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A BOOLEAN APPROACH IN FOREST MANAGEMENT

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ABSTRACT

Multi criteria analyses have been used mostly to deal with spatial decision problems since their emergence. Spatial multi criteria analysis is different from conventional multi criteria decision analysis (MCDA). Because it includes a geographic component. Multi criteria evaluation (MCE) and multi criteria decision making (MCDM) are very important concepts in Geographical Information Systems (GIS). Many spatial decison problems entail GIS and MCDA integration. GIS-MCDM integration can be thought of a process that uses value judgements and then represents results of these judgements spatially on a digital map. Forestry decision problems involve many alternatives and evaluation criteria. Most of the forest management problems are spatial in their nature and usually involve multi criteria. Fire management is an important component of forest management. In this study Boolean approach is used for the fire management. The areas that can cope with fire effectively are examined according to their distances from water resources, streams and settlement areas criteria for İzmir Forest Administration Chief Office by using Boolean approach. IDRISI Software Package is used for all analyses.

Keywords: Boolean analysis, Forest fire management, GIS, Spatial multi criteria decision making.

1. INTRODUCTION

Many problems in life can be thought of as multi criteria decision making problems. As stated by Vassilev et al. (2005), multi criteria decision making problems can be divided into two distinct classes. In the first class, a finite number of alternatives are explicitly given in a tabular form. These problems are called discrete multi criteria decision making problem or multi criteria analysis problems. In the second class, a finite number of explicitly set of constraints in the form of functions define an infinite number of feasible alternatives. These problems are called continuous multi criteria decision making problem or multi criteria optimization problems. The methods used in the different approaches of decision analysis are called Multi Criteria Decision Methods (MCDM).

Multi criteria analyses have been used largely to deal with spatial decision problems since their emergence. The preliminary works including integration of Geographical Information Systems (GIS) and multi criteria analysis were in the late 1980s and the early 1990s (Chakhar and Martel, 2003).

Banai (1993) used Analytic Hierarchy Process (AHP), a multi criteria decision making technique, and GIS in order to find optimally suitable sites for landfill. In another study,

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GIS-MCDM was used to improve quality of landscape ecological forest planning (Kangas et al., 2000). Ananda and Herath (2003), examined the use of AHP in regional forest planning. Jumppanen, et al. (2003) applied GIS-MCDM in spatial harvest scheduling approach for areas involving multiple ownership. Evans et al. (2004) used Boolean (suitable/unsuitable) and weighted map overlays in the site search problem for waste management. Mau-Cummins et al. (2005) used AHP in the selection of forest wilderness sites. Our study used Boolean approach in determining the most appropriate areas that can cope with the forest fires subject to a defined set of criteria.

Spatial multi criteria analysis requires information on criterion values and the geographical locations of alternatives, and the results of analysis are represented visually on a digital map (Jankowski, 1995; Malczewski and Ogryczak, 1996). As stated by Carver (1991) and Jankowski (1995), two important components of spatial multi criteria decision analysis are GIS component and multi criteria decision making component.

In this study integration of GIS and MCDM is applied for İzmir Forest Administration Chief Office. The main objective is to do spatial MCDA, which is different from conventional MCDA, for our study area. For this reason the most appropriate areas that can cope with forest fires are represented according to Boolean approach. IDRISI software package, which is a GIS package named after the famous geographer Abu Adb Allah Muhammed al-Idrisi (1100-1166 A.D.) and is dedicated to him, is used for all analyses.

1.1 An Overview of GIS

Environmental management has been a major motivator of developments in GIS. Some authors suggest that the roots of current GIS is Canada Geographic Information System (CGIS), which emerged in the 1960s. It was designed to produce the map of land capability for forestry. Its initial task was to classify and map the land resources of Canada. The second objective of the system was to provide data to the Government of Canada on land resources and their management.

