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Review

Visualization of forest fires interactively on the internet

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The Internet has rapidly changed the transfer and dissemination of geographical information. The rapid and enormous development of the Internet technology has resulted in usage of the Internet as a tool for data access, data transmission and access to GIS analysis tools. The combination of Geographic Information System (GIS) and the Internet offers great possibilities, such as interactive access to geospatial data, enhancement of the functions of geographic information and the access of to GIS analysis tools. The Internet GIS is a GIS tool that uses the Internet for displaying spatial data and analysis results. It is necessary to make use of GIS and Internet technologies in order to struggle with wildfires, which are causing great amount of loss every year and to contribute to planning activities. By means of these technologies, it is possible to gather necessary spatial data from different resources and to prepare products, which will contribute to the decisions of fire managers. In this study, usage of GIS in the phases of wildfire management was researched. The aim of the study is to establish wildfire information management system in order to help wildfire managers to reduce fire risk and make use of resources effectively and economically.

Key words: GIS, the internet, ASP; AspMap.

INTRODUCTION

12 million hectares of Turkey's forests, which extends the 160 km depth part of the 1700 km shore band of the Mediterranean and the Aegean coasts is fire prone areas.

35% of the 20.7 million hectares forest resource takes place in the first degree, 23% in the second degree, 22% in the third degree, 15% in the fourth degree and 5% in the fifth degree regions with respect to the fire proneness. Especially, Mediterranean and Aegean regions, having hot and arid climate, are the areas first-degree sensitive to the fire (GDF, 2003).

Fires, taking place in these regions, burns thousands of hectares of feasible forest areas and zillion Turkish Liras cost for fighting against wildfire. It is necessary to make use of improved technologies by taking required steps in the correct place and at correct time and using the sources effectively to fight against wildfire. The technology, which will be used, is GIS because of the spatial characteristics of the information like forests, roads, settlements and agricultural areas, used by the fire managers (Sahin, 2006).

The tragic results of the Southern California wildfires in 2003 and Hurricane Katrina in 2005 demonstrated the importance of a spatial decision support system for effective emergency response. Among the first demands made on relief agencies after those events were requests for satellite imagery, GIS maps and wireless communications. Successful implementation of such systems in a spatial decision support service can save thousands of lives during a natural disaster (Tsou, 2006).

A GIS is a collection of information technology, data and procedures for collecting, storing, manipulating, analyzing and presenting maps and descriptive information about features that can be presented on the maps. On the other hand, the internet is a modern information relay system that connects hundreds of thousands of telecommunication networks and creates an "internetworking" framework (Peng et al., 2003).

Internet GIS is the cyber-infrastructure framework for GIS utilizing both wired and wireless Internet to access geographic data and spatial analytical tools (Jankowski et al., 2007).

Today, Internet GIS applications enable access to cur-

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rent data through simple to use Web-based map viewers. The basic capabilities of the viewers include navigating around a map and querying an application database, which usually resides on server computers connected to the viewers through the Internet (Jankowski et al., 2007).

The aim of the study is to establish the Wildfire Management System, which will support the fire managers to make decisions about wildfires and to reduce the risk of the wildfire by using GIS and the internet technologies.

INTERNET GIS

Geographic Information Systems

GIS is a computer-based information system designed to efficiently capture, store, update, manipulate, analyze and display many forms of geographically referenced and associated tabular attribute data (Fischer and Nijkamp, 1993). GIS are used extensively in various applications such as land-use mapping, transportation mapping and analysis and natural resource assessment. GIS allow efficient and flexible storage, display and exchange of spatial data (Sadagopan, 2000).

The Internet

The Internet is any network composed of multiple, geographically dispersed networks connected through communication devices and a common set of communication protocols (Peng et al., 2003). Internet is an interconnected system of networks that connects computers around the world via the TCP/IP protocol. Many applications in journalism, sciences, publishing and other fields have been changed by and adapted for use on the Internet (Plewe, 1997). Likewise, the internet has changed how GIS data and processing are accessed, shared and manipulated (Peng et al., 2003). The internet is shaping the ways of traditional GIS function. It is changing the access and transmission of GIS data, applications and visualizations. The Internet has facilitated three major changes in GIS: Access to data, transmission of data and access to GIS analysis functionalities.

The Internet GIS

The Internet GIS is a special GIS tool that uses Internet as a means to access and transmit remote data, conduct analysis and make GIS presentation. The Internet GIS should have all or almost all functionalities the traditional GIS software has. In addition, the Internet GIS should have additional functions that take advantage of the Internet and its associated protocols such as World Wide Web (WWW) and File Transfer Protocol (FTP). These additional functions include exchanging remote data and application programs, conducting GIS analysis on the internet without owning GIS software on the local machine and presenting interactive maps and data on the internet (Peng, 1999). Internet GIS is different from traditional geographic information systems (GISystems) in that GIServices focus on open, distributed, task-centered information services, which broaden geographic information uses into an increasingly wider range of online geospatial applications (Jankowski et al., 2007).

The key features of the Internet GIS

The Internet GIS is an integrated client/server network system. The concept of client/server involves splitting an application into tasks between the server and client. A client/server application has three components: a client, a server and a network. Each of them is supported by specific software and hardware. The client sends a request to the server, which processes the request and returns the result to the client; the client then manipulates the data and/or results and presents them to the user.

Besides, the Internet GIS is an interactive, distributed and dynamic system. The Internet allows users to access distributed database and to perform distributed processing through its hypertext linkage. The user does not have to install the data and application programs in his/her local computer. Whenever it sends requests to the server, the server would deliver the data and analysis tool modules for just-in-time performance. Those data and application programs are updated by those who manage them. Once the data and application programs are updated, they are available to every user on the Internet (Peng, 1999).

The components of the Internet GIS

There is a wide variety of ways in which you can distribute geographic information on the internet, but they are all founded on the same general design. The basic architecture is similar to the client/server model (Figure 1).

The classic model includes a client program (a Web browser), which makes a request to a server program. The server processes the request and returns the information to the client (Plewe, 1997).

The model used in digital geographic information is an extension of the client/server architecture, known as a multi-tiered server. In this architecture, there are three components (Figure 2).

