyses performed, showed that SKIRON forecasting accuracy remained high even during the 5th-day of forecast. Discrepancies, systematic or not, from the observations always do exist. To remove systematic temperature and wind errors, Kalman filtering techniques have been applied (Galanis et al. 2006). The use of a 3rd-order polynomial in Kalman filtering gave the best improvement in wind strength forecasting. These corrections were done for the study areas. The forecasts were also validated from RAWS observations.

Fire detection module

A ground-based forest fire detection (FFD) system was developed and demonstrated in Lesvos Island, Greece, and in Buitrago de Lozoya, Sierra de Guadarrama, Madrid, Spain, by the TNO Physics and Electronics Laboratory of the Netherlands (den Breejen et al. 1998; Tettelaar 2004). The detection system consists of a multi-spectral camera on a scanning pan-tilt unit that detects smoke via its near-infrared channel. It also provides on-line and real-time normalized difference vegetation index (NDVI) images that help assess the condition of vegetation which, in turn, is related to the level of fire risk. Within the AHP DSS, field sensors of the fire detection system can be linked to operational centers, where the manager evaluates the alarm signal and the image to initiate proper response (Fig. 4). When an alarm is raised by the system, as a result of smoke detection, the operator can request a false color image for visual confirmation of the fire starting. True-color images can also be used to monitor the fire incident. The system also has the option to provide an NDVI image real-time and on-line for vegetation monitoring. The operations center can then use the FFD outputs to make decisions on

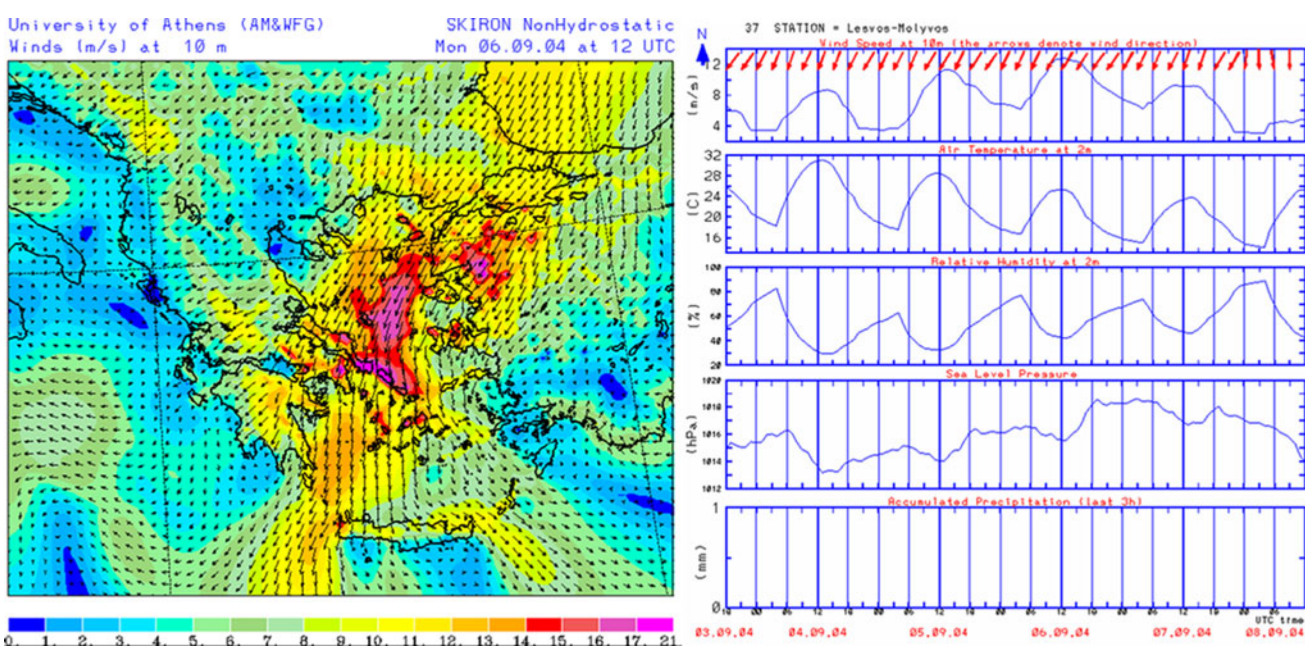

Fig. 3 72nd-h *SKIRON* forecast of the wind field over Greece on September 6, 2004 at 12UTC (*left*); and meteograms for the whole 120-h forecasting period for Lesvos (*right*)