Created maps were classified according to various themes. Some of these themes were soil capability for agriculture, forestry capability, and present land use (DeMers, 1997; Heywood et al., 2002; Goodchild, 2003). When these systems were first developed in the early 1960s, they were no more than a set of innovative computer-based applications for data processing on maps. Today GIS is one of the fastest growing sectors in computer industry and an important component of the information technology (Franklin, 2001; Lo and Yeung, 2002). GIS technology offers combined power of both geography and the information systems and provides ideal solutions for effective natural resource management (Shamsi, 2005). This technology integrates common database operations such as query and statistical analysis with visualization and geographic analysis offered by maps. These abilities distinguish GIS from other information systems and make it valuable for several applications (Lang, 2001).

1.2 Integration of GIS and MCDM

Spatial multi criteria decision problems typically involve a set of geographically defined alternatives from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria.

Multi Criteria Evaluaiton (MCE) and MCDM are very important concepts in GIS. Many spatial decision problems lead to GIS and MCDA integration. These two disciplines can benefit from each other. On the one hand, GIS techniques have an important role in analyzing decision problems and it is a decision support system that integrates spatially referenced data into a problem solving environment. On the other hand, MCDA provides many techniques and procedures for structuring decision problems, and evaluating and prioritizing alternative decisions. GIS-multi criteria decision making integration can be thought of as a process that transforms and combines geographical data and value judgements of the decision maker to obtain information for decision making (Malczewski, 2006).

In the context of GIS, two procedures are common for MCE. The first includes Boolean overlay, the second is known as Weighted Linear Combination (WLC). In Boolean approach, all criteria are assessed by thresholds of suitability to produce Boolean maps, which are then combined by logical operators such as intersection (AND) and union (OR). With WLC, continuous criteria (factors) are standardized to a common numeric range, and then combined by weighted averaging. The result is a continuous mapping of suitability (Jiang and Eastman, 2000).

Boolean analysis is used only when two states are possible (criterion satisfied and not satisfied). This analysis was developed by George Boole, who devised rules and methodologies for combining two-state variables. In Boolean search it is generally concerned with the AND operator. The logical AND operator produces a true result from the phrase “A AND B” only if both A and B are “true”. In GIS, this methodology is used in a multiplication overlay between layers containing only “zeroes” (representing areas where conditions are “false” or “criterion is not satisfied”) and “ones” (representing areas where conditions are “true” or “criterion is satisfied”) (Eastman, 2003).

1.3 Forest Management

Forestry involves the management of a wide range of natural resources. In addition to timber, forests provide various resources such as land for livestock to graze, recreation areas and water supply resources. In this context, forest management includes management of harvesting and recreational areas, protection of endangered species and archaeological sites. Management of forest resources is a complex task due to multi-functional nature of these resources. Therefore, the problems of forest management and planning usually involve decisions which have to take into account multiple objectives (Aronoff, 1995; Kazana et al., 2003; Mohren, 2003).

The amount of data and information involved in the forest management is often overwhelming. Integrated decision support systems help forest managers to make consistently good decisions about forest ecosystem management (Potter et al., 2000). Compared to previous forest management approaches, new forest management strategies require integration of spatial information technologies, such as GIS, remote sensing, and decision support systems (Franklin, 2001).

The designing of a forest database is crucial in a comprehensive forest management plan. Data should be accurate, properly organized, detailed and obtained easily and economically. The gathering of spatial and nonspatial data and their analysis determine the quality of forest management plans. Forest management constists of several subsystems one of which is the fire management system. It is very important to minimize damage caused by a forest fire. This can be achieved by developing an efficient fire management system. Fire fighting planning is an important component of fire management system. Martell (1982) reviewed Operations Research approaches in forest fire management comprehensively.

2. MATERIALS AND METHODS

In this study, integration of GIS and MCDM is applied for İzmir Forest Administration Chief Office. This Institution is subordinate to İzmir Directorate of Forest Administration, which has eleven chief offices. It is aimed to represent the most appropriate areas that can cope with forest fires effectively in the boundary of our study area according to Boolean approach.