Client

A client is the computer that send request through web

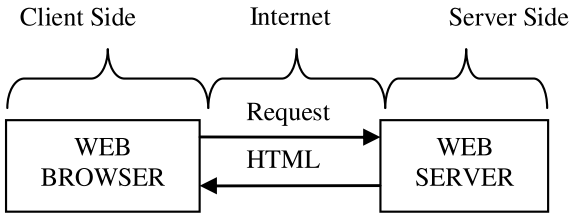

Figure 1. Classic client/server design.

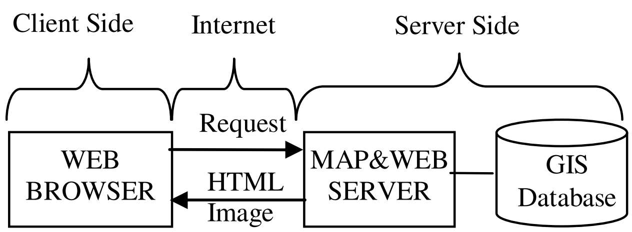

Figure 2. Multi-tiered Internet GIS architecture.

to the GIS server. Widely used Web browsers are Internet Explorer and Netscape Navigator.

GIS Web Server

GIS Web browsers establish the connection between client and GIS Map program. Web browsers cannot directly communicate with GIS programs, which have to connect with GIS Web server. The web server works to enhance and customize the World Wide Web's capabilities to link with GIS data and functions. The Web server receives requests from the client and sends it to GIS programs and interprets their output information to Web browsers.

GIS Map Server

GIS Map Server performs the analysis based on the user's request the request and sends back the result to GIS Web server. GIS Web server and GIS Map Server can be installed on one machine or separate machines.

Internet-based GIS Architectures

There are basically two types of architectures for developing Internet-based GIS applications: client-side and server-side. In a client-side Internet GIS application, the client (Web browser) is enhanced to support GIS functionality, while in a server-side GIS application, a Web browser is used only to generate server requests and display the results (Marshall, 2000).

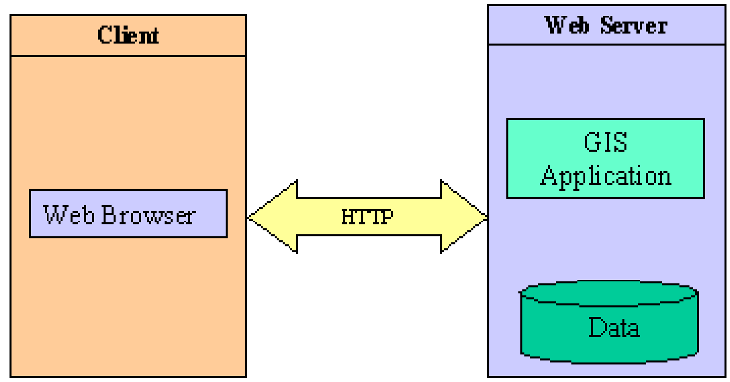

Figure 3. Server-side Internet GIS.

Server-Side Internet GIS

In these applications, users send a request to a server and the server processes the request and sends the results back as an image embedded in an HTML page via standard HTTP. The response is a standard Web page that a generic browser can view. In server-side Internet GIS applications, all the complex and proprietary software, in addition to the spatial and tabular data remain on the server (Figure 3).

This architecture has several advantages because the application and data are centralized on a server. These advantages include simplified development, deployment and maintenance. In server-side Internet GIS, proprietary software required by the application stays on the server. The main problem of this architecture is the work overload on the server-side. All of the processes requested by the client are performed by the server. That is why; server machine must be very powerful.

Client-Side Internet GIS

Client-side GIS applications are implemented typically by enhancing the Web browser with a Java applet, ActiveX, or plug-ins. Some client-side applications even require users to install a complete client application. In either case, client-side applications require software of some kind (other than a browser) to be transferred to the user. GIS data and analysis tools initially reside in a server. Users usually request for data and process tools from the server, which sends the data and analysis modules to the client for local processing. The architecture of Client-side GIS applications is shown in Figure 4.

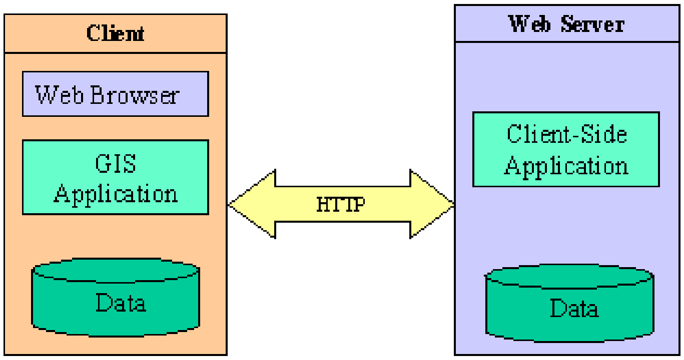

Figure 4. Client -side Internet GIS.

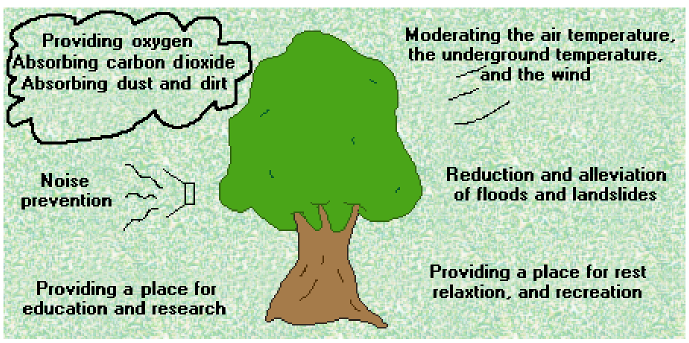

Figure 5. The role of forests.

Comparison of Server-Side and Client-Side Internet GIS

The two most crucial questions when deciding whether an operation should be performed by the server or the client are:

a) Is the processing going to place too large a load on the server? If the answer is yes, client-side Internet GIS must be used.
b) Does the volume of data to be sent to the client place too great load on the network? If the answer is yes, server-side Internet GIS must be used.

WILDFIRE MANAGEMENT

Forests are natural resources that help regulate surface water runoff, moderate high and low temperatures and prevent soil erosion (Figure 5). In performing these functions, forests stabilize the climate and shape the landscape.

