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**Conference Paper**

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55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Sakellariou, Stavros; Tampekis, Stergios; Samara, Fani; Christopoulou, Olga (2015) : The added value of modern Decision Support Systems (DSS) against forest fires in a global scale, 55th Congress of the European Regional Science Association: "World Renaissance: Changing roles for people and places", 25-28 August 2015, Lisbon, Portugal, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

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## **The added value of modern Decision Support Systems (DSS) against forest fires in a global scale**

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### **Summary**

Forest fires constitute one of the greatest hazards for the viability and sustainable development of forests with consequences both on natural and cultural environment, undermining the economy and the quality of life of local and regional populations. The outbreaks of forest fires could stem from either natural or anthropogenic causes. The latter usually compose the greatest percentage of ignition of forest fires especially at the Mediterranean regions. The best strategic to grapple with forest fires while taking under consideration both functional and economic efficiency is considered of primary importance. To this effect, great share have the usage and adoption of decision support systems (DSS) which contain tools of G.I.S. and satellite technology and function as information systems which support the managers responsible for eliminating the forest fires.

DSS make up a valuable tool for prevention and fighting against forest fires and lately they are adopted at growing rate at global level. The basic models-subsystems which comprise the structural elements for confronting forest fires and most DSS use are the following: 1) Retrieval, analysis, update, edit and prediction models of geospatial (geomorphology – topography, socioeconomic and environmental data), meteorological and satellite data, 2) Risk indexes and thematic maps (past fire incidents - records, moisture data etc.) of indigenous vegetation and forest fuel, 3) Fire propagation and behavior models and 4) Utilizing of interactive programs for the preparation, plans establishing, coordination and prompt dispatch of specific forces of the fire department (human force, land or aerial firefighting forces or even a combination).

Definitely, the sub-systems of the most DSS can be used independently depending on the main purpose, such as for prevention or suppression procedures; for the financial estimation of the planned mission; for the smoke detection and the prediction of its repercussions on the human health etc. Hence, the paper aims to a comparative assessment of the most contemporary DSS which are in use in different geographic scales -such as national and federal level- as well as to a thorough exploration of the effectiveness and contribution of such systems to the confronting of forest fires.

*Key words: forest fires, decision support systems, g.i.s., remote sensing*

**Acknowledgements:** *This research has been co-financed by the European Union (European Social Fund-ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Thales. Investing in knowledge society through the European Social Fund.*

*In addition, the authors would like to thank Mr. P. Georgas for his contribution to the language review process.*

## **Introduction**

Forest fires are a natural phenomenon with multiple implications on the natural and cultural wealth of every society. Beyond its natural contribution to the ecological processes, forest fires affect a significant portion of the global population with many ways. Indicatively, we should mention the frequent human loss; the financial consequences and the general environmental degradation.

The most frequent forest fires incidents come from either natural or anthropogenic causes (accidents from certain activities or infrastructure, carelessness, arsons). Fire ignitions due to human factor are the dominant fire cause at the Mediterranean countries (Carmel et al. 2009; Christopoulou 2011; Demir et al. 2009).

At a federal scale, in the European Union countries, 55,543 forest fires have been recorded only for the year 2011, which means 269,081 ha of burned land ([www.fire.uni-freiburg.de](http://www.fire.uni-freiburg.de), 2011). On the other side, in the USA and for a timeframe of four years (from 2007 to 2011), local fire agencies have been called to deal with approximately 334.200 brush, grass, and forest fires annually. This fact leads us to an extraordinary number of 915 fires daily (<http://www.nfpa.org>, 2015).

For these reasons, the best solution to grapple with forest fires while taking into account both functional and economic efficiency is considered of vital importance. To this effect, great share have the usage and adoption of DSS which contain tools of G.I.S. and satellite technology and function as information systems which support the managers responsible for eliminating the forest fires. As a result, managers' ability is strengthened so that they can prevent and suppress effectively the forest fires implications on the natural and build environment as well as to the fully protection of human life which constitutes the framework and milestone of our society.

## **Primary characteristics of DSS and their contribution against forest fires on different spatial scales**

### **General structure of DSS**

Generally, Decision Support Systems constitute a useful ally for the efficient forest fires management. For this reason, nowadays, the usage and exploitation of their capabilities are getting more and more popular and frequent from many fire agencies all over the world. Most DSS have certain sub-models which are responsible for certain activities. These models may include (but not limited to) (Bonazountas et al. 2007; Dimopoulou and Giannikos 2004; [ec.europa.eu](http://ec.europa.eu) 2012; Giovando et al., no date; Glasa 2009; Gumusay and Sahin 2009; Kalabokidis et al. 2011; Keramitsoglou et al. 2004; Lee et al. 2010; Noonan-Wright et al. 2011; Wybo 1998):

1. Data retrieval, analysis process, updates, edit and prediction models of geospatial (topography, social, economic and environmental data), meteorological and satellite data,
2. Fire risk indexes and thematic maps (based on fire history, moisture data etc) of local vegetation and forest fuel,
3. Fire propagation and behavior models and
4. Utilizing of interactive programs for the preparation, plans development, coordination and immediate dispatch of specific forces of the fire agency (human force, quality and quantity of fire machinery – land or aerial forces).

