DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEVELOPING AN EFFECTIVE AND EFFICIENT DECISION SUPPORT SYSTEM FOR FORESTRY IN İZMİR

by
Nurcan TEMİZ

July, 2008
İZMİR

DEVELOPING AN EFFECTIVE AND EFFICIENT DECISION SUPPORT SYSTEM FOR FORESTRY IN İZMİR

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by
Nurcan TEMİZ

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İZMİR

Ph.D. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"DEVELOPING AN EFFECTIVE AND EFFICIENT DECISION SUPPORT SYSTEM FOR FORESTRY IN İZMİR"** completed by **NURCAN TEMİZ** under supervision of **ASSOC.PROF.DR. VAHAP TECİM** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy.

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DEVELOPING AN EFFECTIVE AND EFFICIENT DECISION SUPPORT SYSTEM FOR FORESTRY IN İZMİR

ABSTRACT

Information systems and information technologies are very essential concepts of today's information society. Spatial Information Systems and technologies of Geographical Information Systems (GIS), and Remote Sensing (RS) have become very important component of decision making in ecosystem management, natural resource management and other application areas. GIS provides resource managers with tools to use in understanding and analyzing a forest and allow decision-makers to visualize and integrate data better. As the forest planning process becomes increasingly complicated, there is a need for assisting forest planners with operative tools. The combined use of GIS and Operations Research (OR) give forest managers the chance to visualize solutions proposed by OR and to get a better understanding of the problem they confront.

It is aimed to develop an effective and efficient decision support system for İzmir Forest Administration Chief Office by this thesis. For this reason, it is attempted to initiate steps of contemporary forest management by developing database based on digital maps. Prototype study that integrates GIS and OR is presented and in order to facilitate forest management decision process of directorates several analyses are done. These analyses can be summarized as, queries, location set covering problem (LSCP), spatial multi criteria decision analyses, road analyses, the shortest path analysis, clustering analysis, development of a new clustering algorithm and finally creation of a new menu in MapInfo. MapInfo, MapBasic, Vertical Mapper and IDRISI software packages are used for analyses.

Keywords: Spatial information systems, forest management, GIS, location set covering problem, spatial multicriteria decision making, clustering analysis, the shortest path analysis.

İZMİR'DE ORMANCILIĞIN ETKİN VE VERİMLİ BİR ŞEKİLDE GELİŞTİRİLMESİNE YÖNELİK BİR KARAR DESTEK SİSTEMİNİN OLUŞTURULMASI

ÖZ

Bilgi sistemleri ve bilgi teknolojileri günümüzün bilgi toplumunun oldukça önemli kavramlarıdır. Coğrafi Bilgi Sistemleri (CBS) ve Uzaktan Algılama (UA) gibi bilgi sistemleri ve bilgi teknolojileri, ekosistem yönetimi, doğal kaynak yönetimi ve diğer uygulama alanlarında karar verme sürecinin önemli bir bileşeni olmuştur. CBS, kaynak yöneticilerine, ormanı anlamaları ve analiz etmeleri için araçlar sağlamakta ve karar vericilerin verileri daha iyi görselleştirmesine ve bütünleştirmesine imkan tanımaktadır. Orman planlama süreci giderek karmaşık bir hale geldiği için, orman planlamacılarına yardımcı olacak operasyonel araçlara ihtiyaç duyulmaktadır. CBS ve Yöneylem Araştırmasının (YA) bütünleşik kullanımı, orman yöneticilerine, YA tarafından önerilen çözümleri görselleştirme ve karşılaştıkları problemleri daha iyi anlama şansı vermektedir.

Bu tez ile İzmir Orman İşletme Şefliği için etkin ve verimli bir karar destek sisteminin geliştirilmesi amaçlanmaktadır. Bu nedenle sayısal haritalara dayalı veri tabanı geliştirerek çağdaş orman yönetimi anlayışının adımları başlatılmaya çalışılmıştır. CBS ve YA'yı bütünleştiren prototip bir çalışma sunulmakta ve müdürlüklerin orman yönetimi karar sürecini kolaylaştırmak için birçok analiz yapılmaktadır. Bu analizler, sorgulamalar, konumsal küme kapsama problemi (KKKP), konumsal çok kriterli karar analizleri, yol analizleri, en kısa yol analizi, kümeleme analizi, yeni bir kümeleme algoritmasının geliştirilmesi ve son olarak MapInfo'da menu oluşturma şeklinde özetlenebilir. Analizlerde, MapInfo, MapBasic, Vertical Mapper ve IDRISI yazılım programları kullanılmaktadır.

Anahtar Sözcükler: Konumsal bilgi sistemleri, orman yönetimi, CBS, konumsal küme kapsama problemi, konumsal çok kriterli karar verme, kümeleme analizi, en kısa yol analizi

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

Because of the understood importance of information our day was named as information era. Information systems and information technology are very essential terms in today's information society. Spatial information systems are an important and more sophisticated branch of information systems. Most of the problems encountered in the organizations have a spatial aspect. So handling and analyzing spatial data gained a wide importance for most of the organizations.

Forestry involves the management of a wide range of natural resources. In addition to timber, forests provide various resources like 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. Contemporary forest management requires development of database which also have a spatial dimension and both spatial and tabular terms must be taken into account. In other words, it is important to develop not only conventional database but also the database that has a geographic reference. It is possible to integrate spatial and nonspatial data and to do several analyses with them by GIS. Location is an important factor for forestry to conduct certain activities. It is clear that most of the problems encountered in forestry have a spatial dimension.

As the forest management process becomes increasingly complicated, there is a need for assisting forest planners with operative tools. The combined use of GIS and OR techniques gives forest managers the chance to gain a better understanding of the problem they confront and to visualize solutions proposed by OR.

In this thesis primary focus is specifically on the use of GIS and OR techniques in forest management. Purpose of this thesis is to implement forest management by using spatial information systems, GIS, in combination with OR techniques for our study area, İzmir Forest Administration Chief Office. Our purpose is to generate a prototype study for İzmir Forest Administration Chief Office.

In this context studies done can be summarized as:

- Constitution of Forest Information System.
- Constitution of thematic forest maps.
- Fire management and control.
- Road analyses.
- The shortest path analyses from potential fire crews to the potential fire areas.
- Proposing locations of new fire crews by using functions of GIS.
- Proposing locations of new fire crews by using clustering analysis.
- Visibility analysis.
- 3D map of study area.
- Slope, altitude and aspect analyses that will guide to forest managers in different problems such as, in aforestation studies, in reforestation studies, in construction of forest road studies and in erosion control studies.
- Development of a special menu in MapInfo as to analyses done in this thesis by using MapBasic, to support decision making process of forest managers.

Forests can not be managed without a forest management plan. Our aim is to show to the forest manager how to plan forestry in the short and long-term by using GIS and OR techniques. Then we will show how to use new information tool for management.

Thesis is composed of theoretical parts and application part. The second and the third chapter of thesis constitute theorotical part of thesis, fourth chapter constitutes application part of thesis. The second chapter handles the spatial information systems. Information systems and information technologies, fundamentals of GIS, importance of GIS as an information system, basics of Remote Sensing (RS), and integration of RS and GIS are the topics which are discussed in this chapter.

The third chapter represents the use of OR and GIS in forestry. Firstly, the forestry, forest management and sustainable forest management concepts are examined. Then forestry in Turkey is overviewed. Usages of OR techniques in forestry and RS and GIS integration in forestry in the world are reviewed. Following this, OR and GIS integration in forestry is examined.

The fourth chapter is designated to carry out theorotical features mentioned in the second and the third chapter of thesis. OR and GIS integration in forest management is discussed for İzmir Forest Administration Chief Office and several analyses are done. The fifth chapter discusses results obtained.

Outline of thesis can be summarized as shown in Figure 1.1.