Every year millions of hectares of the forests are consumed by fire, which results in enormous economic losses because of destroyed timber, burnt housing, high costs of fire suppression, damage to environmental and loss of life.

Forests are subject to extensive fire damages, especially in areas with dry and hot climate. Wildfires are considered natural phenomena. However, the unusual number of fires and the extent of burned areas are mainly due to fuel accumulation and human intervention. The damages they cause to the environment are both direct and indirect. Such damages include fauna reduc-tion, vegetation retrogression, temporal accelera-tion of the soil erosion process, increase of floods, deterioration of atmospheric quality and acceleration of the green-house phenomena by the addition of high quantities of carbon dioxide and smoke particles in the atmosphere. Fires also cause financial losses, related to the reduction of forest production (timber, fruits and recreation), loss of private properties (agricultural and urban) and destruct-tion of public constructions. Finally, in areas with dry climatic conditions, wildfires accelerate the desertifi-cation process. Given therefore the volume of damages they cause, much money is spent on fire prevention, fire suppression and forest restoration (Kaloudis et al., 2004).

The Importance of GIS in Wildfire Management

GIS is a powerful tool for wildfire management analysis and planning. GIS plays a critical role in mapping and documenting fire, then subsequently predicting its course, analyzing alternative fire-fighting strategies and directing tactics and strategies in the field. A digital base map can be overlaid with data or other layers of informa-tion onto the map in order to view spatial information and relationships. Information about features on maps can be viewed in databases behind the map when needed. GIS allows fire managers to better view and understand physical features and the relationships that influence fire behavior. Factors like steepness of slopes, aspects and vegetation can be viewed and “overlaid” to determine where intense fires may occur. This information can be displayed and compared with high value resources such as critical wildlife habitat, improvements, endangered plants, cultural resources, sensitive soils near drainages, housing development, etc. (ESRI, 2000). It is extremely important to take precautions by identifying the probability of fire using decision support systems rather than to extinguish the fire (Kucuk, 2004).

Wildfire Management Phases and Implementation

Emergency management activities can be grouped into five traditional phases that are related by time and function to all types of emergencies or disasters (Johnson, 2000). These are: identification and planning; mitigation; preparedness; response; and finally, recovery (Figure 6). These phases also relate to each other and each involves

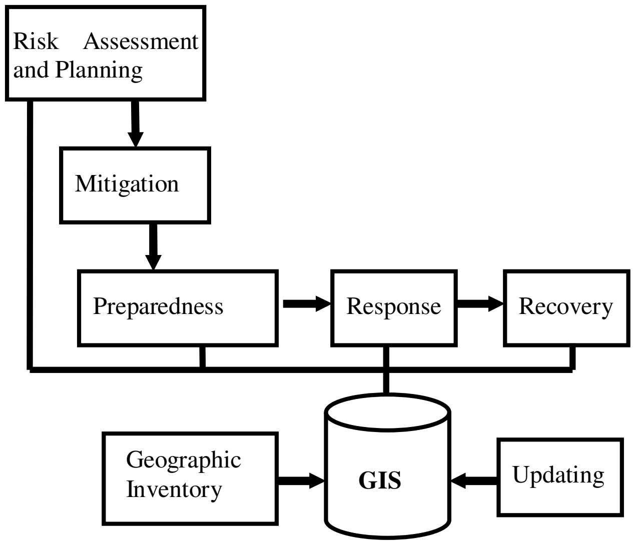

Figure 6. Wildfire management phases.

different types of skills. The first three stages deal with tasks that an organization or community can take before a disaster event, while the latter two focus on post disaster efforts (Green, 2002). In a dynamic and ever-changing world there may be activities that are nontraditional and not easily pigeonholed in traditional phases. Regardless, GIS can help managers make assessments and focus on where mitigation efforts will be necessary, where preparedness efforts must be targeted, where response efforts must be strengthened and the type of recovery efforts that may be necessary. GIS facilitates all of the requirements of wildfire planning by allowing decision makers to view appropriate combinations of spatial data.

Risk Assessment and planning

Emergency management programs begin with locating and identifying potential emergency problems. Disaster events such as wildfires, floods, earthquake faults and hazardous material spills can be modeled and displayed in a GIS. This allows managers to make comprehensive assessments and develop mitigation plans. When disasters are viewed with other map data (forests, residential areas, fire stations, power lines, roads, pipelines, buildings, storage facilities, etc.), emergency management officials can begin to formulate mitigation, preparedness, response and possible recovery needs (Johnson, 2000).

Fire managers can focus on where mitigation efforts will be necessary, where preparedness efforts must be focused, where response efforts must be strengthened and the type of recovery efforts that may be necessary. Before an effective emergency management program can be implemented, thorough analysis and planning must be done. GIS facilitates this process by allowing planners to view the appropriate combinations of spatial data through computer-generated maps (Johnson, 2000).

GIS can display the location, size, value and signify-cance of assets. It can show kinds of environmental and other conditions that give rise to particular kinds of natural disasters. GIS can display a particular kind of asset with specific hazardous conditions over a wide geographic area, allowing a precise calculation of potential assets in danger in the immediate area. When this kind of graphic depiction is drawn, the choices about what to do and where to do it are appreciably clarified for those who have to make those choices (Green, 2002).

Mitigation

Mitigation includes activities that are necessary to eliminate or reduce the probability of a disaster. As potential emergency situations are identified, mitigation needs can be determined and prioritized. Mitigation analysis can examine potential human injuries and infrastructure damages within the potentially fire zones. GIS analysis can easily determine adjoining affected population areas and other utilities. More important, human life and other valuable resources (property, infrastructure, environmental, etc.) at risk from wild fires can be quickly identified and targeted for protective action. Utilizing existing databases linked to geographic features in GIS makes this possible (ESRI, 2000).

Preparedness

Preparedness includes those activities that are to the extent that mitigation measures have not, or cannot, prevent disasters. In the preparedness phase, govern-ments, organizations and individuals develop plans to save lives and minimize disaster damage (for example, compiling state resource inventories, mounting training exercises, installing early warning systems and predeter-mined emergency response forces). Preparedness mea-sures also seek to enhance disaster response operations (for example, stockpiling vital food and medical supplies, performing training exercises and mobilizing emergency response personnel on standby) (ESRI, 1999).