## National Level

One of the first DSS that exploited the usage of several technological tools for the efficient forest fires management is the application of Wybo. The key in that system is the fact that the DSS incorporates in their databases a certain number of pre-processed scenarios which correspond to specific fire incidents and consequently, there is no need for composing new scenarios from the beginning, for example in case new meteorological data is received. Therefore, valuable time is saved up during the process of monitoring, management and fighting of each fire incident in real time. Furthermore, this system contains an integrated sort of feedback, where the manager has the ability to produce or modify/update the pre-existing scenarios (according to new input). So, there is the chance that those new-generated scenarios may be made productive in the future in similar fire incidents (Wybo, 1998).

Dimopoulou and Giannikos (2004) exploited an integrated information system on which the databases of G.I.S. include and provide all the necessary spatial information to the subsystem which is responsible for the application of the mathematical programming. Next, through all the appropriate equations and calculations of mathematical programming, the best (spatial) allocation of the fire department units (including the amount and type of the forces) on the study area is estimated, so that the fire-fighting authorities will be prepared to locate the fire and act within 10 minutes to any possible combustion. Afterwards, the model of fire behavior forwards the new input, which relies on fire evolution (e.g. not available fire engines, natural barriers across the main roads etc.), to the subsystem of mathematical programming -like an active feedback, so that a new best re-allocation of the fire department units will be achieved, adjusted to the new data, which will lead to the immediate containment of the forest fire (Dimopoulou and Giannikos, 2004).

Concerning the DSS developed by Bonazountas et al. (2007), besides the basic structural elements of DSS, they adopt an additional model of socioeconomic factors (e.g. demographic data, tourism industry) of the study area, where an analysis of the most important socioeconomic factors is conducted which could affect the fire risk levels for combustion and a thematic map is produced as an output of this model. Furthermore, the probabilistic model contributes to the whole process, so that the managers could effectively plan the best (spatial) allocation of the infrastructure (firemen, land and aerial fire engines etc). In addition, an effectiveness analysis of the current infrastructure (human force, number and type of fire machinery, estimation of the time which is needed for fire brigade to reach the point of the fire) is carried out. Moreover, various restrictions like topography, fierce winds, low visibility due to smoke, the narrowness of economic resources etc. are taken into account and the aims and corresponding strategies are adjusted accordingly (Bonazountas et al. 2007).

Akay et al. (2011) combine the advantages of G.I.S. and DSS and apply the Network Analysis which incorporates: a) the method of the nearest fire unit-settlement, where the fastest route between each fire unit and the fire incident is estimated, so the fire team, which needs the smallest distance and the least time, is activated (Condoreli and Mussumeci 2010; Gumusay and Sahin 2009; Keramitsoglou et al. 2004;); b) the second method involves the spatial covering (buffers) of forest land from the current fire units, based on the critical time of response which is necessary from every fire team in order to approach the district of fire. In case that this combination is inadequate (in terms of distance and critical time of response), then it is concluded that more installations of fire agency must be established, so that every possibility of outspreading of the fire and their implications could be limited. Last but not least, another method involves the vital contribution of fire team using aerial means (helicopter) as they cover a great percentage of those areas, especially when the land-based counter-fire means could not react to the incident within the critical time of response (Akay et al., 2011).

## **Federal Level**

At upper spatial level, the adopted DSS in the USA presents special interest. The Wildland Fire Decision Support System (WFDSS) is provided not only with the essential inputs (geospatial data, air quality data etc.), but also with tools of financial evaluation of past fire incidents. These procedures are manageable in real time, while they are supported directly via internet from many agencies responsible for dealing with forest fires at the same time. Besides the basic structural elements of DSS, WFDSS incorporate additional economic and environmental tools. More specifically, WFDSS includes those economic tools which reckon the estimated economic cost on the basis of past fire incidents with similar characteristics. In addition, risk assessment of crucial structures (towns and infrastructure network; natural habitats; cultural resources) is conducted and these resources are shown in the fire propagation map based on the fire intensity (Noonan-Wright et al. 2011).

The respective EU information system (EFFIS – European Forest Fire Information System) demonstrates several innovating and quite valuable functions. Specifically, the immediate evaluation of catastrophes whose aim constitutes the mapping of those areas which have been damaged from forest fires and are greater than thirty ha, with direct reference to the affected land cover type. The land sources of information support the whole process of forest fires monitoring and management and their significance is reflected when natural barriers (cloudy weather) or technical restrictions are happening during the attempt to retrieve satellite images and to locate active fire hotspots. So, the relative information is collected through RSS method from several EU sources (Google news, blogs etc.) in various geographical levels. Finally, a filtering and automatic geocoding procedure are conducted and each fire incident is immediately located in any piece of territory (Giovando et al., no date).