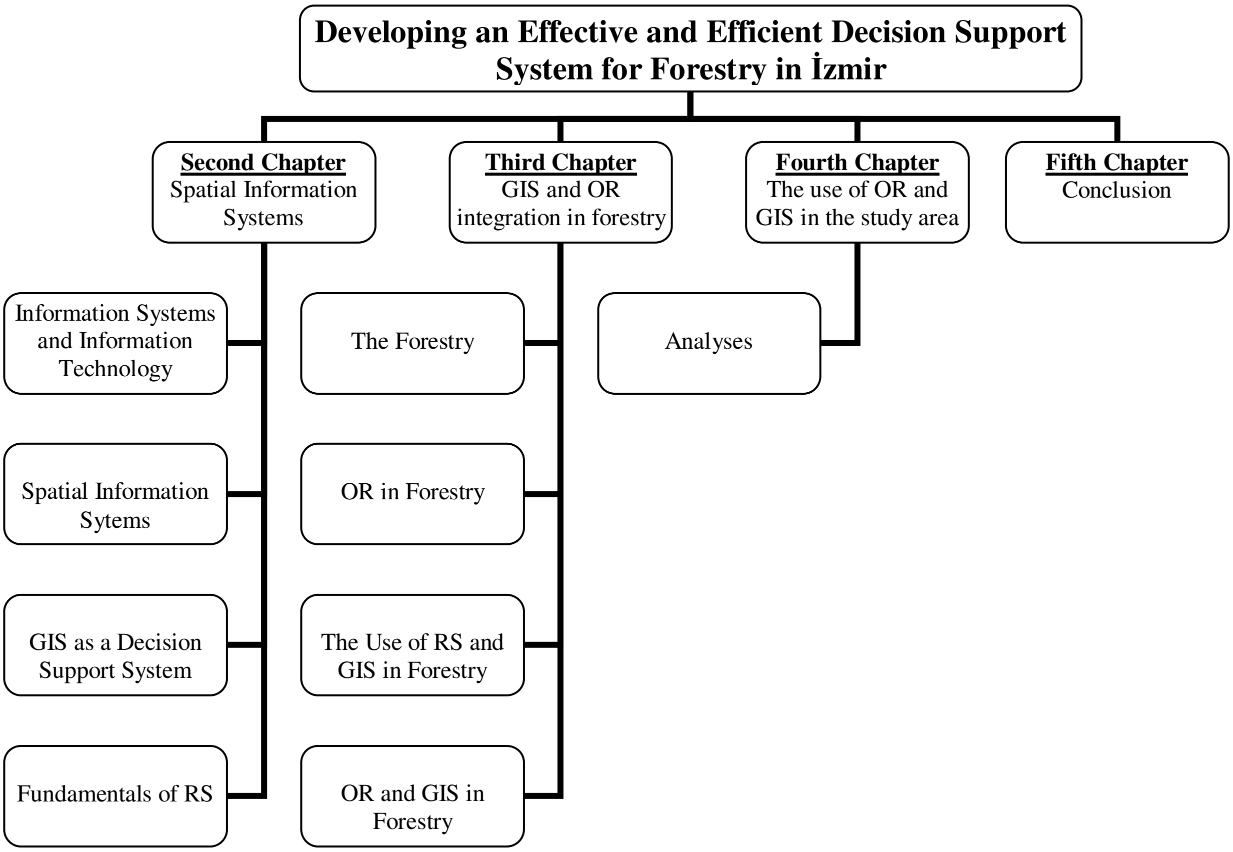

Figure 1.1 Outline of the thesis.

CHAPTER TWO
SPATIAL INFORMATION SYSTEMS

2.1 Information Systems and Information Technology

This chapter discusses information systems and information technologies, spatial information systems, fundamentals of GIS, functions, application areas of GIS, importance of GIS as a decison support system and fundamentals of RS. Figure 2.1 summarizes outline of this chapter.

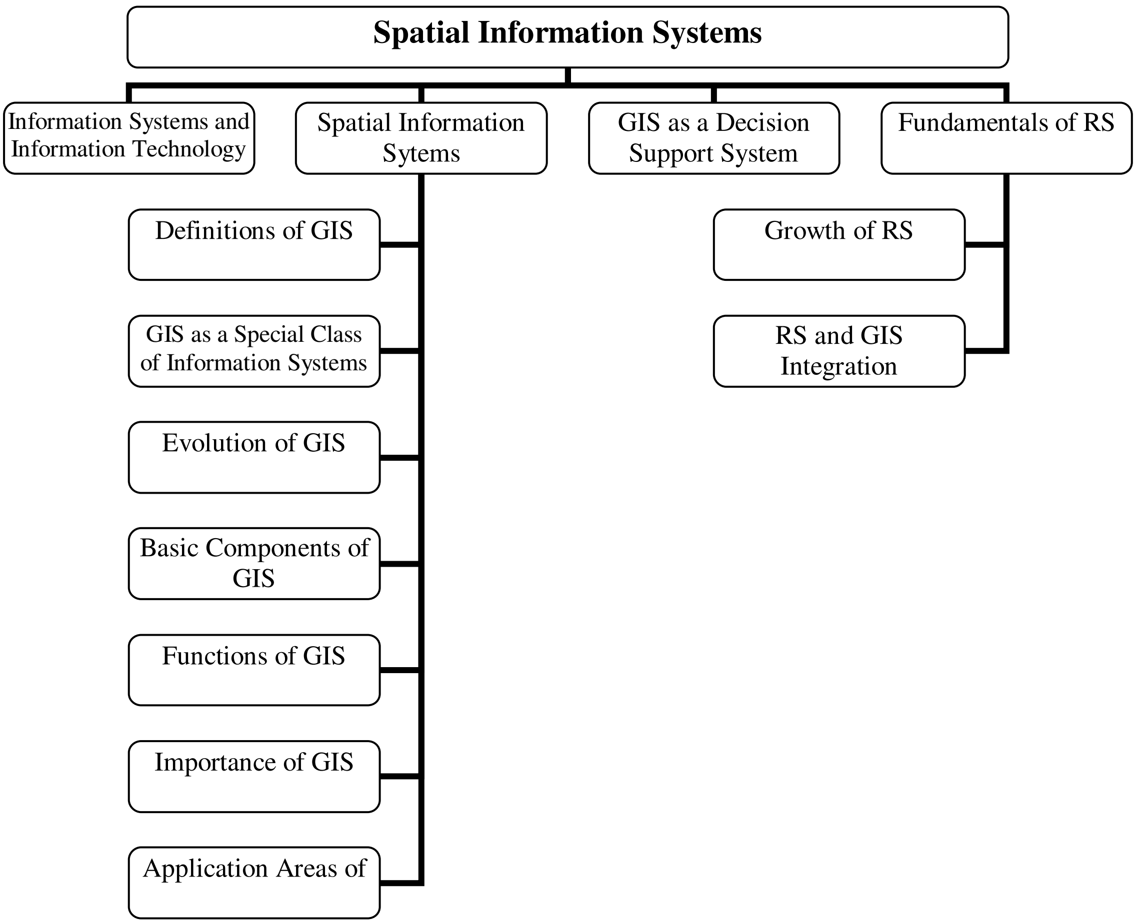

Figure 2.1 Outline of the second chapter.

Because of the understood importance of information our day was named as information era, and countries entered to a big race on this subject. So, it is tried to make use of information in the best way. Information systems and information technologies are very essential terms in today's information society.

Input and output of information systems are two important concepts; data and information. Data usually refers to facts and figures relate to people, things, events and concepts. These facts and figures can be in the form of numerical values, alphanumeric characters and symbols. When data are transformed into a form that is meaningful to user, it is referred to as information. As stated by Checkland and Scholes (1990), information equals data plus meaning. Presentation of information in a particular manner and at an appropriate time improves the knowledge of person receiving it. Knowledge is an awareness and understanding of a set of information and ways of making information useful to reach a decision. Users deploy this knowledge to perceive relationships, formulate principles and introduce personal values and beliefs he/she develops is called intelligence (Lo&Yeung, 2002; Ormerod, 1995).

An Information System (IS) is a framework that provides answers to questions from a data source. The primary function of an IS is to turn data into useful information. The process that transform data into information by structuring, formatting, conversion and modeling of data is called an IS, as shown in Figure 2.2 (Lo & Yeung, 2002; Shamsi, 2005, Stair & Reynolds, 2001).

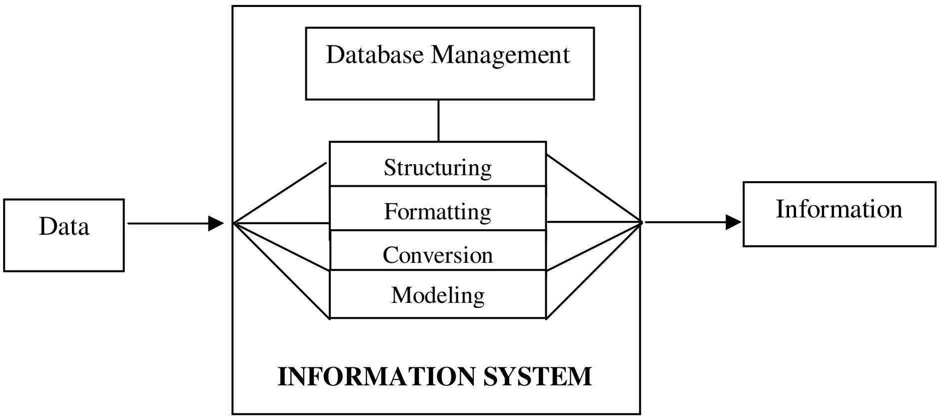

Figure 2.2 Transformation of data into information using an IS (Stair & Reynolds, 2001; Lo & Yeung, 2002; Shamsi, 2005).

An IS is a set of interrelated components that collect, manipulate, and disseminate data and information and provide a feedback mechanism to meet an objective. All of us interact daily with information systems, both personally and professionally. We use automated teller machines at banks, we access information over the Internet, and we witnessed how an online information system is improving productivity. Computers and information systems are constantly changing the way organizations conduct business. Information itself has value, and commerce often involves the exchange of information rather than tangible goods. Systems based on computers are increasingly being used to create, store and transfer information Information systems are combination of hardware, software and telecommunications networks built and used by people to collect, create and distribute useful data (Stair & Reynolds, 2001).

Five basic components of IS are, people, hardware, software, data and telecommunication, as shown in Figure 2.3 (Jessup & Valacich, 2006).

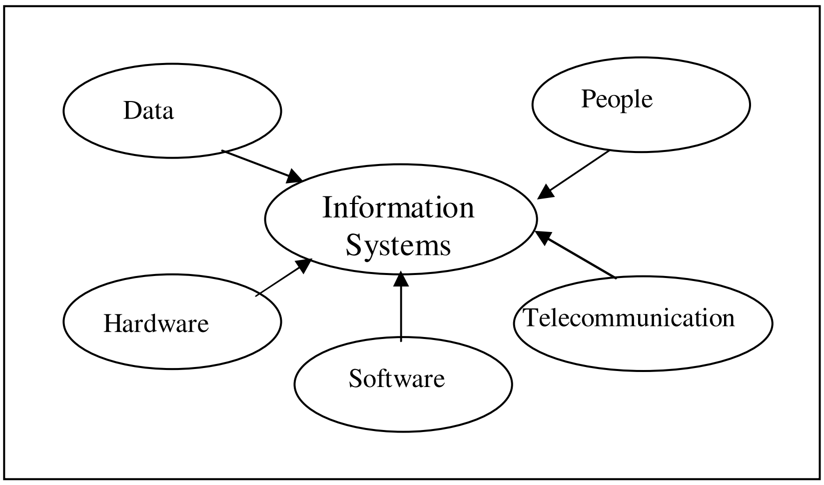

Figure 2.3 Components of information systems (Jessup & Valacich, 2006).