Response

The most urgent question asked at the moment of disaster is “What has happened?” GIS helps clarify the answers to this question. Response includes activities following a terrorist event, emergency, or disaster. These activities are designed to provide emergency assistance for victims (for example, search and rescue, emergency shelter, medical care, mass feeding). They also seek to stabilize the situation and reduce the probability of secondary damage (for example, shutting off contaminated water supply sources; cordoning off affected areas to prevent further injury, looting, or other problems) as well as to speed up recovery operations (for example, damage assessment) (Johnson, 2000).

After the first shock of a catastrophic event the focus of everyone even remotely connected to the disaster will be on one thing: understanding all that has happened. Of all the tasks of disaster management, it is this one at which GIS excels. Its visualization and data consolidation capabilities allow GIS convey large number of people in short period of time (Greene, 2002).

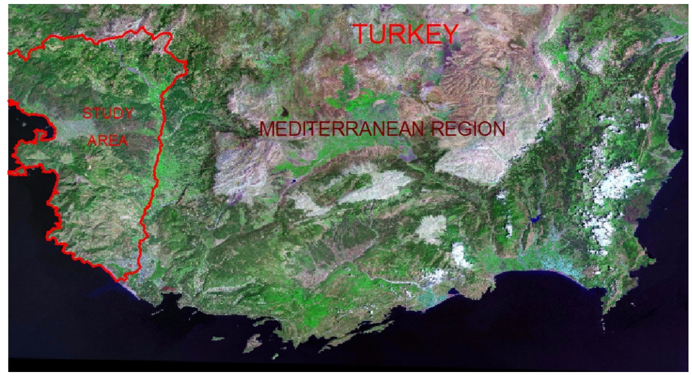

Figure 7. The study area.

Recovery

If the first most urgent question asked at the moment of a disaster is “What has happened?” the second equally urgent question is usually, “How can I help?”

In the same way that GIS helps clarify the answers to the first question, so too can it help refine the answers to the second- because the third obvious question in the series is “Where is the help needed?”

In the aftermath of disaster, GIS can map patterns of destruction, letting those bringing aid to the task of rebuilding target their reconstruction efforts with precision (Greene, 2002).

GIS managers should seriously consider using the Internet and interactive mapping applications to keep the community informed of recovery progress in the wake of disaster. There will be a deep hunger for this information, but hard-copy paper map products in many instances may be an impractical way to satisfy it. Moreover, events can change quickly in this environment and such changes can be made far more quickly in an online context.

Implementation of Phases Disaster Management

Study area

The study area is located in Mediterranean Region where wildfires occur frequently. The study site is bounded by longitudes 29° 0′E, 29° 26′E and by latitudes 36° 17′N, 36° 53′N (Figure 7). The major type of the tree is red pine. The regional climate is characterized as of Mediterranean climate, hot and dry summers.

System Analysis and Design

Wildfire Information Management Systems are expen-expensive to be established and maintained. It is critical to implement these systems effectively. In order to determine system requirements, the assessment of hazards, risks and values becomes the foundation for planning decisions (Sahin, 2006).

In this study, the phases of wildfire management are analyzed in order to determine wildfire management functions and data required for those functions. It is necessary to find answers to the following location-based questions:

i) What are the factors that affect likelihood of a wildfire?
ii) Where are the past forest fires?
iii) Where are the areas at highest risk?
iv) Where are the most valuable resources?
v) Where is the shortest path from the nearest fire station to the fire location?

The following answers can be determined using GIS queries related to these questions:

a) Factors such as roads, power lines and urban areas can be viewed and overlaid to determine where intense fires may occur.
b) This information can be displayed and compared with high value resources.
c) The likelihood of future wildfires can be determined by overlaying historical fire locations with all of the other landscape information.
d) Potential ignition sources can be determined by overlaying factors over flammable vegetation.
e) The closest fire station dispatched to the fire location can be found using shortest path algorithm.

In order to perform wildfire management functions the following data sets are required:

1. Forests
2. Urban areas
3. Roads
4. Power lines
5. Fire history
6. Fire stations

Table 1. Data layers used in this study.

Layer name	Description	Type
Region	Forest Administration Boundaries	Polygon
Division		Polygon
Forest	Forest Boundaries	Polygon
Urban Areas	Urban Areas	Polygon
Roads	Roads	Line
PowerLines	Power Lines	Line

Table 2. Data layers used in this study.

Layer name	Description	Type
Fire2003	Wildfires occurred in 2003	Point
Fire2004	Wildfires occurred in 2004	Point
Response team	Wildfires Response Teams	Point
ObsTower	Observation Towers	Point

7. Terrain slope.

First dataset listed in Table 1 is prepared by digitizing forest maps (1:25000 and 1:100000 scales) and then combining graphical data with tabular data. The second dataset, obtained from Wildfire Management Center records, listed in Table 2 is prepared by converting Latitude and longitude values and other feature data in Microsoft excel files to spatial data. Output data are in ED-50 datum, geographic projection and in ESRI Shapefile format. A raster file in Enhanced Compressed Wavelet (ECW) format is used as background image.

The user interface, designed to perform wildfire management functions, has the following parts:

a) Layers
b) Map
c) Map tools
d) Analysis functions
e) Legend
f) Overview map.

In this study, because of the huge data volume and low processing load on the server, Server-Side Internet GIS is used.

The graphical user interface (Figure 8) is created by using HTML, ASP scripts and AspMap Software.

Risk Analysis and planning

“What is there to burn?” That simple question is an effect-tive way to begin thinking about using GIS in the risk assessment and planning phase of wildfire management. The purpose of that question is to identify physical, human and other assets in a community most in danger

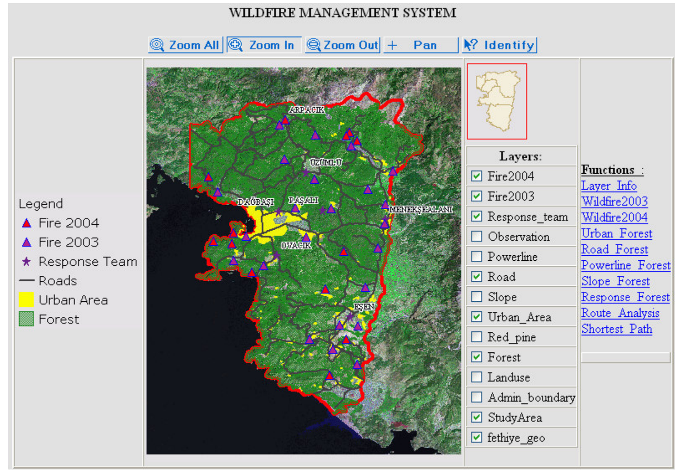

Figure 8. Wildfire management system graphical user interface.