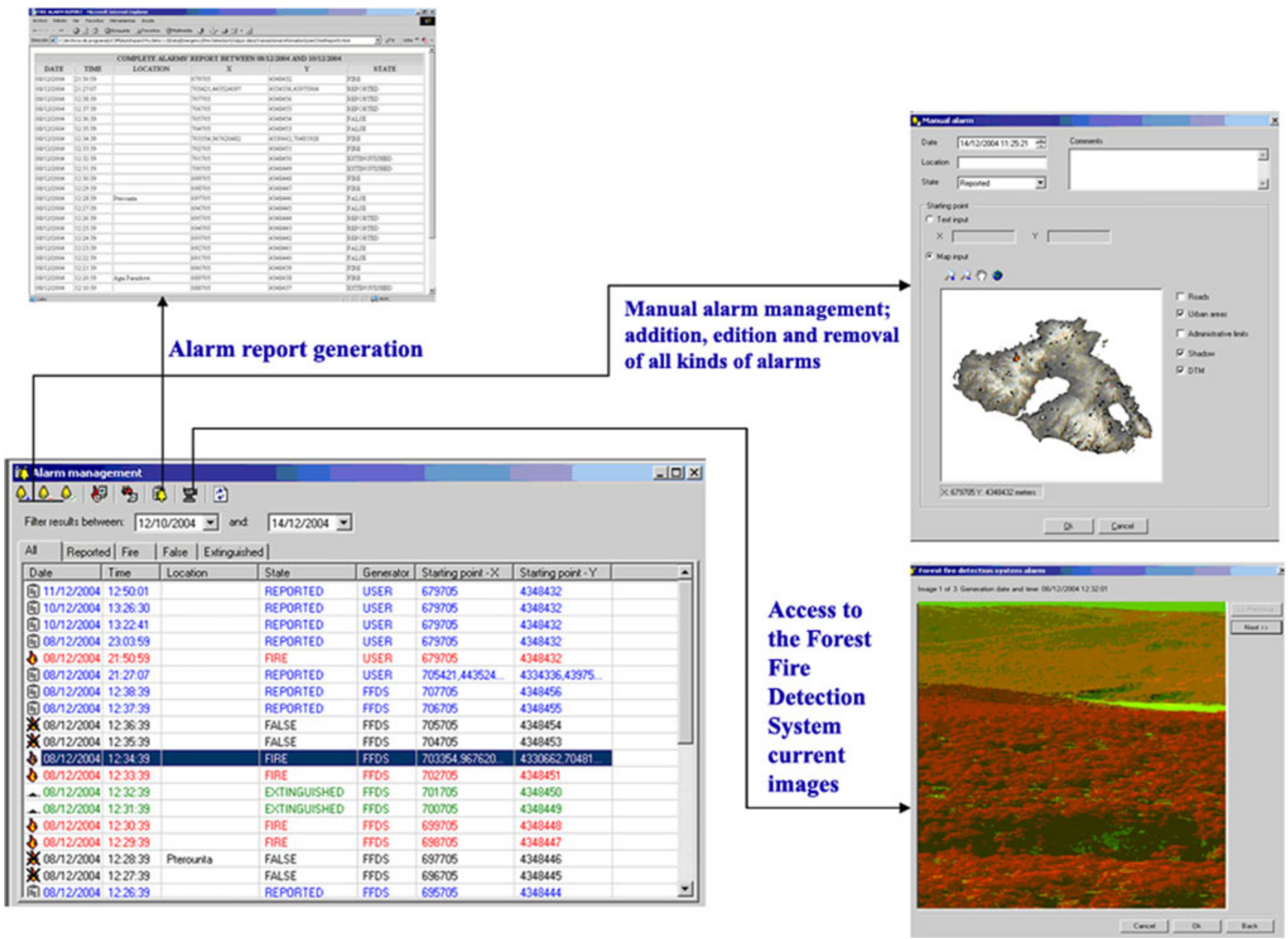

Fig. 4 The *AUTO-HAZARD PRO* fire detection module: in emergency mode, a process called "AlarmDetection.exe" is running in the background that downloads periodically the information from the forest fire detection system FTP server, checks the existence of previously unregistered alarms and displays a window with the main information and associated images for each new detection alarm

dispatch them when a fire starts, to adjust patrol/control when fire behavior changes, and to manage resources according to fire risk.

The software and hardware of the FFD system were tested in detail for its continuous operation and functionality. Initially, alarms were simulated in the TNO Physics and Electronics Laboratory by introducing simulated smoke into the image with various "noise" levels to test the alarm detection and reduce false alarms by setting the correct thresholds. Then, the FFD system was set up and tested operationally on Lesvos Island, Greece in the summer of 2003 and near Madrid, Spain in the fall of 2004. Controlled fires were lit to create smoke columns in both areas. The distances at which fires were lit ranged from 3 to 12 km. The Greek and Spanish end-users participated in planning and setting up the fire experiments and were present at the system demonstration. The trial tests were successful with a number of fires that were detected and registered as alarms, validating the FFD system in regard to spatial accuracy, time detection lag, and false alarm proportion.

The DSS fire detection module demonstrated that camera scanning is feasible for FFD with accurate results. There are four main outputs with regard to the detection accuracy of the system in the FFD system validations (Tettelaar 2004). Firstly, detection is very accurate for distances up to 12 km as registered in test trials. Secondly, positional accuracy of the camera is sufficient to create a good overlap between consecutive images. Thirdly, in some cases, the detection is limited by the speed of the pan and tilt unit, increasing the detection time as the system has to scan a full round. Finally, the system generates some false alarms in certain circumstances such as sunsets, passing clouds, road traffic, and camera alignment and detection grid. These problems are to be solved in future versions of the detection algorithm.