IS are used typically in an organizational settings but are evolving for personal use. Data component includes raw inputs for entry into information systems. They are organized, processed and stored by an IS to support user information needs and provide basis for qulitative and quantitative analysis. Hardware is physical components of information system. Hardware components contain processors, input and output devices and storage devices. Software components are the instructions that operate the information system. System software controls the hardware. The communication mechanism of information systems is telecommunication component. It allows two or more computers to communicate, such as internet (Jessup & Valacich, 2006).

Information systems are special class of systems set up to achieve the specific objectives of collecting, storing, analyzing and presenting information in a systematic manner. It is made up of interrelated components that include a combination of data, technical and human resources. A good information system is one that provides us with the necessary data relevantly organized so that we can make right decisions about the real world (Aronoff, 1995; Lo&Yeung, 2002).

A system which assembles, stores, processes and delivers information to people, including managers, staff, clients and citizens, who wish to use it in a such a way that the information is accessible and useful to them is defined as an IS by Buckingham et al. (1987). They pointed out that an IS is a human activity (social) system which may or may not involve computer systems (Avison & Myers, 1995).

An IS is a set of interrelated components that collect, process, store and distribute information to support decision making and control in an organization. IS developed in response to the increasing necessity of organizations to improve their capabilities to process and manage data. With this origin, an information system was initially seen to be an application of computers to help organizations process their data so they could improve their management of information (Avison & Elliott 2005; Laudon & Laudon, 2005).

As stated by Laudon & Laudon (2005) an IS is a combination of formal systems and computer based information systems. In formal systems there are fixed definitions of data and procedures for collecting, storing, processing, disseminating and using data. Formal systems can be computer based or manual wheras computer based information systems use computer hardware and software to process and disseminate information. Information sytems are at the core of organizations, technology and management and they are more than computers. IS concept includes behavioral knowledge about organizations, technical knowledge about computers and individuals using information systems (Laudon & Laudon, 2005).

In organizations information systems consists of three main categories according to their level, operational-level systems, management-level systems and strategic level systems. In these categories there are four major types of systems as, Transaction Processing Systems (TPS), Management Information Systems (MIS), Decision Support Systems (DSS) and Executive Support Systems (ESS) (Laudon & Laudon, 2004, 2005).

TPS is a computerized system that performs and records the daily routine transactions necessary to the conduct of the business. It is a basic business systems that serve the operational level of an organization. Some examples for the types of TPS are, sales/marketing systems (sales management, market research), manufacturing/production systems (scheduling, purchasing, engineering), finance/accounting systems (budgeting, general ledger, billing). TPS processes day to day business event data in an organization. Inputs of TPS are, transactions and events. They are processed through sorting, listing and updating and oupts are detailed reports, lists and summaries. Users are operations personel and supervisors (Laudon & Laudon, 2004, 2005).

MIS provides reports and access to company data and serves management level. Inputs for MIS are, summary transaction data, high-volume data and simple models. These inputs are processed by routine reports, simple models and low-level analysis. MIS solves structured problems and outputs are obtained as summary reports. Output is often the kind that managers need routinely each term (quarter, month, year) to evaluate how to proceed next. Users of MIS are middle managers in an organization. Example includes weekly, monthly and annual resource allocation. Not five year plans and not daily details, but something in between. DSS serves management level with data analysis for decision making. Inputs for DSS are, massive databases, analytic models and data analysis tools. Processing consists of simulation and statistical analysis, and outpus are represented as special reports, decision analyses, responses to queries, statistical test results. DSS solves structured and semi-structured problems of organizations. Users of DSS are professionals and staff managers (Laudon & Laudon, 2004, 2005).

Management information systems are transaction-based systems that seek to summarize data for routine managerial decision making. DSS provides highly flexible computer modeling frameworks that allow the decision maker to address semi-structured managerial problems. Structured problems are solved by programmed decisions in which a repeatable process can be employed and these can be automated. Semi-structured problems require unprogrammed decisions and can be addressed (or partially be addressed) with DSS whereas structured problems can be addressed by an MIS (Oz, 1999; Rubin, 1986).

A MIS is an interconnected set of procedures and mechanism for data accumulation, storage and retrieval, designed to convert organizational data into information appropriate for managerial decision making. MIS generally summarizes data produced by transaction-based systems (data on clients, employees, salaries, etc.) and stored in organizational databases for analysis by operational, middle and upper level management. The concept of DSS was introduced in the early 1970s. DSS is an interactive computer-based system structured around analytic decison models and specialized database management directly accesible to managers. DSS can be used to assist management at all levels of an organization with unstructured problems (Rubin, 1986).

ESS provides communications and computing environment that serves the organization's strategic level. Inputs, external and internal aggregate data, are processed through graphics and simulations and outputs are obtained as projections, responses to queries. Users of ESS are senior managers. Example of ESS is five-year operating plan (Laudon & Laudon, 2004, 2005).

TPS generally feeds all other systems, MIS generally indicates when a DSS is needed and provides input for them to crunch. ESS takes mainly external data but usually only summary data from MIS and DSS level as shown in Figure 2.4 (Laudon & Laudon, 2004, 2005).

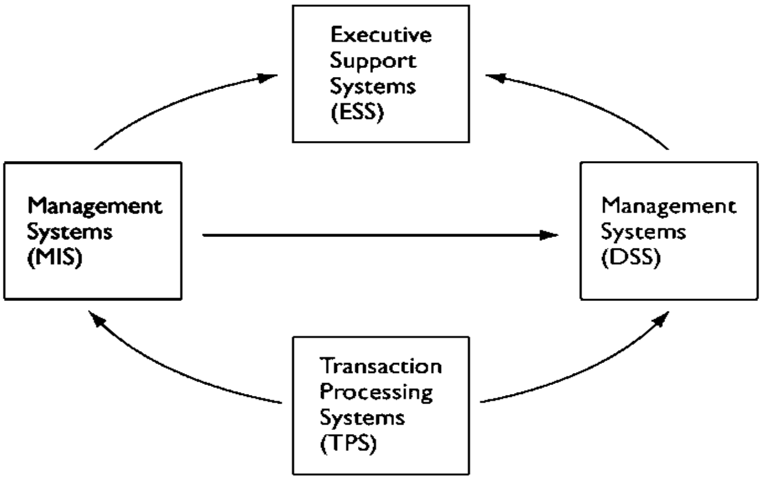

Figure 2.4 Interrelationships among systems (Laudon & Laudon, 2004, 2005).

As the types of computer technologies developed and potential areas of their application increased, so did the role of information system. Information and communication technologies are now widespread across the world. Their impacts extend from business, across a broad range of application areas, including health and government, to the community at large. It is important to differentiate terms IS and IT. IS is different from Information Technology (IT). IS doesn't focus on fundamental technologies and theories rather it emphasizes the applications of technology. IS focuses more on interactions between people and organizations and technology rather than on the technologies themselves (Avison & Elliott, 2005).

Checkland notes that information systems exist to serve, help or support people taking action in the real world. He asserts that, in order to create a system that effectively supports users, it is first necessary to conceptualize that which is to be supported (the IS), because the way it is described will dictate what would be necessary to serve or support it (the IT) (Ward & Peppard, 2002).

IT is a collective term used to describe the use of computers and communications technology. Sometimes IT is said to refer to the hardware elements of the technology, IS is used to refer to the software elements of technology. Technology is any mechanical and/or electrical means to supplement, extend or replace human manual operations, like building heating/cooling systems, car brakes, etc. Information technology is any machine technology that is controlled by information and uses information for operation, such as a programmable industrial robot receiving instructions from a computer-based database. Rapid development of IT has the capability of providing most organizations to conduct their business operations efficiently. The use of IT in organizations provides an interesting arena in which the new interacts with the old, since IT enables new ways of doing old things and also facilitates the introduction of new kinds of social practices within a particular context (Barrett, Sahay, & Walsham, 2001; Jessup & Valacich, 2006; Lan, 2003).

IT comprises a converging set of technologies in microelectronics, computing (hardware and software), telecommunications, broadcasting, and genetic engineering with its expanding set of developments and applications. All technologies increase our ability to process matter and information and IT increases the amount of information circulated (Low, 2000).

IT refers specifically to technology, essentially hardware, software and telecommunications networks. It is thus both tangible (e.g. PCs, network cables) and intangible (e.g. with software of all types). IT facilitates the acquisition, processing, storing, delivery and sharing of information and other digital content (Ward & Peppard, 2002).

The distinction must be made between IS strategy and IT strategy. Most of the IT strategies were strong on technology issues and technical terminology and weak on identifying application needs and business thinking. IS strategy be concerned with the organization's required information systems or application set, mainly addressing what question, and the IT strategy be concerned with the technology, infrastructure and associated specialist skills, how question (Ward & Peppard, 2002).