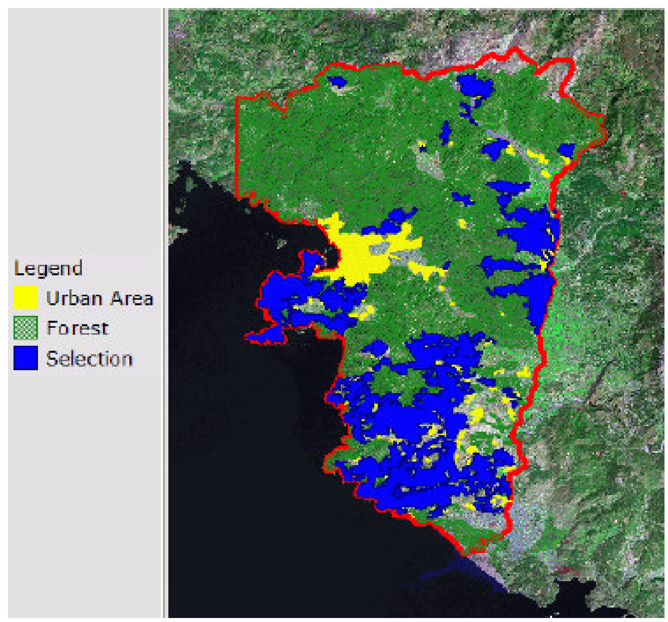

Figure 9. Urban areas adjacent to forests.

from natural or human-caused wildfire (R.W. Green, 2002). In case of a wildfire, the urban areas adja-cent to forests are the assets at highest risk. Those urban areas neighboring highly flammable forests are depicted in yellow, in Figure 9 (Sahin, 2006).

The likelihood of a wildfire ignition can be determined by locating historical fire locations. GIS can help at the hazard risk assessment by mapping the wildfire history in a particular area. Areas where wildfires occurred in 2003 and 2004 are the susceptible to fire (Figure 10) (Sahin, 2006).

The information about wildfires occurred in 2004 can be listed as in Figure 11, using “Layer Information“ tool of the

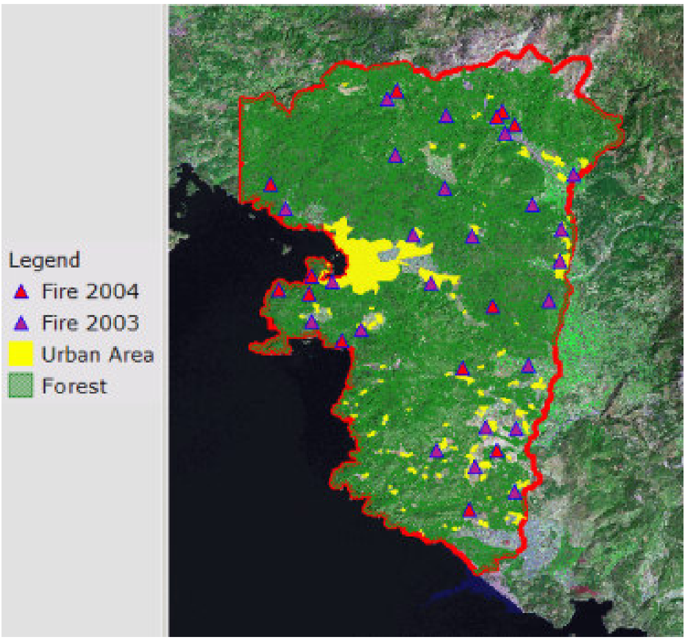

Figure 10. Wildfires occurred in 2003 and 2004.

FIRE2004 INFORMATION TABLE

FeatureID	BOLGEMD	ISLETMEMD	TARIH	SAAT	SONTAR	SONSA	ALAN	NEDEN	SEFLIK
0	MUĞLA	FETHİYE	13.09.2004	21,2	13.09.2004	23,55	0,1	İHMAL	EŞEN
1	MUĞLA	FETHİYE	21.09.2004	15,15	22.09.2004	21	0,2	KAZA	FETHİYE
2	MUĞLA	FETHİYE	08.08.2004	2,2	08.08.2004	21	1	KASIT	EŞEN
3	MUĞLA	FETHİYE	10.09.2004	20,05	14.09.2004	20,3	29	YILDIRIM	ÜZÜMLÜ
4	MUĞLA	FETHİYE	18.03.2005	4	19.03.2004	13,3	0,1	KASIT	GÖCEK
5	MUĞLA	FETHİYE	06.10.2004	1,15	06.10.2004	16,3	0,4	KAZA	FETHİYE
6	MUĞLA	FETHİYE	18.06.2004	14,5	18.06.2004	20	0	KASIT	FETHİYE
7	MUĞLA	FETHİYE	28.06.2004	23,15	29.06.2004	0,45	0,2	YILDIRIM	ÜZÜMLÜ
8	MUĞLA	FETHİYE	18.10.2004	19,3	16.10.2004	23	0,1	İHMAL	EŞEN
9	MUĞLA	FETHİYE	06.07.2004	16,5	06.07.2004	17,5	0,1	İHMAL	FETHİYE
10	MUĞLA	FETHİYE	20.07.2004	14	20.07.2004	16,45	0,1	İHMAL	FETHİYE
11	MUĞLA	FETHİYE	01.11.2004	12,3	01.11.2004	23,45	0,5	İHMAL	ÜZÜMLÜ
12	MUĞLA	FETHİYE	31.12.2004	4	31.12.2004	11,3	0,1	YILDIRIM	ÜZÜMLÜ

Figure 11. Fire2004 layer information table.

Wildfire Management System.