Figure 1 shows the forest boundary map of İzmir Forest Administration Chief Office. General area is 39270 ha and 50.88 % of this area is forested land. Total forest area is 19983.5 ha of which 11494.5 ha (57.52 %) is productive forest and 8489 ha is unproductive forest.

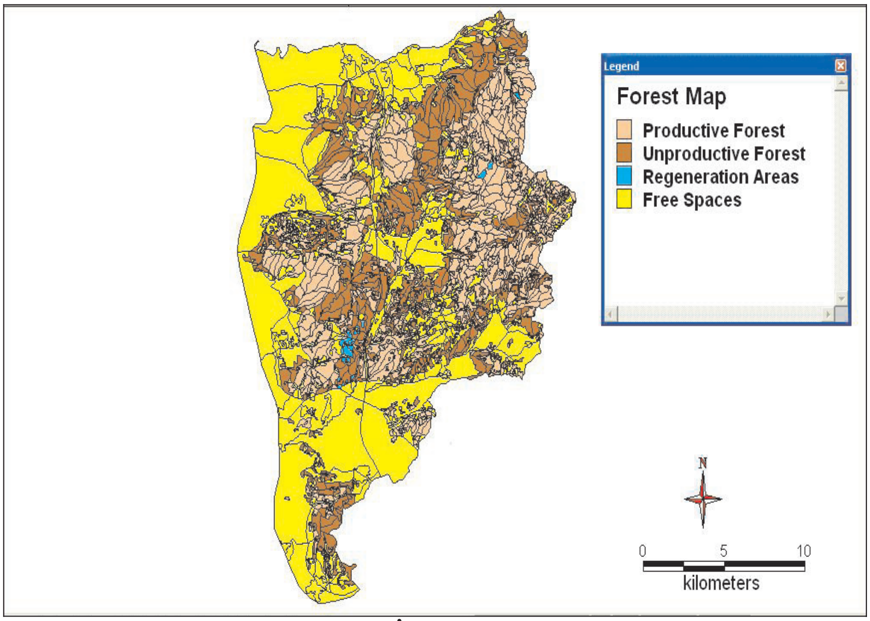

Figure 1. Forest boundary map of İzmir Forest Administration Chief Office

There are several criteria that must be considered in forest fire fighting planning process, such as fuel/vegetation type, soil properties, topographical information, slope, aspect and altitude information, distance from roads, distance from water resources, distance from settlement areas, and distance from streams. However, in this study only the last three criteria were used. This was due to the fact that maps of the other criteria were unavailable to authors, whereas maps for the three criteria above could be constituted by the data obtained from the study area. The most important point that must be taken into in spatial multi criteria decision making is the availability of maps of all criteria. Water resources map, settlement areas map and stream map are used for the analyses. First phase of the application is the conversion of all vector-based maps to the raster-based maps. Then Boolean analysis is done and results are visualized by the maps.

3. RESULTS

3.1 The Boolean Approach

In our study Boolean approach is used to determine the most appropriate areas that can cope with forest fires effectively. Firstly all criteria are standardized to Boolean values (0 and 1). Factors (criteria) of our study are distances from water resources, streams and settlement areas.

3.1.1 Distances from Water Resources, Streams and Settlement Areas

Water resources and streams are very important in fire management. The areas closer to the water resources and streams are considered more appropriate to cope with fire than the areas that are distant from water resources. Settlement areas can be considered as an important factor to intervene and control fire. However, according to different points of view settlement areas can also be considered as a risky factor. In some cases, the areas closer to the settlement areas are more fire prone because of the human factor.

As interviewed with the directorates of fire combatting department of İzmir Forest Administration Chief Office the areas closer to the water resources, streams and settlement areas were considered as appropriate (1) and the others were considered as not appropriate (0) in this study.