IS/IT strategy has two componets, an IS component and an IT component. The IS strategy defines the organization's requirement or demand for information and systems to support the overall business strategy. It defines and prioritizes the investments required to achieve ideal applications, the nature of the benefits expected and the changes required to deliver those benefits, within the constraints of resources and systems interdependencies. The IT strategy is about outlining the vision of how the organization's demand for information and systems will be supported by technology (Ward & Peppard, 2002).

Focusing only on the technology itself does not lead to successful strategic application for businesses. The most effective way to achieve strategic benefit from IS/IT is to rethink business by analysing current business problems and environmental change, and considering IT as just one ingredient of the solution. IS/IT and its various applications must be managed in accordance with the type of contribution it is making; improving efficiency, effectiveness and/or competitiveness through business change (Ward & Peppard, 2002).

2.2 Spatial Information Systems

Information systems can be classified as spatial information systems and nonspatial information systems depending on the nature of tha data they process. Nonspatial information systems are designed for processing data that are not referenced to any position in geographic space. Student information system, library information system, accounting, banking, and goods inventory are some examples of nonspatial information systems (Lo & Yeung, 2002).

Spatial information systems are computer-based tools for working with data about phenomena that is on, above or below the earth's surface. With the aid of spatial information systems it is possible to create, manipulate, store and use spatial data of many forms much more rapidly. The term spatial refers to located data, not just geographical, but objects positioned in any space of the world (Laurini & Thompson, 1992).

Spatial information systems are an important and more sophisticated branch of information systems. Most of the problems encountered in the organizations have a spatial aspect. So handling and analyzing spatial data gained a wide importance for most of the organizations. As stated by Gilfoyle&Thorpe (2004), geographic information is derived from spatial data. This is a very broad term refers to datasets such as astronomical observations, topographical maps, etc. The term spatial data refers to geoographic data that result from observations or measurement of earth, particularly those data that describe natural resources as well as social and economic characteristics. This raw data can't solve any problem and only becomes information when it is asked questions, such as who, what, when, where and how many. Geographic information supports most human activitiy. It records the location of physical assets like, roads, pipes, provides an inventory of natural environment, describes character of an area and the people who live and work within it.

There was a need for system that can answer questions about locations, patterns, trends and conditions, such as, where features are found, where changes occur over time, what geographic patterns exist. After realizing the necessity and easiness of usage of spatial information sytems and maps by several organizations a new spatial information system and technology which is known as Geographical Information Systems (GIS) has emerged.

Geographical Information Systems (GIS), also known as Geographic Information Systems, are computer-based systems that are used to store and manipulate geographic information. When these systems were first developed in the early 1960s, they were no more than a set of innovative computer-based applications for map data processing. Today GIS is one of the fastest growing sectors of computer industry and an important component of the information technology infrastructure of modern society (Franklin, 2001; Lo & Yeung, 2002).

The first GIS was developed to solve environmental problems and the use of GIS for analysis, modelling and decision support in a wide range of applications as mapping, monitoring, decision making benefit greatly from the GIS technology. GIS is a specialized database management system, displaying maps on the computer screen, performing queries and links between records based on spatial location and the general computing skills. It is devoted especially to analyze spatial and non spatial data (Chakhar, 2003; Sha & Hu, 2004).

GIS relates geographic information to attribute information. Its primary task is to store, update, manipulate, analyze and display geographically referenced data. The most important feature of GIS that differentiates it from other computer mapping systems is its ability to link spatial data with geographic information about a particular feature on the map. For example, on a paper forest map, it is impossible to learn forest feautures except their locations and only static information written on a map can be seen. Since paper maps have not database and it is impossible to do any queries with them. However, GIS can be used to query information from database and everything can be learned such as tree types, age of trees, soil types, particular tree diseases etc.

GIS is used to understand, analyze and manage spatially referenced data mapped to a geographical region. These spatial datasets can also contain additional attributes reflecting demographic or socioeconomic conditions within a region. GIS is becoming useful tools in making strategic decisions in a variety of government and business activities. This usefulness comes from the capability of GIS to present a large amount of data in a short period of time on a map, using geographical coordinate system (Rob, 2003).

While handling and analyzing spatial data are main capabilities of a GIS, the power of the system is most evident when the quantity of data involved is too large to be handled manually. There may be thousands of features that must be considered or there may be hundreds of factors associated with each feature or location. These data may exist in the form of maps, tables, and list of names and addresses. Such large volumes of data are not handled using manual methods which would be too costly and too time-consuming. But when these data have been input to a GIS, they can be easily manipulated and analyzed (Aronoff, 1995).

In short GIS is a computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS 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 to a wide range of public and private enterprises for explaining events, predicting outcomes and planning strategies (Lang, 2001).

2.2.1 Definitions of GIS

There have been so many attempts to define GIS but it is difficult to select one definitive definition. Maguire (1991) offers 11 different definitions. As Pickles (1995) suggests, this variety can be explained by the fact that any definition of GIS will depend on who describe it, their background and viewpoint. Some of the definitions give an idea of what a GIS is. Burrough (1986) defines GIS as a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. Another definition for GIS provided by Department of Enviroment (1987) is, a system for capturing, storing, checking, integrating, manipulating, analysing and displaying data which are spatially referenced to the Earth (Heywood, Cornelius, & Carver, 2002).

GIS is a hardware/software system for managing and displaying data. It is a similar to a traditional Data Base Management System (DBMS), where we think in spatial as well as in tabular terms. Thus we can consider GIS as a spatial DBMS as opposed to traditional tabular DBMS. GIS provides tools to support decision making with regard to spatially referenced entities.

From different perspectives GIS definitions can be summarized as follow:

The process-oriented approach (A GIS is a toolbox): A GIS is a computer-based system that provides a powerful set of tools - capture and input, storage and retrieval, manipulation and analysis, display and output- to handle georeferenced data (Naesset, 1997).

The database oriented approach (A GIS is an information system): A GIS is a special case of information systems which manages spatial database and provides answers to queries of a geographical nature. One of the major advantages of GIS for many beginners has been their ability to store and integrate different data sets within a single system (Birkin, Clarke, Clarke & Wilson, 1996; Clarke, 2000).

GIS is a computer system that collects, stores, updates, controls, queries, analyzes and visualizes geographically refererenced data for specific purpose (Tecim, 2001).

GIS is used to understand, analyze and manage spatially distributed data mapped to a geographical region. Although it started with the purpose of creating digital maps, it quickly became valuable tool for decision making process in various industries (Rob, 2003).

As stated by Kleynhans, Coppin, & Queen (1999), the development of GIS technology makes it possible to compile, store, retrieve, analyse and display vast quantities of spatial data. While the use of GIS is expanding day by day, its most important applications include those that support decision making.

2.2.2 GIS as a Special Class of Information Systems

Geographic data are generally characterized by their two fundamental components: the physical dimension or class of the phenomenon and the spatial location of the phenomenon. Population of a city, width of a road are some examples of physical dimension. The class can be a rock type, a vegetation type or the name of a city. The location is usually specified with reference to a common coordinate system such as latitude and longitude. A third component must also be included as time. The time component often is not stated explicitly, but it is important. Geographic information describes a phenomenon at a location at a specific point in time. For example a land cover map describes the location of different classes of land cover as they existed at the time of data collection. If the area is changing rapidly this information becomes outdated and unsuitable for decision making. Geographic data are a form of spatial data (Aronoff, 1995).

A GIS is a special type of information system in which the data source is a database of spatially distributed features and by these information systems procedures such as collecting, storing, retrieving, analyzing and displaying are used for geographic data. GIS technology offers combined power of both geography and the information systems and provides ideal solutions for effective natural resource management (Shamsi, 2005).

Spatial data stored in GIS can be defined by three concepts, entity, attribute, and relationship. An entitiy refers to a phenomenon that cannot be subdivided into like units. An entitiy is referenced by a single identifier, such as place name, or code number. An attribute is a description of some aspects of the entity. Relationship is the spatial association among entities. For example a river is an entity. The length and the width of river are examples of attributes. When the river drains into a lake or the sea, it represents a relationship between the river as one entity and the lake or the sea as another entity. Geographic data are a special form of spatial data that is characterized by two important features; Geographic space and geographic scale. Geographic space means that the data are registered to an accepted geographical coordinate system of Earth's surface so that data from different sources can be integrated spatially. Representation at geographic scale means that the data are normally recorded at relatively small scales and must be generalized and symbolized (Laurini & Thompson, 1992; Lo & Yeung, 2002).

GIS posseses all characters of information systems. The word geographic in GIS has two meanings: earth and geographic space. By earth it means that all data in the system are related with Earth's features and resources, including human activities based on or associated with theses features and resources. By geographic space it implies that both the data and the problems systems try to solve is geography, i.e. location, relationship within a specific geographical reference framework (Lo & Yeung, 2002).

Spatial information systems are those designed for processing data pertaining to real world features or phenomena that are described in terms of locations. A GIS is included in the spatial information systems category. But it is important to note that every spatial information systems can not be regarded as a GIS. Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) systems are typical examples of spatial information systems that are not GIS. These systems also use spatial data but they are different from GIS in terms of purpose and data-processing requirements. Therefore spatial information systems that are used for processing and analyzing only geographic data (or georeferenced data, geographically referenced data) can be labeled as GIS. The term geographic data or georeferenced data refers to spatial data that pertain to a location on the earth's surface. So the two terms, spatial data and geographic data, can be used interchangebly in many sources (Aronoff, 1995; Lo &Yeung, 2002).