Mitigation

The actual burning capability of different kinds of vegetation can be taken into account for calculation of hazard risk. The forests in the study area are susceptible to fires during summer droughts due to abundance of coniferous trees and highly flammable ground vegetation. As known by fire experts Red-pine forests, especially younger ones, are the fiercest- and fastest-burning forests. The age classification of red pine can help fire managers to assess risk category of forests. Young forests are more prone to fire than old forests. Red pine forests can categorized in four classes according to trunk

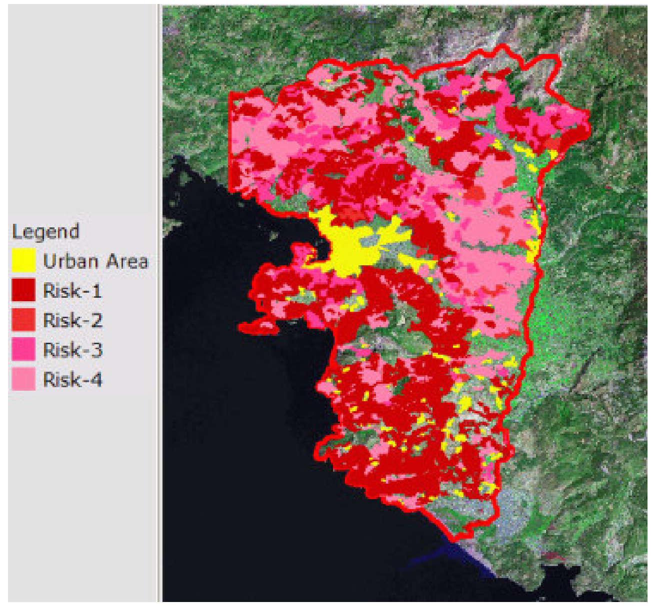

Figure 12. Risk assessment for red pine forests.

diameter. Forests, 95% of which is red-pine, in the study area are classified according to stem diameter. Trees having 0 - 7.9, 8 - 19.9, 20 - 35.9 cm and greater than 36 cm diameter are first, second, third and fourth degree sensitive to fire, respectively. Risk assessment of red pine forests, categorized in four risk groups, is shown in Figure 12 (Sahin, 2006).

Wildfire prevention can be focused where wildfires pose the greatest risk of resource loss. In order to determine hazardous forests and wildfire-prone areas, historical fire information can be viewed with all of the other landscape information. Intense fire areas near high risk areas (highly flammable landscapes) can be identified by selecting red-pine forests containing ignition sources in 2004 (Figure 13). The selection is performed using “polygons containing points” overlay analysis as shown in Figure 14.

The prediction of where and when human-caused wildfires are common has, as a first step in reducing their effects, been the focus of some research. For example, the probability of human-caused wildfire decreases with increased distance from different human infrastructures, such as roads, power lines, industrial areas, housing areas, etc (Pew et al., 2001).

Roads passing through forests increase the probability of wildfire. Forest containing roads are identified by intersecting forests and roads (Figure 15). The selection is performed using “lines intersecting polygons” overlay analysis as shown in Figure 16.

Powerline is another factor that affects the probability of wildfire. Forests containing power lines are determined by intersecting forests and power lines (Figure 17).

With the most dangerous areas now identified, it is that much easier for mitigation measures to be targeted at the

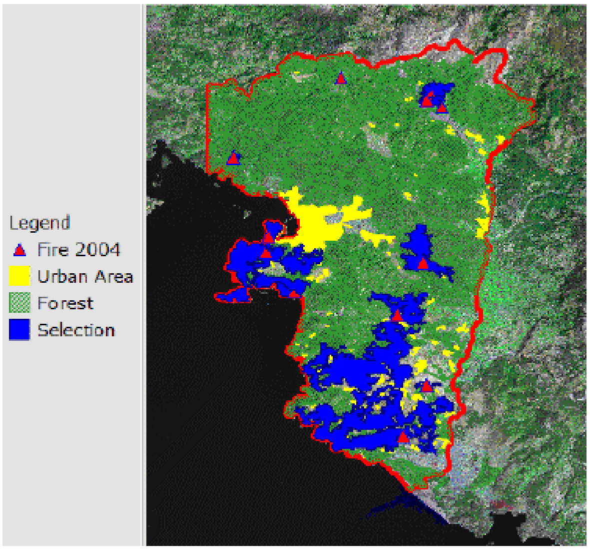

Figure 13. Forests fires in 2004.

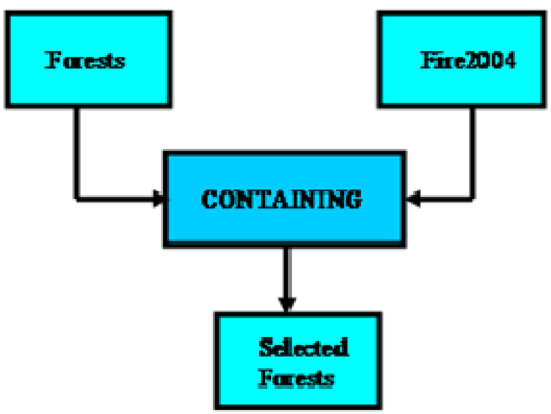

Figure 14. Flowchart of selecting forests fires in 2004.

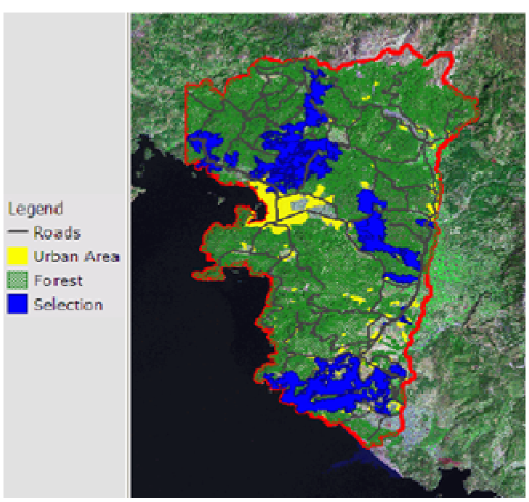

Figure 15. Roads passing through forests.