Mavsar et al. (2012) examined the economical effectiveness of four DSS, where in addition to the desired protection level which could be resulted from the best spatial allocation of land and aerial fire forces, economic data of the adopted prevention measures as well as of the global operational forest fires planning are taken into consideration. The evaluation of alternative scenarios in terms of economic and environmental effectiveness will finally lead to the selection of the best scenario. The studied systems are the following: 1) Leopards model (Canada), 2) Kitral model (Chile), 3) Sinami model (Spain) and 4) FPA (USA). Regarding the economic assessment of the aforesaid systems, it should be highlighted that the most integrated program, which permits the economic analysis of the different management strategies is the Sinami model, which adopts the techniques of the “C+NVC<sup>1</sup>” method and incorporates the economic cost of prevention and suppression planning as well as of natural resources which are affected from any natural catastrophe. The last parameter is absent from the other models (Leopards and Kitral), while FPA adopts Goal Programming techniques (Mavsar et al., 2012).

## **Discussion**

Decision Support Systems constitute a powerful tool and provide the opportunity to drastically support the effective forest fires management and give solutions to the appropriate decision making, when the time frames of making rational decision are very narrow.

The combination of operational research models and G.I.S. is of crucial importance while it may cope with complicated (of spatial nature and not only) problems which include a great deal and variety of data. So, in case of forest fires, the exploitation of G.I.S. and new routing

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<sup>1</sup> C+NVC: Financial cost (prevention and suppression planning expenditures) + net value among destructive and beneficial implications of forest fires (Mavsar et al., 2012).

techniques (Vehicle routing models) in the DSS may contribute to the effective decision making concerning for example with the choice of best routes which lead to the minimization of distance and time of each route as well as to the immediate rerouting with the choice of the second best route for the timely confrontation of every incident due to a natural or technical barrier or restriction.

Another issue of secondary importance -but imperative in situations of global economic narrowness- constitutes the fact of fiscal resources saving through the minimization of fuels consumption and vehicle maintenance with the choice of best routes in terms of travel time (Manusaridis et al., 2007). In this context, the adoption of trustworthy tools for the management of natural catastrophes is a crucial issue aiming to the general saving of resources. The competitive advantage of online applications (Web DSS) is that any distant user does not have to spend extraordinary amount of money for covering substantial needs from such an application like the retrieval, usage and edit of mass volume of geospatial and meteorological data, the needs for sophisticated equipment as well as the long-term periodic maintenance work (ec.europa.eu, 2012; Gumusay and Sahin 2009).

According to Martell (2011), the physical presence, the participation into virtual environment of crisis management of the researchers as well as the interaction between fire managers and researchers are of primary importance, while facilitates the assimilation and the way of approach during (or before) fighting forest fires. Furthermore, the creation of a global network of natural catastrophes – fire managers which will aim to the ideas exchange and dissemination as well as to the exploring of more effective and suitable solutions is suggested (Martell, 2011). Finally, it should be clear that any DSS cannot substitute the human factor for the appropriate crisis management. However, DSS may highly contribute to the quantification of complex interactions which take place during confronting a forest fire and they may facilitate the timely handling of critical situations. The positive key points of DSS combined with a manager expertise and experience could achieve the moderation of consequences of forest fires to the natural and cultural environment as well as to the economic impact of every fire confrontation mission (Mavsar et al., 2012).

## **Conclusions**

Primary aim of the paper is the comparative exploration of various Decision Support Systems (DSS) at two distinct but interrelated geographic scales, namely, the national and federal level. As we can conclude from the thorough description of the adopted DSS, the general structure remains the same contributing to the effective prevention and suppression of forest fires and generally, to the efficient and rational fire management. Beyond the intensive efforts, on the part of fire agencies, for maximizing the environmental and ecological protection from destructive fires, special care is taken for the minimizing of the financial cost for each mission.

Hence, the adoption of the state-of-the-art DSS which combine sophisticated information and communication technology may highly contribute to the immediate confrontation of forest fires, where necessary. Therefore, complex computation (prediction of fire propagation based on the meteorological data; spatial optimization of the land firefighting forces etc.) can be solved immediately, saving valuable time and consequently, safeguarding human life, property and ecological wealth.

However, it should be highlighted the fact that the adopted DSS should be a supplementary tool to any fire mission, while the human factor and its experience is considered irreplaceable. On the other hand, it shouldn't be ignored that every version of DSS has its own value because any DSS is constructed to support special needs which may be different based on the

local characteristics. However, a comparative assessment of their usefulness in a unique territory (even in hypothetic level) will be of great interest, while we could have the opportunity to explore any deficiencies or common ground for further improvements.

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