Geographic and non-geographic information systems are two general classes of spatial information systems. Nongeographic information systems rarely have strong locational links to the earth itself, they are not geocoded. It is very important for GIS that the data contain a locational identifier in order to be mapped. Street address, zip code are some examples of locational identifiers. If this information is in the data, then the data can be associated to a base map and analyzed in a GIS. The term used to describe the association of attribute data to a base map in a GIS is called geocoding, or geographically encoding the data to allow it to be mapped. Geocoding is the process of converting an address into a point location. In other words it is the process of determining the coordinates of a point or an attribute (e.g., an address) so that it can be located graphically. To locate addresses on a map, it is necessary to determine their grid references in an accepted georeferencing system. Address-level data are typically geocoded to a street-level base map, county statistics are geocoded against a county-level base map, and so forth. Geocoding is not applicapable in CAD and CAM. Thus CAD and CAM are included in the nongeographic information systems category (DeMers, 1997; Heywood, Cornelius, & Carver, 2002; Jardine & Teodorescu, 2003; Lo &Yeung, 2002).

Taxonomy of information systems can be summarized as shown in Figure 2.5.

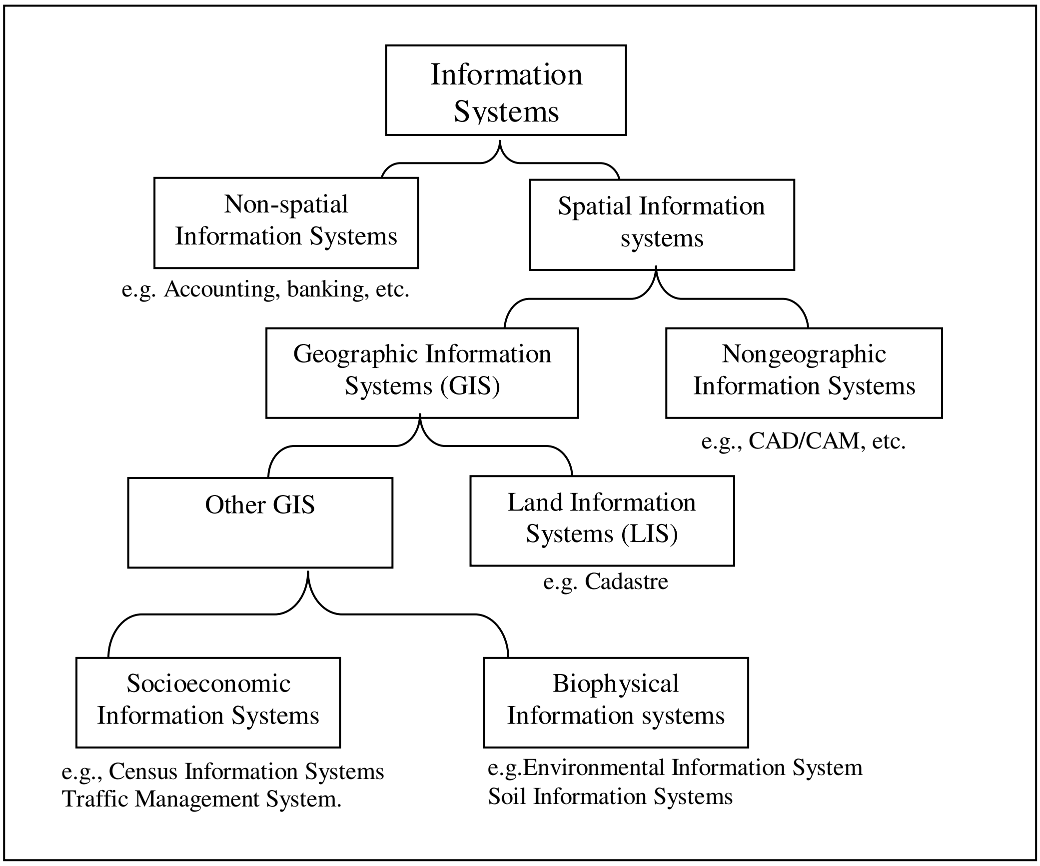

Figure 2.5 Taxonomy of information systems (DeMers, 1997; Lo &Yeung, 2002).

2.2.3 Evolution of GIS

Key groups, companies and individuals influenced development of GIS. Several factors, such as computer technology, development of theories of spatial processes in economic and social geography, antropology, increasing social mobility and education levels, awareness of environmental problems, caused a change in cartographic analysis. GIS and map analysis development began around the same time. These developments were incited by restraints of hard copy maps, problems with overlaying datasets and the increase in the size and number of data sets. A detailed history of GIS is not well understood because GIS technology evolved through multiple paralel but seperate applications across numerous disciplines.

As suggested by Goodchild and Haining (2004) that, there were several important motivations for GIS development. Difficulty of obtaining accurate measurements from maps and the simplicity of obtaining such measurements from a digital representation is one reason that induced GIS development. Among the other reasons are, the need to integrate data about various features (such as, traffic analysis zones, streets, households, workplaces) and relationships among them, the need to integrate multiple layers of information in evaluating the ecological impacts of development projects.

Emergence of the first electronic computers in the late 1940s marked the beginning of the computer era and a time of rapid evolution for the technology. GIS relied on the integration of three distinct aspects of computer technology, database management, routines for manipulating, displaying and plotting graphic representation of the data, and algorithms and techniques that facilitate spatial analysis, in its development stage (Antenucci, Brown, Croswell, Kevany, & Archer, 1991).

In the 1950s, the first attempts to automate thematic mapping began in the United States, Britain, and other parts of the world. In the mid 1950s British botanists used punched cards and a modified tabulator in preparing an atlas of British flora. Some of the first thematic maps were produced by meteorologists for forecasting crude land contours. By the late 1950s meteorologists, geophysicists, and geologists had incorporated computer generated maps into their work. In the 1950s the Unites States military developed graphic display capabilities, as part of Semi-Automatic Ground Environment (SAGE) air defense system, the system that converts radar data into computer-generated pictures (Antenucci et al., 1991).

GIS is a relatively new branch of information technology and this term appeared in the early 1960s when Canada Geographic Information System (CGIS) was developed. During this short period of history, both the technology used to construct GIS and the functions of GIS have experienced significant changes. GIS in today’s form is very different from its predecessors (Lo & Yeung, 2002).

Environmental management has been a main motivator of developments in GIS. Some authors suggest that the roots of current GIS lie in the 1960s known as CGIS. It was designed to produce maps of the crops that areas of land were capable of producing and to map land capability for forestry. Its initial task was to classify and map the land resources of Canada. The purpose of the system was to analyze data collected by the Canada Land Inventory and to produce statistics to be used in developing land management plans for large areas of rural Canada and to provide data to the Government of Canada on Canada's land resource, its utilization, and its management. Created maps were classified according to various themes. Some of these themes are, soil capability for agriculture, forestry capability, present land use, shoreline. Maps were created at the scale of 1:50000. This system required the development of new technology, which was very high cost of technical development (Bian, Sha, & Hong, 2004; DeMers, 1997; Goodchild, 2003; Heywood, Cornelius, & Carver, 2002).

By rapid progresses in computing technology 1970s experienced many and different developments in GIS and related disciplines. New computer cartography products entered the market, such as, GIMMS, MAPICS and SURFACE II. In the early 1970s, Swedish Land Data Bank (SLDB) was developed to automate land and property registration. In Britain, for land-use controlling and monitoring Local Authority Management Information System (LAMIS) and the Joint Information system (JIS) were used (Heywood, Cornelius, & Carver, 2002; Lo & Yeung, 2002).

In 1970s, U.S. Bureau of the census constructed a rudimentary geographic information system on the grounds that computerization could reduce the rate of errors in tabulating and spatially aggregating census results. For these purposes DIME files were produced. The development of the DIME files led to the production of the Census TIGER files, one of the most important socioeconomic spatial data sets about USA in use today (Goodchild, 2000).

The 1970s saw the first conferences and published work on GIS. The first UK meeting of academics to discuss GIS was in 1975. The first texts on GIS were published by International Geographical Union. In 1979 technical paper of Corbett on the concept of topology as applied to spatial data was an important milestone in the development of GIS concepts and techniques (Heywood, Cornelius, & Carver, 2002; Lo & Yeung, 2002).

In the 1970s it was recognized that the problems facing GIS were not only technical but also managerial. There were many problems associated with the management side of implementing an information system (Heywood, Cornelius, & Carver, 2002; Lo & Yeung, 2002).

Important geographic work was also done at universities throughout the 1960s and 1970s. Growing interest in computer-based map processing initiated several research and development programs in universities in Europe and North America SYMAP was developed at the Harward Laboratory For Computer Graphics and Spatial Analysis in 1966. Another Harward Packages were CALFORM, SYMVU, GRID, OPLYVRT and ODYSSEY. Center for Urban and Regional Analysis, University of Minnesota developed Minnesota Land Management Information System (MLMIS), the Department of Geography, University of Edinburgh, Scotland, developed Geographic Information Mapping and Management System (GIMMS) package (Lo & Yeung, 2002).

By the 1980s, demand for good graphics, data analysis and querying of databases had grown. In 1982, Environmental System Research Institute, Inc. (ESRI) released Arc/Info, a standart package which developed for mainframe computers. As computing power increased and hardware prices plummeted in the 1980s, GIS became a viable technology for state and municipal planning. Other GIS software packages developed in the mid-1980s were INFOMAP, CARIS. 1980s experienced significant technical developments included the increased use of raster data. There were also new GIS research initiatives. The USA’s National Center for Geographic Information and analysis (NCGIA) and UK’s Regional research Laboratories (RRLs) were perhaps the two largest initiatives began in the 1980s. Training was facilitated by the establishment of the International Journal of GIS in 1987 (Heywood, Cornelius, & Carver, 2002; Lo & Yeung, 2002).