An interesting observation is that the main challenge to commercially exploiting the results of the FFD will not probably be the detection accuracy of the system, although it is important. The principle hurdle is probably the lack of infrastructure in remote areas, especially communicating data to a control center. In our research study, this problem was recognized and new wireless technologies, particularly 3-G mobile telephony, were proposed to bring the possibility of large bandwidth communication at an affordable price in remote areas. Such telephony allows for remotely monitoring other sensors, like weather stations, as well. This information could then be used to improve predictions and risk forecasts within the context of the AHP DSS.

Fire danger module

An innovative large-scale wildfire danger rating system (WDRS) was also developed in the frame of AHP. The main output of the WDRS is a dynamic fire danger index (FDI) that is composed of five other indices. The FDI is used for determining preparedness levels and also as a critical element of the decision-making process for dispatching resources to a forest fire. The five indices are as follows:

1. Fire weather index (FWI): It contains the correlation between fire weather parameters and fire ignition and includes meteorological conditions such as air temperature, relative humidity, wind speed, and rainfall during the previous 24 h from the time the index is calculated. It is based on data received by RAWS and the SKIRON weather forecasting system.
2. Fire hazard index (FHI): It is based on topography and vegetation and includes fuel models, 10-h fuel moisture content, terrain elevation, and aspect.
3. Fire risk index (FRI): It refers to the fire risk at a particular area due to human presence. It is based on the distance from anthropogenic structures and activities. The role of this index is to predict human-caused fires by accident or arson.
4. Fire ignition index (FII) is a composite index representing the accumulated ignition risk of an area that is the probability of a fire starting based on the fire weather, hazard and risk indices.
5. Fire behavior index (FBI) is based on topography, weather, and forest fuel of the study areas. The role of this index is to characterize the probability of a fire to spread after ignition.