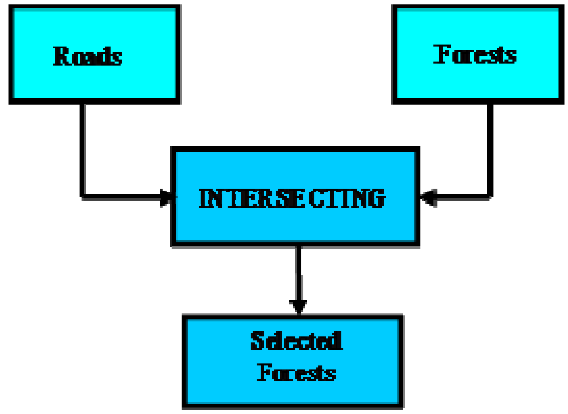

Figure 16. Flowchart of selecting forests containing roads.

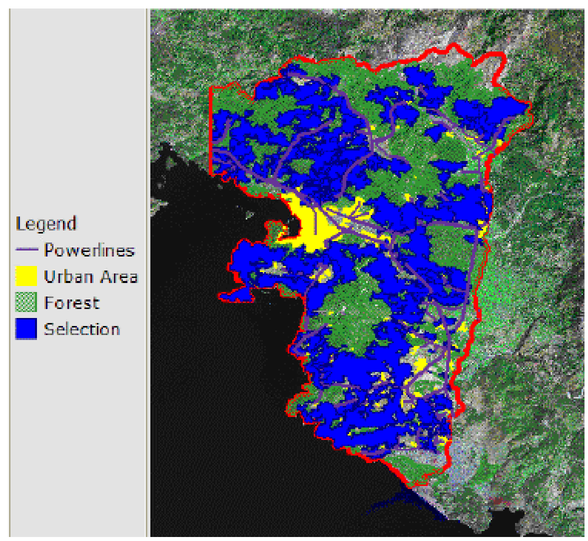

Figure 17. Powerlines passing through forests.

areas where they will be the most good. Just what these measures will consists of and to what extent they will be carried out, are decisions to be made according to the wishes of fire managers. GIS helps clarify the choices to be made by creating GIS analysis.

Preparedness

Steep slopes affect the direction and spread of wildfires. Steep slopes increase winds, cause wildfires to spread faster and affects wildfire response efforts. Intersection of forests and areas having steep slope (greater than 50%) is shown in Figure 18. “Polygons intersecting polygons” overlay analysis shown in Figure 19 is used to perform selection function.

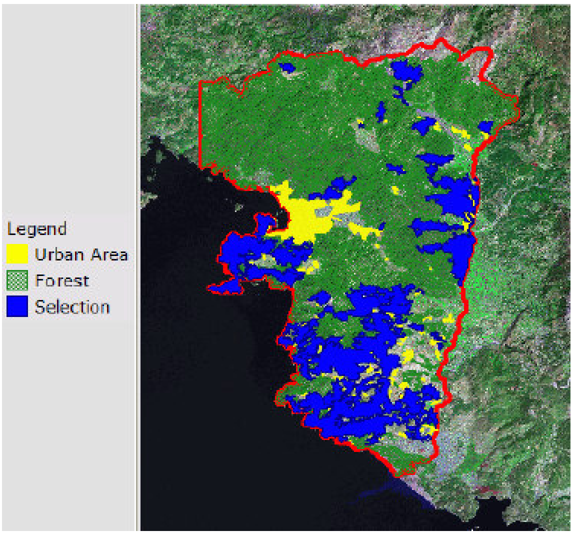

Figure 18. Forests having slope greater than 50%.

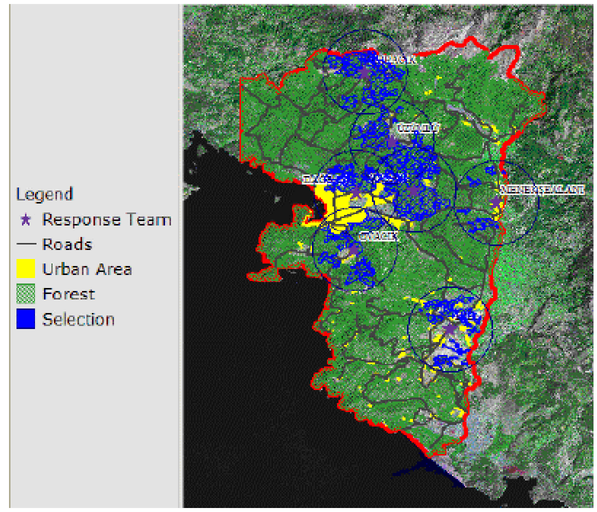

Figure 20. The effective areas of response teams.

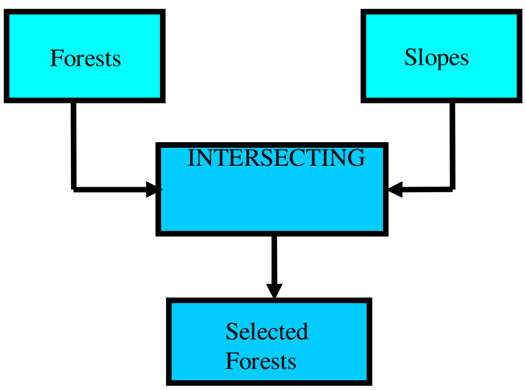

Figure 19. Flowchart of selecting forests intersecting steep slopes.

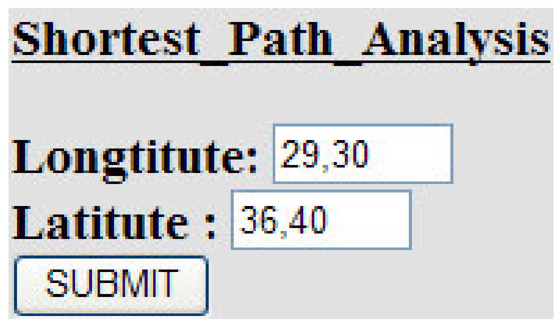

Figure 21. The coordinates of fire location.

Precautions can be taken by fire managers which will prevent wildfire occurrence and spread of wildfire. In order to minimize the risk of wildfire, precautions might be developing a network of firebreaks and thinning of dense forests (Sahin, 2006). GIS can provide answers to questions such as “Which of forests are in the effective areas of the response teams?” (Johnson, 2000). The result of this analysis shows the response capability of available teams. When effective area of the response team is entered as 6 km, the forests in the effective area of response teams are shown in blue (Figure 20).