By the mid-1980s the focus of GIS development shifted toward methods of data collection, quality, standards, data analysis and database organization. This data-oriented approach changed the way of GIS technology development (Lo & Yeung, 2002).

By the 1990s, the development of GIS was speeded up by the growth of computer technology. With advances in operating systems, computer graphics, database management systems and graphical user interface design GIS became multiplatform applications that able to run on different classes of computers. In 1990s the applications of GIS were no longer limited to the land and resource management, but expanded to new areas that included facility management, vehicle navigation and decision support in business management (Lo & Yeung, 2002).

It is generally agreed that by the mid 1990s, GIS reached its maturity in terms of both technology and applications.

Since the mid-1990s, development of GIS has entered a new era called the Age of Geographic Information Infrastructure. The concept of information infrastructure emerged in the early 1990s when the United States government proposed the National Information Infrastructure (NII) initiative. The aim of this initiative was to provide all U.S. citizens access to information concerning government, health care, education. In 1994, President Clinton suppported implementation of National Spatial Data Infrastructure (NSDI). He defined this term as " technology, policies, standards and human resources to acquire, process, share, distribute and improve utilization of spatial data" (Lo & Yeung, 2002, p.8).

The word infrastructure means that to treat geographic information similarly as other economic and political infrastuructures, such as highway and bridges, education systems. At national level, geographic information infrastructure provides government with more cost effective means in services by using information technology. Geographic information infrastructure also allows citizen to access public information, enables businesses and industries to renew and reorganize to achieve competitive advantage in the global economy. At the local level it enables citizens to patricipate public affairs, to know more about community (Lo & Yeung, 2002).

In Canada, the European Union, Australia, New Zeland and many other countries similar national geographic information infrastructure have also been established. These initiatives remarkably raised the profile of using geographic information in business, government and academia. The concept of geographic information infrastructure has induced revolution in the development of GIS in both philosophical and technological term (Lo & Yeung, 2002).

Now GIS is not used only as a software tool for processing and analyzing geographic data stored locally. It is the most important feature of GIS now to have an access and integrate geographic data from different resources located locally and globally. Increasingly business people rely on GIS in selecting where to build their factory, in determining best routes to deliver their goods and services. It also has a great importance in government organizations in managing land and natural resources, monitor the environment, etc.

2.2.4 Basic Components of GIS

A GIS is a very powerfool tool that can be used to capture, store and analyze geographic data but it is not a stand-alone system. Several other important components are needed to make up a GIS. Basic components of GIS consist of hardware and software (also known as technology component), people, data, and methods.

Hardware is the computer on which GIS software provides the functions and tools needed to store, analyze and display geographic information (PCs, printers, large size plotters, large size scanners, GPS...). GIS run on several computer systems ranging from personal computers (PCs) to multi-user supercomputers. Presence of a processor with sufficient power to run the software, sufficient memory to store mass volumes of data, a good quality, high resolution colour graphics screen, data input and output devices (such as digitizers, scanners, printers and plotters) are very important elements for effective GIS operation (Heywood, Cornelius, & Carver, 2002).

In order to use a GIS in the most efficient manner it is important to run the most up-to-date version of the software that is available. Since the first PC-based GIS software developed use of GIS has increased steadily in the latter half of the 1980s. Before that, GIS was run on mainframe computers and was relatively primitive technology by today's standards. Everybody can not reach or have an access as it is today. In 1982 ESRI released Arc/INFO which ran on mainframe computers. In the early 1990s, ArcView from ESRI and MapInfo from MapInfo Corporation emerged as the leaders. Both packages offer all the basic GIS tools and capabilities and are easy to learn (Jardine & Teodorescu, 2003).

Atlas GIS, IDRISI, Microstation MGE, ERDAS IMAGINE Professional, Geographic Explorer, GRASS, MrSID Stand Alone Viewer, SAGE GIS for Windows are some examples from other GIS software developed.

But as stated by Nasirin, Birks, & Jones (2003), GIS cannot just be installed as a piece of software. The person who will use GIS needs to be aware of many implementation issues (e.g. data conversion) and have to know what to do with data at hand to attain success.

According to their information needs and the ways they interact with the system, people component of GIS can be categorized as viewers, general users, and GIS specialists.

Viewers can be defined as the people whose only need is to browse a geographic database occasionally for referential information. They don't play an active role in GIS design and operation, so they are in general passive users. Main requirements of viewers are accessibility to information and easiness in system use (Lo & Yeung, 2002).

People who use GIS for conducting business, performing professional services and making decisions are named as general users. Facility managers, resource planners, scientists, engineeers, land administrators, lawyers and politicians fall into this category. They are active users because GIS is implemented to support their information needs. Hence, viewers have direct and considerable influence on the successful use of GIS in an organization (Lo & Yeung, 2002).

People actually make GIS work are named as GIS specialist. They include GIS managers, database administrators, system analysts and programmers. They are responsible for the maintenance of the geographic database and the provision of technical support to viewers and general users. They build applications for advanced spatial data analysis and modeling. Although GIS specialists are usually small in number, they play the most direct role in the successful implementation of GIS in an organization (Lo & Yeung, 2002).

GIS specialists are very important component in understanding study purpose, data collection, management and conversion, and doing and interpreting analysis. GIS technology has limited value without people who manage the system and develop plans for applying it to real-world problems. Without well trained, competent personnel operating and supporting GIS, the system would not function. Skill in selecting and using tools from GIS toolbox and the intimate knowledge of data being used are essential factors to be successful in GIS.

Geographic data and related tabular data are very important for performing work in a GIS. The core of a GIS is the database through which questions, such as what a feature is, where it is, and how it relates to other features, can be answered. Although it can create maps at different scales, in different projections, with different colours GIS is not simply a computer system for making maps. A GIS is an analytical tool. The major advantage of a GIS is that it allows us to identify the spatial relationship between map features. A GIS does not store a map in any conventional sense, nor does it store a particular image or view of geographic area. Instead, a GIS stores the data from which we can draw a desired view to suit a particular purpose.

All GIS software has been designed to handle spatial (geographical) data. Spatial data are characterized by information about position, such as latitude and longitude, connection with other features and details of nonspatial (attribute) characteristics (Heywood, Cornelius, & Carver, 2002).

As mentioned by Lo & Yeung (2002), real world features exists in two basic forms as, objects and phenomena forms. Objects are discrete and definite, such as buildings, highways. An object is a spatial feature that has identifiable boundaries and is describable by one or more characteristics, referred as attributes. Phenomena are distributed continuously over a large area, such as terrain, temperature, rainfall. Geographic data represent the real world in these two basic forms and this led to two distinct approaches in representing real world in geographic database: object-based model and field based model. The object-based model treats geographic space with discrete and identifiable objects. Spatial objects are represented as graphical elements of points, line and polygons, depending on the nature of the objects and the geographical scales at which they are recorded. The field-based model treats geographic space as defined by one or more spatial phenomena. Spatial phenomena are real world features that change continuously over space witn no specific extent. Topographic data and digital elevation models (DEM) are some examples of spatial phenomena.

At the database level, a spatial database can be constituted using either the field-based model or object-based model. Object-based and field-based spatial databases are generally labeled as vector data model and raster data model, respectively.

Vector data in a digital geographic database depict individual spatial features as discrete entities using points, lines and polygons. Discrete geographical features, points, lines and polygons, represented in a digital data structure is named as spatial entities. In the database these entities are identified as feature classes, each relating to a particular theme, such as transportation, land parcels and vegetation. Vector data stores objects that have point, line and polygon (area) characteristics according to particular coordinate system. Points are used to represent features that are too small to be shown as polygons (areas). They represent anything that can be described as an x, y coordinate on the face of the earth, such as schools, shopping centers, banks in the city. Lines data are data that composed of combination of several point data. Lines represent anything having a length such as streets, highways, rivers, fault lines and utility lines. Polygon data are data that start with a particular point and ends with the same point and are represented by a closed set of lines. They describe anything having boundaries, such as, forests, boundaries of countries, cities. Points, lines and polygons (areas) are the basic spatial entities used to represent a feature in the world. Vector data are used for GIS applications that focus mainly on individual or individual classes of spatial features. In a digital geographic database, feature classes are organized as layers (Gilfoyle & Thorpe, 2004; Lo & Yeung, 2002; Tecim, 2001).

Raster data, store map features in raster or grid format, generalize the location of features to a regular matrix of cells. In raster data, each cell in the matrix shows value of attribute information about region that falls in that cell. And it can take only single value. For example, in a database that defines roads, the value 4 that cell takes can show that this road is an intercities autobahn. The number of cells that points out this road is directly proportional to the length of that road. The size of each cell can be few meters or few kilometers. The cell size you use will affect the results of analysis and how the map looks. Using a cell size that is too large will cause some information to be lost or using a cell size that is too small requires a lot of storage space and takes longer to process (Tecim, 2001).

Raster data are best used to represent continuous spatial phenomena such as elevation, temperature, but discrete spatial features such as roads, land parcels may also be represented by raster data type. However, discrete spatial features in raster form don't exist as distinct individually identifiable entities. For example, a lake on a raster map can visually be recognized as a lake by differentiating cells that form the lake from surrounding cells, but the database doesn't store the lake as a single entity. In the raster database, the stored entities are the cells, which are referred as pixels, not the individual spatial features they represent (Lo & Yeung, 2002).