These indices are not a relative probability for fire occurrence but a cumulative analysis for fire danger appraisal in a systematic manner. The parameters have been chosen in a defined and measured way to be easily included in an operational system. The functional mapping of the FWI, FHI, and FRI was accomplished with artificial neural networks (ANN) (Rosenblatt 1958; Vasilakos et al. 2007). Training of ANN was based on historical fire data and was performed using an error back-propagation algorithm (Rumelhart and McClelland 1986). These methodologies have been proven useful for classification and function approximation/mapping problems that are tolerant of some imprecision and have been used in spatial prediction of fire ignition probabilities (e.g., Chuvieco et al. 1999; Vasconcelos et al. 2001; Vega-Garcia et al. 1996).

The FII is composed of the FWI, FHI, and FRI by using multi-criteria analysis (Vasilakos et al. 2007). More specifically, the analytical hierarchy process is used to retrieve the weights by pair-wise comparisons between indices using a relative importance scale (Saaty 1980). Validation of the FII was performed during the summer of 2004 in the study area of Lesvos Island to verify its effectiveness under operational conditions. The validation included interpretation of the outputs by the end-users, operation of the system by non-expert staff, the processing time and communication reliability among the system, the meteorological stations via cellular GPRS connections, and the FTP server that stored the weather forecast data. During this phase, validation of the output provided satisfying results regarding fire problems in the study area (Vasilakos et al. 2007) including:

- Fire occurrence depended mainly on human factors (i.e., FRI), regardless of the size of burned area. This was also confirmed by actual fire data of the local Fire Department.
- Operational use resulted in 12 out of 28 actual fires ignited in areas classified as medium danger and 16 actual fires ignited in high danger areas–no areas were actually classified as having extreme danger during the tested summer fire season.
- The FII has been suitable for mid-term forecast of wildfire danger.

The FBI is based on topography, weather, and forest fuels of the study area. The methodology applied for the calculation of this index relies, first, on the estimation of intrinsic components of potential fire that are relevant to the potential destruction capacity and the difficulty of fire fighting. Then, a code is developed for the calculation of the intrinsic components of fire and the ranking of the resulting values into broad categories. To have an integrated FBI, a combination of linear intensity mapping and rate of spread mapping was done according to criteria obtained from fire managers and firefighters. The integrated FDI is obtained from the estimation of the FII and the consideration of the FBI. Within the DSS, six maps of indices are generated for both the current day and the following 4 days based on meteorological data: FWI, FHI, FRI, FII, FBI, and FDI maps. The maps of fire indices can be displayed by clicking on the corresponding link at the Risk indices tab.