There are four water resources in our study area namely Buca Gölet, Kaynaklar Göleti, Sarnıç Göleti and BP Olduruk. Water resources map was derived by rasterizing and using the module DISTANCE in IDRISI software package. Then the distance image, which shows a simple linear distance from all water resources in our study area, was obtained as shown in Figure 2.

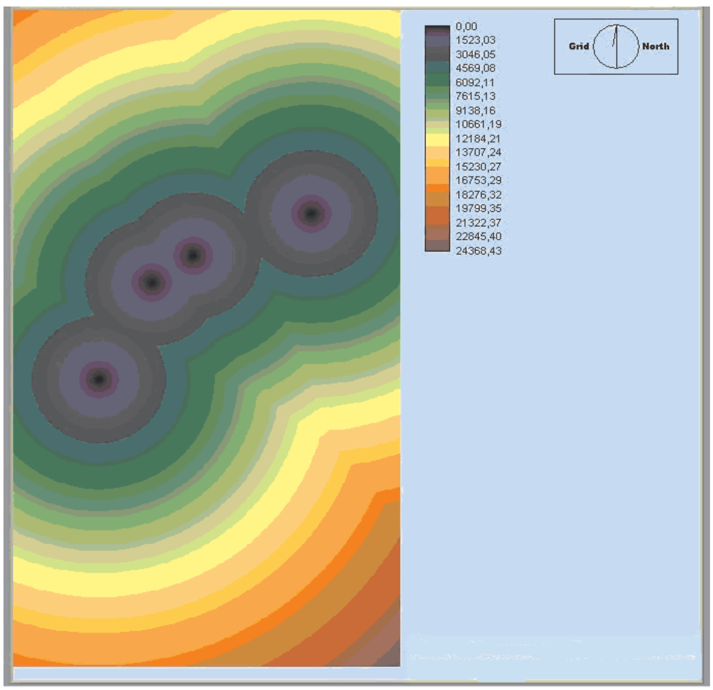

Figure 2. Distance map of the water resources

In this stage it was needed to RECLASSIFY continuos image of distance from water resources to determine the distances that are appropriate and the distances that are not appropriate. As interviewed with the directorates of fire combatting department of İzmir Forest Administration Chief Office, the areas that have a distance less than 5000 meters to the water resources were considered as appropriate (1) and those equal to or larger than 5000 meters were considered as not appropriate (0). Reclassified distance map of the water resources is shown in Figure 3.

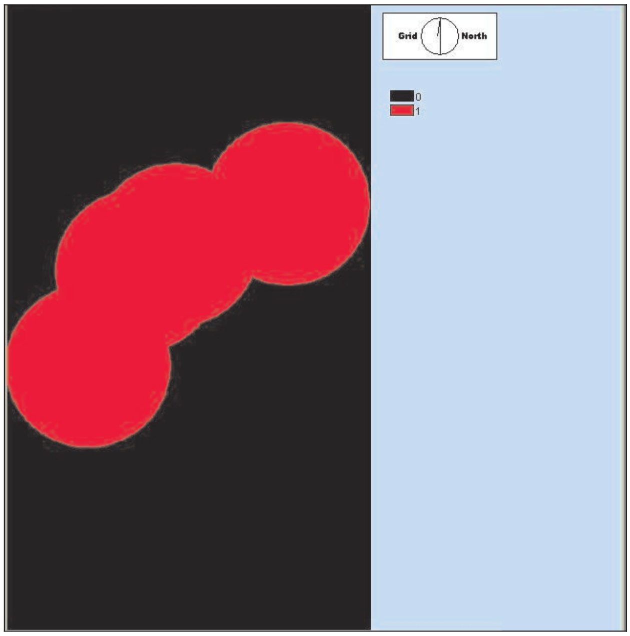

Figure 3. Reclassified distance map of the water resources

The same procedures were followed for the distance from streams and the distance from settlement areas. For reclassification of distance from streams factor, areas that have a distance less than 5000 meters to the streams were considered as appropriate (1) and those equal to or larger than 5000 meters were considered as not appropriate (0). For reclassification of the distance from settlement areas factor, areas that have a distance less than 2000 meters to the settlement areas were considered as appropriate (1) for effectively struggling with the fire and those equal to or larger than 2000 meters were considered as not appropriate (0). Figure 4 and Figure 5 show reclassified distance maps of the streams and the settlement areas, respectively.