Figure 2.6 and 2.7 show vector and raster data examples.

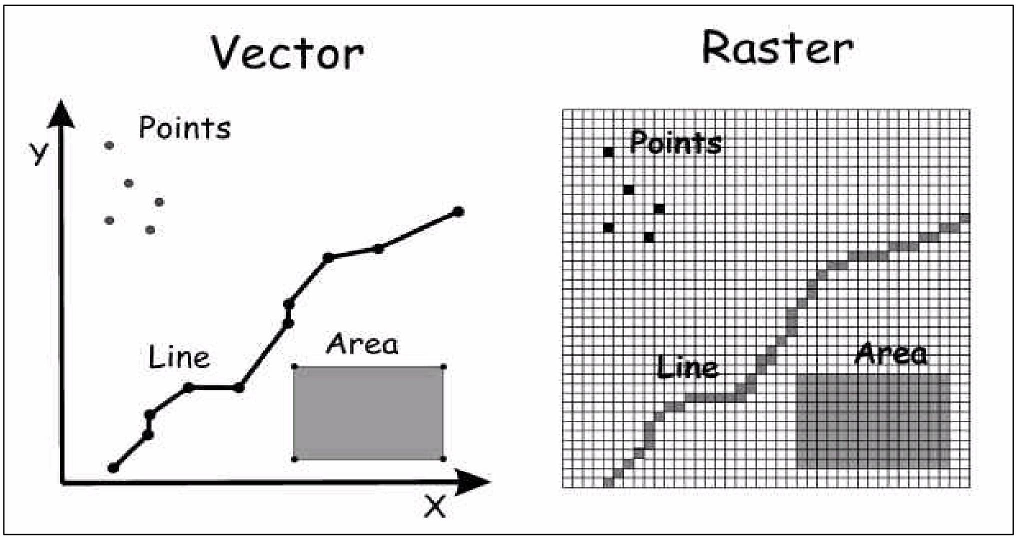

Figure 2.6 Vector and raster data models (Bolstad, 2005).

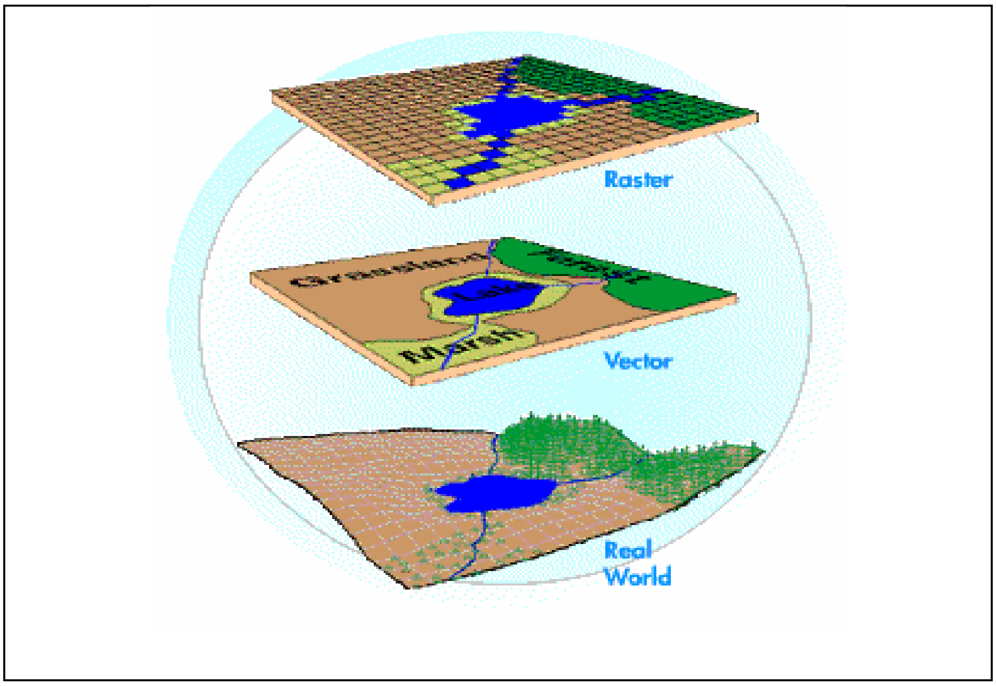

Figure 2.7 Vector and raster data (Bolstad, 2005).

Both the vector and the raster data represent real world. But they are distinct both in the types of data they use and in their application area. Vector-based models are used primarily for digital mapping and resource inventories while raster-based methods are more concerned with spatio-temporal modeling. By adding a time dimension to spatial data and analysis, named as spatio-temporal analysis, changes in some variable/condition within the same location with time can be tracked. Furthermore the variable/condition studied might change locations with time, or extend beyond the original location to involve additional ones. Vector data structure is preferred when tight spatial control is desired, such as the outlines of houses or roads. Raster data is the most suitable for data that includes values for every part of space, such as elevation or topography (Lo & Yeung, 2002).

Besides these forms of data mentioned above, other type of data known as attribute (tabular, non-spatial) data. Attribute data are descriptions or characteristic of entities. They describe what the features represent and are information describing a map feature. Beside the spatial information in map, the GIS can usually store non-spatial information which is related to the spatial entities. For instance, non-spatial data may be stored which provide extra information about the hotels (standard number of rooms, and restaurant facilities) or an urban GIS database may have a map theme of property boundaries. Attached to each parcel will be tabular database which might store the name of the owner, the address, the assessed value of the property (Lang, 2001).

Figure 2.8 shows spatial and tabular data of compartment 67 in İzmir Forest Administration Chief Office, simultaneously. Data was obtained from İzmir Forest Administration Chief Office, but maps were constituted by author of this thesis.

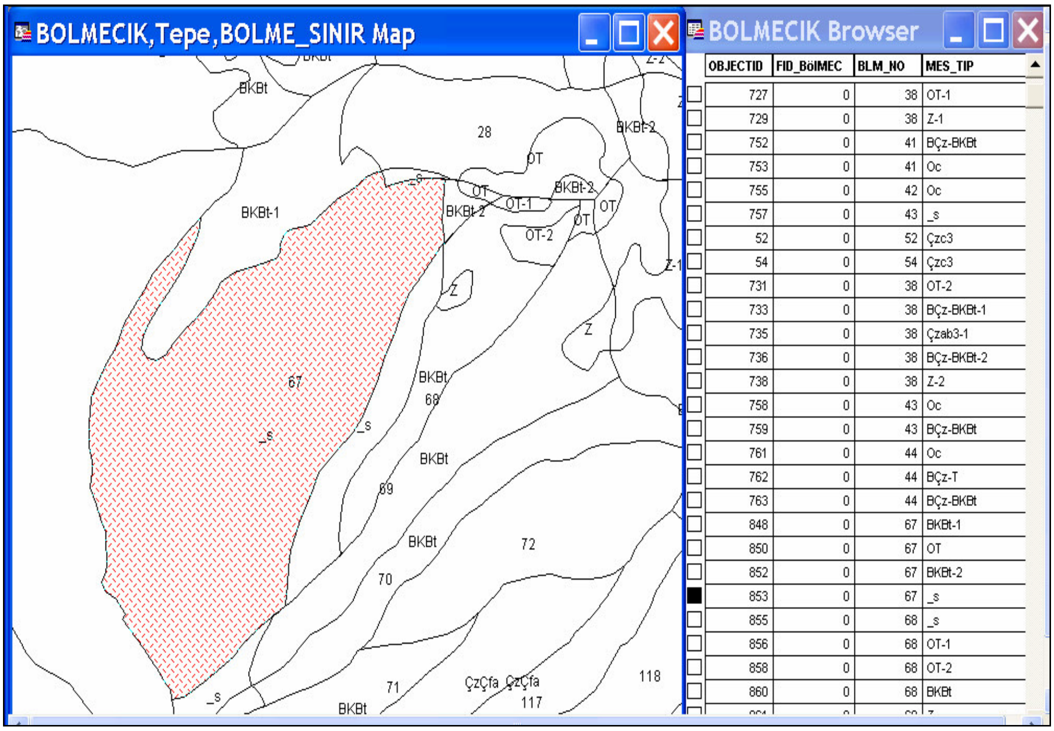

Figure 2.8 Spatial and tabular data.

GIS is seen as a tool to bring together different data that come from aerial photographs, satellite images, census data, maps, Global Positioning Systems (GPS) and etc. GIS can also import data from various data management formats, such as DBF, Excel, Access. But to do right analysis and to make right decisions geographic data content and quality are very important.

A relatively new technique of field data collection that has become very popular among GIS users is GPS. GPS is a set of satellites and control systems that allow a specially designed GPS receiver to determine its location anywhere on Earth 24 hours a day. These are hand-held devices that use signals from GPS satellites to find the exact location of the user on Earth's surface in terms of x, y, z co-ordinates using trigonometry. Positions are obtained quickly and accurately at the push of a button. Most GPS receivers store collected co-ordinates and associated attribute information in their internal memory. Thus they can be downloaded directly to a GIS database. Two main systems are American NAVSTAR system and the Russian GLONASS system (Heywood, Cornelius, & Carver, 2002).