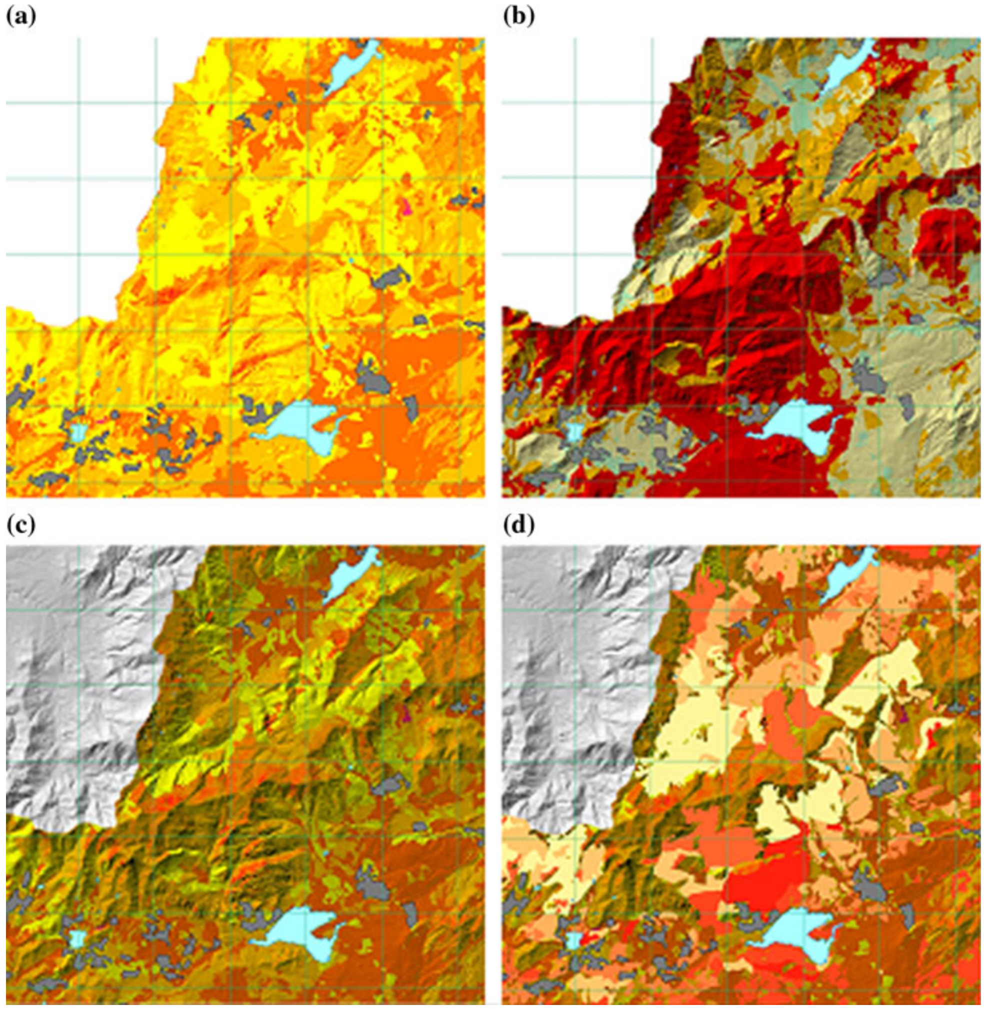

Fig. 5 Maps of (**a**) linear fire intensity; (**b**) potential crown fire; (**c**) rate of fire spread; and (**d**) potential fire loss index in resolution of 20 m

Fire propagation module

The propagation module allows the user of this DSS to estimate the growth of a fire in a fixed amount of time and under a set of customized meteorological and other fire environmental factors. A "wizard" interface guides the user through the steps where necessary information for the simulation is defined. The starting point of a simulation must be the information regarding one of the alarms stored by the application, and the output of the simulation is in the form of GIS-formatted layers. As new data are fed into the system, the simulation of the initial fire front is constantly updated. Both maps of the initial fire front and final fire propagation are displayed simultaneously to allow the analysis of the propagation progress.

The forest fire simulation module estimates the severity of an incipient fire by predicting fire size (area and perimeter), fire spread speed and direction, energy release, flame length, and linear intensity (Fig. 5). It also predicts possible threats and damages; helps to plan tactical operations; and selects and dispatches resources. The application has been embedded in the AHP GIS platform.

Within the fire propagation module, a computer model called "Fire Spread Engine" (FSE) is utilized that estimates the fire front expansion on surface forest fuels, using spatial data about topography, moisture content, wind vector field, and fuel type. The FSE uses Rothermel's (1972) theoretical approach and calculation algorithms based on those found in the BEHAVE (Andrews 1986) and FARSITE (Finney 1998) systems. A cellular-automata algorithm is applied for the spatial simulation of the fire spread (Caballero 2006). The FSE code is an improved version of a code that had been used previously in the FOMFIS (Caballero 1998) and E-FIS (Caballero et al. 2002) research projects.