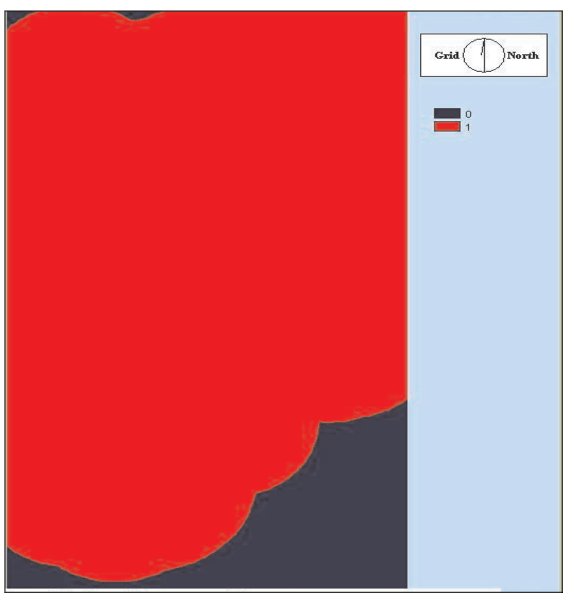

Figure 4. Reclassified distance map of the streams

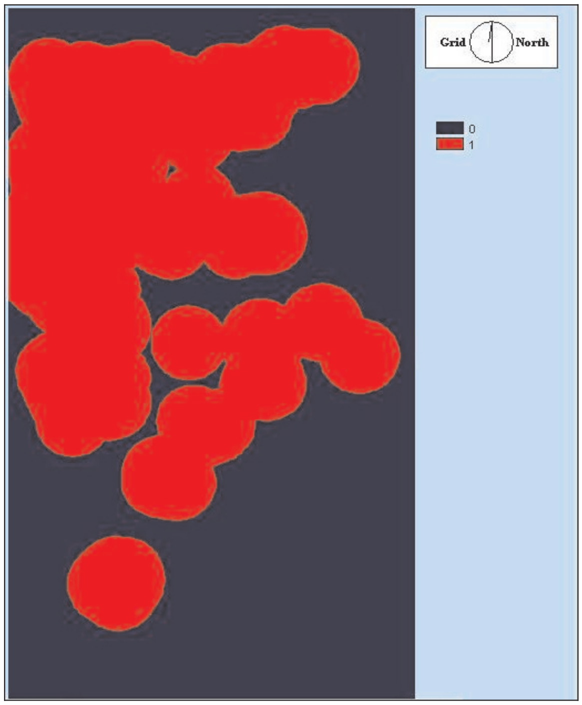

Figure 5. Reclassified distance map of the settlement areas

3.1.2 Boolean Aggregation of Factors

All factors have been transformed into Boolean images and they were ready to be aggregated. All of these three factors were multiplied together to produce a single image of appropriate areas that can effectively cope with the forest fire. This aggregation process was done by using image calculator with the AND operation in IDRISI software package. By using the AND operation it is aimed to represent the intersection of the areas according to the distance from water resources, streams and settlement areas criteria and to visualize the 'most appropriate' areas in terms of meeting all of these criteria simultaneously.

At the end of Boolean approach process, the most appropriate areas that can cope with forest fire were determined as shown in Figure 6.