Response

After the first shock of a catastrophic event, emergency response units based at fixed locations can be selected and routed for emergency response. The closest (quickest) response units can be selected, routed and dispatched to a wildfire whose location is observed by fire watch towers (Russ Johnson, 2000).

For example, during a wildfire, it is possible to identify the closest response team to the fire location using shortest path analysis. When the coordinates of the fire location is entered (Figure 21), the closest response unit is determined as “EŞEN” at the distance of 7.442 km (Figures 22 and 23) (Sahin, 2006).

It is also possible to find the distance of any selected response team to the fire location using shortest path analysis. For example, the distance from the fire location to “UZUMLU” response team is 5,327 km (Figures 24 and 25).

CONCLUSION

Forests are natural resources which are very important for

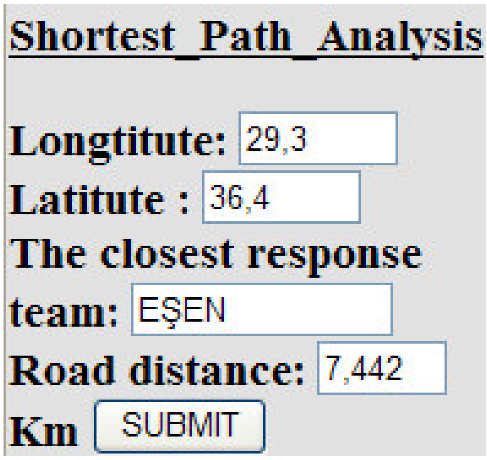

Figure 22. The result of shortest path analysis.

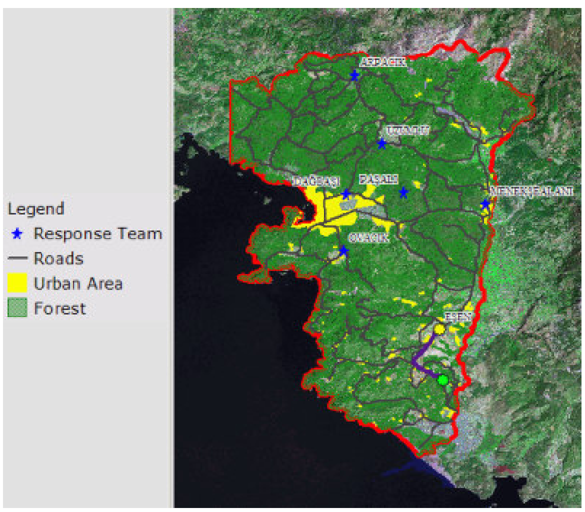

Figure 23. The result of shortest path analysis.

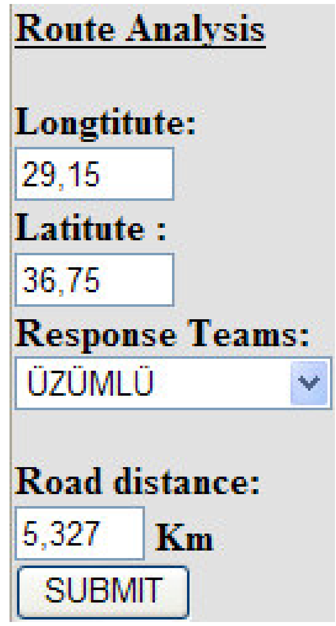

Figure 24. The result of shortest path analysis for "UZUMLU" response team.

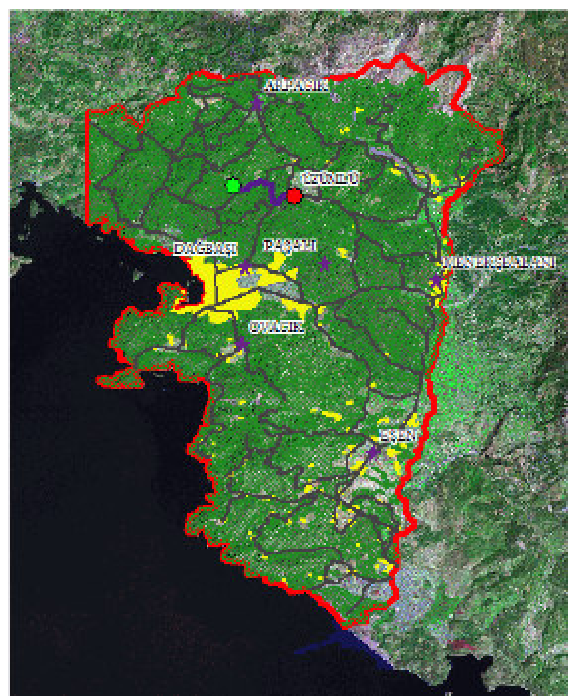

Figure 25. The result of shortest path analysis for "UZUMLU" response team.

mankind. For this reason, they must be protected from wildfires, using wildfire management programs. At past, these programs covers fire suppression and recovery activities after wildfire occurs. Nowadays, wildfire managers can determine highly flammable forests by creating wildfire hazard and risk maps. Because of the spatial behavior of data used in wildfire management, GIS is the most appropriate tool in the applications of wildfire management. When GIS is used together Internet technology, it allows users to access geographic data stored through Internet and to perform applications on geographic data.

In this study, the phases of wildfire management are analyzed in order to determine wildfire management functions and data required for those functions.

In this study, the data and analysis requirements in the Wildfire Management phases are identified and the ways of meeting these requirements are researched. Available forests, assets and resources are together displayed wildfire risk using data obtained from different resources. It’s aimed to construct Wildfire Management System that will allow fire managers to take necessary measures on the fire location and in time and to use available resources effectively by providing required analysis and queries. These analysis and queries are implemented using GIS, HTML and ASP tools in risk assessment and planning, mitigation, preparedness and response phases of wildfire management. The future of wildfire management will be influenced considerably by the use geographic information systems technology. GIS technology will continue to provide powerful analysis and query capabilities and become increasingly more important at the phases of wildfire management.

As a future work, after fire information, such as location of fire, location of dispatched teams, etc. are collected using mobile GIS technology, an online system assisting fire managers to manage fires by using online information can be constructed.

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