Resource dispatching module

According to the DELFI vocabulary of forest fire terms (Conese et al. 1999), the term "dispatch" is defined as "the act of ordering attack units and/or support units to respond to an emergency.” The aim of the dispatching module of AHP was to provide decision support for this response. It is the part of the DSS that helps the user to determine the size and type of resources to be sent to a particular fire. This is the most advanced “direct” functionality (meaning that it can make direct suggestions about the use of resources) that can be offered by such a DSS. Beyond this, the complexity and the risks involved in firefighting itself preclude direct “decision support” suggestions about firefighting *per se*. Only data and predictions (such as predicted fire behavior and fire spread simulations) can be offered as support information from that point on. The stakeholders are the officers at the coordination center where the system is installed. One of their most important tasks is to make decisions on what resources to send to each reported or detected fire. The dispatching module of AHP can be used operationally in support of dispatching but can also be used for dispatcher training and for “what-if” scenarios testing as part of pre-suppression planning.

Within the analysis phase of the AHP DSS, the need for a resources management and communication module was expressed by the end-users. The resource management and dispatching module was designed to cope with these basic needs of the managers. The first version of the module was based on a stable and simple algorithm dealing with the delimitation and identification of resources, which was derived from expert opinion and experience of the AHP research team. The algorithm was then adapted to the already developed AHP information (fire indices, etc.) and fitted to the DSS’s architecture. Eventually, the DSS included a communication module that allowed the managers to define communication channels between the resources (every single resource defined in the system) and the emergency management team, operating the AHP DSS (Fig. 6). The defined communication channels were as follows:

- SMS (mobile/cellular telephone message dispatching)
- e-mail
- LAN sending.

A GSM/GPRS modem attached (or equivalent mobile phone connected through the serial port) to the computer where the application is installed is required and makes the system independent of third parties.

The module obtains, from the user, some information on the conditions related to a newly reported or detected fire. These conditions are then evaluated through a specially developed, relatively simple algorithm (Xanthopoulos 2002). The size of ground and aerial forces needed for fire control within a given time are then suggested by the model, and it proposes combinations of fire trucks and aerial means that can achieve extinction within this time.

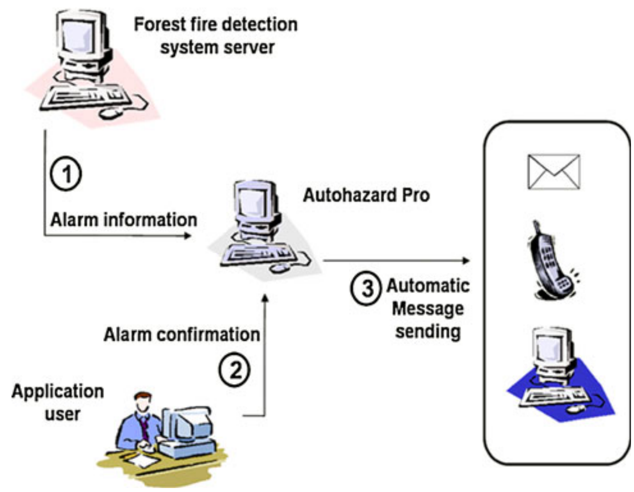

Fig. 6 The *AUTO-HAZARD PRO* communication scheme

This allows the dispatcher to select a combination that is convenient under the existing conditions (location and status of resources, other simultaneous fires, etc.). The dispatcher may choose a different time-to-extinction if the required size of resources is not available at the moment and get a different set of combinations of resources.

Module outputs include:

- An assessment of the seriousness of the fire, on a scale of 1–100, which can be used in tandem with general organization protocols for specific actions that need to be taken. For example, “if SERIOUSNESS > 70, then send aerial forces.”
- An assessment of the average perimeter growth rate (km/h).
- An assessment of effectiveness of aerial forces for the particular topography, wind, and distance-from-water-source conditions, as a guide for the dispatcher for choosing the appropriate mix of resources to dispatch.
- An assessment of average fire truck effectiveness, expressed through the fire perimeter extinction rate per hour, under the existing fire, topography, and road conditions.
- An estimate of the number of fire trucks needed to control the fire without aerial support.
- An assessment if the fire can be extinguished by the ground means in the vicinity of the fire and the length of time needed for that. Further to this, the dispatcher is informed if aerial means that will be dispatched at the time of the analysis will get to the fire before it is extinguished by the ground forces in the vicinity of the fire performing initial attack.
- A set of potential combinations of resources that can control the fire, in a pre-specified length of time (hours).