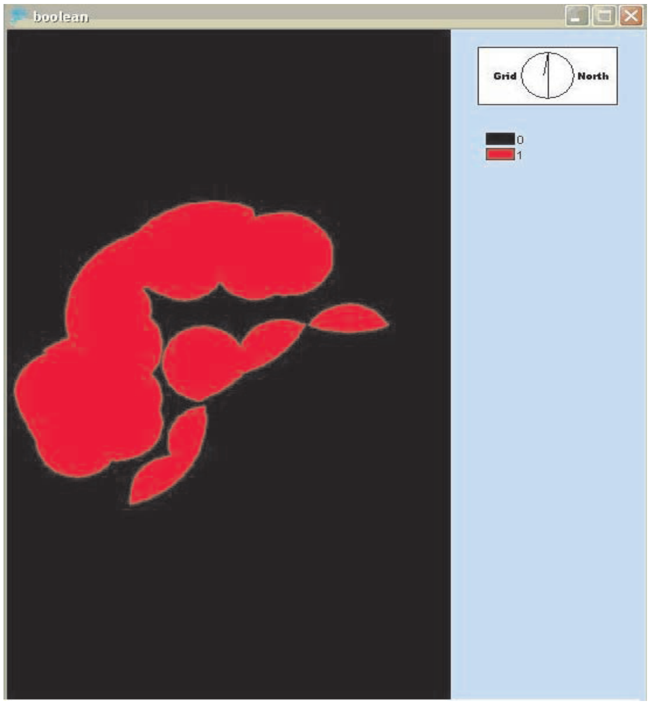

Figure 6. The most appropriate areas that can cope with forest fires effectively according to Boolean approach

5. CONCLUSIONS

This study represents the use of Boolean analysis to determine areas which are the most appropriate in fire fighting according to distances from water resources, streams and settlement areas. Several criteria can be added to this analysis. Hovever, the most important point that must be taken into account is the availability of maps of these criteria. By looking at the results of this study subject to three criteria, it is proposed that İzmir Forest Administration Chief Office must take proactive measures and pay more attention to the areas shown as (0) in Figure 6. The results of this study can change in the case of adding different and more criteria to the analysis.

This study can be further extended by increasing the numbers of criteria. The next step of this study is to use AHP for determining the most appropriate areas that can cope with forest fires. Then the results of Boolean analysis and AHP can be compared as to the details of information they give.

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ORMAN YÖNETİMİNDE BOOLEAN YAKLAŞIMI

ÖZET

Çok kriterli karar problemleri ortaya çıkışlarından beri büyük ölçüde konumsal (mekansal) karar problemlerini çözmek için kullanılmıştır. Konumsal çok kriterli karar analizi, klasik Çok Kriterli Karar Analizi (ÇKKA)'dan farklıdır. Çünkü coğrafi bileşen içermektedir. Çok Kriterli Değerlendirme (ÇKD) ve Çok Kriterli Karar Verme (ÇKKV, Coğrafi Bilgi Sistemleri (CBS) oldukça önemli kavramlardır. Birçok konumsal karar problemi CBS ve ÇKKA'nın entegrasyonunu gerektirmektedir. CBS-ÇKKV entegrasyonu, çıkarımları kullanan ve daha sonra bu çıkarımların sonuçlarını konumsal olarak sayısal harita üzerinde gösteren bir süreç olarak düşünülebilir. Ormancılıkla ilgili karar problemleri birçok alternatifi ve değerlendirme kriterini içermektedir. Çoğu orman yönetimi problemi yapısal olarak konumsaldır ve genellikle çoklu kriter içermektedir. Yangın yönetimi, orman yönetiminin önemli bir bileşenidir. Bu çalışmada yangın yönetiminde Boolean yaklaşımı kullanılmıştır. İzmir Orman İşletme Şefliği için yangınla etkin olarak mücadele edebilen alanlar; su kaynaklarından uzaklık, akarsulardan uzaklık, yerleşim birimlerinden uzaklık kriterlerine göre incelenmiştir. Tüm analizler için IDRISI paket programı kullanılmıştır.

Anahtar Kelimeler: Boolean analizi, Orman yangını yönetimi, Coğrafi bilgi sistemleri, Konumsal çok kriterli karar verme.