Discussion and conclusion

Development of the AHP system was pragmatic from the conception phase. The system relied mainly on proven, published models that were improved for the particular needs where required. Exceptions were the fire danger module (Vasilakos et al. 2007, 2009) and, to some extent, the forest fire detection system. By using and improving existing models, our research consortium guided its efforts toward developing a high quality, well-designed, and practical system that meets end-user requirements. To the fire scientists and the experienced firefighting officers in the consortium, it was clearly obvious that, for example, the fire behavior prediction accuracy offered by the Fire Spread Engine which is based on the widely used fire spread model of Rothermel (1972) is adequate for the intended purposes. Instead of trying to develop a new model that would only receive limited testing, the consortium opted for using this well-documented and widely tested model for fire behavior simulation.

Similarly, the AHP weather module is based on an existing high-resolution limited area weather forecasting system (SKIRON). Instead of trying drastic changes in this operational system, significant but incremental improvements offered the desired accuracy without jeopardizing AHP timely development. The upgraded SKIRON system includes non-hydrostatic dynamics and detailed surface energy exchange parameterization based on high resolution land-use, vegetation cover, and soil texture. Such realistic improvements and the use of a horizontal grid increment of 0.1° (~10 km × 10 km) and 38 vertical layers spread up to 50 hPa (~20 km) greatly improved SKIRON predictions and better suited it for meteorological predictions over an island such as Lesvos. Introduction of Kalman filtering was another innovation that further improved predictions by removing systematic temperature and wind errors. Even the development of the new and advanced FFD system did not start from scratch. It was built on previous research (de Vries and Kemp 1994) and experience. These factors and the overall resources of the specialized team working on the FFD meant that the objective to have a functional and effective FFD system at the stage of AHP system integration was not a concern for the consortium.

As a result, the emphasis in the development of the AHP system was on identifying the true user requirements, designing cleverly a system that would help in both training and operations, and producing a prototype that, through extensive testing and demonstration, would convince the users about its reliability and usefulness. In particular, the incremental procedure used during the coding of the AHP application helped in guiding the development successfully toward the above goals.

Comparing AHP with other fire management information systems (e.g., Butler et al. 2006; Lee et al. 2002), it is quite clear that there are many significant differences. The reason is mainly that fire management is a very broad subject and includes many diverse functions. The emphasis on which functions are needed in a fire management information system depends a lot on the specific objectives set by the users, which often vary significantly between countries with different conditions.

The AHP system has been developed with Southern European users in mind. This is where the user requirements were obtained, where most of the consortium partners come from and where the cooperating users work. As the AHP system is a state-of-the-art system that has undergone significant testing in cooperation with operational users, it is believed that it has the potential to be adopted for practical use. The consortium is making efforts to advance in this direction, making where needed necessary modifications such as translation of the user interface in the native language of each interested organization.

Adoption of a DSS like AHP by an operational organization may initially appear as a burden to people immediately involved because setting-up the system necessitates additional effort to obtain the needed data and develop the corresponding databases and GIS data layers. However, the results can quickly prove overwhelmingly positive as the system can greatly facilitate pre-suppression planning and improve alertness, fire detection, and appropriate response. In practice, the contacts developed between the researchers and the operational officers while developing and testing the AHP DSS revealed an equally important aspect of such a system. The officers learn a lot about the problem they have to manage just by participating in the analysis procedure for system development, by examining the information they have to collect, and finally by evaluating the responses of the system in comparison to the actual evolution of incidents they handle. In this case, the AHP DSS also worked as an effective learning tool. Key points that led to the positive response of the operational users who tested the AHP DSS were as follows:

- a relatively simple and user-friendly interface;
- a manageable level of complexity;
- obvious usefulness of the functionalities offered by the AHP DSS (pre-incident analysis, detection, and dispatching support); and
- efficient communication of alerts (SMS, etc.) according to predefined rules.

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