Data are very essential in GIS implementation. In the early years of the development of GIS, the primary focus was on the acquisition and structure of geographic data. Since the 1990s, the problem of data quality emerged as a new dimension. Users of GIS have realized that merely having data is not enough for using technology beneficially (Lo & Yeung, 2002). Data must be reliable, accurate and pertinent in order to represent events on the earth's surface accurately. Because success of GIS depends on the integrity of the data, the system must be capable of maintaining and updating the data. No matter sophisticated analytical tools used, if data are misused or questionable, the final output will be doubtful.

Data quality refers to the fitness of data for using in intended applications. Several criteria are used to define data quality. Accuracy is the degree to which data agree with the values of the real-world features. It is a measure of how close data match the true values or descriptions. Data must also be sufficently current and up to date. They must be complete and precise; otherwise the degree of uncertainty must be indicated. Precision is a measure of how exact data are measured and stored. Data must be stored in a format that can be conveniently handled (maintained, transmitted, distributed, classified and updated) (Lo & Yeung, 2002).

Basic data quality components, as mentioned by Gilfoyle & Thorpe (2004), are completeness (the measure of inclusion or exclusion of items from the database), thematic accuracy (the accuracy of the values of attributes), temporal accuracy (the accuracy of the values of time-related attributes), and positional accuracy (the accuracy of values of geographic position) are components of data quality.

Methods are other GIS components that must be mentioned. A successful GIS operates according to well-designed plans and business methods, which are the models and operating practises unique to each organization.

2.2.5 Functions of GIS

GIS functions can be summarized as data management (data acquisition and editing, data compilation and data storage, data retrieval) data input and conversion, query and analysis and visualization. In this study GIS functions are classified as main functions and analytical and operational functions. In the main functions of GIS category, data management, data input and conversion and visualization are discussed. In the analytical and operational functions of GIS category, queries, spatial analysis, network analysis and statistical analysis are examined.

2.2.5.1 Main Functions of GIS

For small GIS projects it may be sufficient to store geographic information as simple files. However, when data volumes become large and the number of data users becomes more, it is often best to use a Database Management System (DBMS) to help store, organize and manage data. DBMS is a collection of software programmes that simplify construction, organization, storage and manipulation of data base for various applications.

Data compilation is pulling together all of the spatial and attribute data that are to be stored in a computerized format within the GIS. Data are organized to maximize efficiency and minimize storage space.

Data input is the process of converting data from its existing form to one that can be used by the GIS. It is the procedure of encoding data into a computer-readable form and writing tha data to the GIS database. Data in analogue (non-digital) or digital form need to be encoded to be compatible with the GIS being used. Analogue (non-digital) data are normally in paper form, and include paper maps, table of statistics and printed aerial phtographs. To use these data in a GIS, all of them need to be converted to digital form. Thus data encoding and correction procedures are longer than those for digital data. Digital data are in computer-readable formats and are supplied on disk or CD-ROM, or across a computer network. Map data, aerial photographs, satellite imagery data from automatic data collection devices, such as GPS, are all available in digital form (Heywood, Cornelius, & Carver, 2002).

Spatial data, can be obtained from many different sources in different formats, and can be input to GIS using different methods. Data can be created from paper maps or digital images (aerial photograph or satellite images). Paper map can be converted to a digital file with digitizing tool, or scanned to a computer. Data can also be directly input to GIS from field equipment such as GPS. All digitizing process also served by GIS software for digital or scanned images. There are several methods to get data into a GIS. These include, keyboard entry, digitizing, scanning and electronic data transfer (Heywood, Cornelius, & Carver, 2002).

Keyboard entry is the entry of data into a file at a computer. For example, suppose we have data about hospitals in particular region. Both spatial data (locations of the hospitals, postal codes, etc…) and attribute data (bed capacity, addresses of hospitals, etc…) can be entered at a keyboard. Although typograhical errors are very likely, for small numbers of hospitals it is a manageable task. If there were large numbers of hospitals, alternative methods such as text scanners and optical character recognition (OCR) software can be used to read in data automatically. Attribute data that is in a digital format are linked to relevant map features in the spatial database using identification codes. These are unique codes that are allocated to each point, line and polygon feature in the data set. The coordinates of spatial entities can be encoded by keyboard entry. When there are large numbers of coordinates and features to be encoded it is more common to use manual or automatic digitizing (Heywood, Cornelius, & Carver, 2002).

Before geographic data can be used in a GIS, the data must be converted into a suitable digital format. The process of converting data from paper maps into computer files is called digitizing. Data are converted to a digital form that can be stored and processed by computers. Some land surveying instruments record data in digital form. If we collect data from aerial photographs, satellite images special equipment has to be used to convert analogue graphics to digital data. Data can also be imported from other systems, often requiring the help of format converter to make it compatible with data in your system. Modern GIS technology can automate digitizing process by using scanning technology for large projects, by using a digitizing table for small projects. Today many types of geographic data already exist in GIS-compatible formats (Lo&Yeung, 2002).

Manual digitizing is the most common method of encoding spatial features from paper map. It is suitable tehnique when a selection of features is required from a paper map. It is also used for digitizing feauters from hard-copy aerial photograps. This technique requires a table digitizer linked to a computer workstation. When large numbers of complex maps need to be digitized an alternative method, automatic digitizing, can be used. Scanning is most commonly used automatic digitizing technique. It is an appropriate method of data encoding when raster data are required. A scanner is a hardware that converts an analogue source document into digital raster format (Heywood, Cornelius, & Carver, 2002).

If a digital copy of data is available in a form compatible with GIS, the input of these data into GIS is a question of electronic data transfer. After the process of digital data tranfer data conversion has to be done. With data conversion data are changed to a suitable format that can be used in GIS. Electronic data tranfer is an appropriate method of data encoding where the data are available in digital form in a format compatible with GIS. However, when the data are not in a compatible form with GIS it is necessary to encode data using electronic transfer. So it will be needed to transform or convert data to an appropriate format. Most GIS software packages allow conversion of data from a number of differnet formats (Heywood, Cornelius, & Carver, 2002).

Data input and updating are the most expensive and time-consuming part of any GIS project. Approximately 80 per cent of the duration of many large-scale GIS projects is concerned with the data input and management (Heywood, Cornelius, & Carver, 2002).

Data management functions in any GIS facilitate storage, organization and retrieval of data using a DBMS. An ideal GIS DBMS should provide support for multiple users and multiple databases, allow efficient updating, minimize repeated information and allow data independence, security and integrity. One of the major advantages of GIS has been their ability to store and integrate different data sets within a single system (Aronoff, 1995; Birkin, Clarke, Clarke & Wilson, 1996; Heywood, Cornelius, & Carver, 2002).

Data manipulation tools include coordinate change, projection, and edge matching, which allow a GIS to reconcile irregularities between map layers or adjacent map sheets called, tiles. Data manipulation function determines the information that can be generated by the GIS (Aronoff, 1995).

Because of the problems encountered during data encoding, it would be unwise to expect GIS with error-free data. Data may include errors derived from the original source data and the errors introduced during the encoding process. The process of intercepting errors before they contaminate the GIS database and go on to propagate the higher levels of information that are generated is known as data editing. Most GIS packages provide a suite of editing tools for identification and removal of errors in data. Errors in input data may due to errors in the source data, errors result from encoding or errors done during data transfer and conversion. For example, during encoding a range of errors can occur, such as operator's typing mistake in the case of keyboard encoding; wrong line encoding by an operator during digitizing; loss of data during data transfer (Heywood, Cornelius, & Carver, 2002).

Corrections of these errors can be done interactively by the operator on-screen, or automatically by the GIS software. However, visual comparison of the digitized data against the source document, either on paper or on the computer screen is a good starting point. This will display omissions, duplications or erronous additions (Heywood, Cornelius, & Carver, 2002).

Retrieval functions on the spatial and attribute data involve the selective search of data without the need to modify geographic location of features. Data are retrieved from the database for use in other operations. Retrieval is invoked by user entering search conditions that could include spatial and non-spatial (attribute) components. The retrieved data can be presented in a tabular format or data may be retrieved according to their location on a map layer (Aronoff, 1995; Kleynhans, Coppin, & Queen, 1999).

Query provides a way to retrieve user-specified data from the database. When map data are graphically displayed on a computer monitor, it is possible to select a specified area and examine it visually or analytically in more detail. This function is known as windowing. The elements found in the windowed area can be extracted and set aside on a new layer. Windowing allows for faster analysis of the smaller, selected data set (Kleynhans, Coppin, & Queen, 1999).

Classification and measurement are also among main functions of GIS. The sets of elements which are retrieved can be assigned class names. These classes names can be stored as attribute data. This new class designation can be used to select requested data. The procedure of identifying a set of features as belonging to a group is named as classification. If for example classification is done for land cover, the class names might be forest land, agricultural land, urban areas, and so on. Classification of spatial phenomena requires interpretation and coding of many types of data commonly found in maps, aerial photographs or satellite imagery so that these data types can be stored and used in GIS. Classification is important because it defines patterns. One of the important functions of GIS is to assist in recognizing new patterns. These patterns might be areas of the city with the highest crime rate or areas of forest land suitable for timber harvest (Aronoff, 1995; Kleynhans, Coppin, & Queen, 1999).

Determining the length of a river or the area of forest stand are examples of measurement problems. With a GIS both simple and complex measurement functions can be performed. However, it is possible to obtain different measurements depending on the type of GIS used (raster or vector). Measuring lengths, perimeters and areas is a common application of GIS. For example every service in local government needs to measure lengths (of roads, safe routes to schools, etc.), perimeters (of boundaries), and areas (of buildings, planning application sites, etc.). By using GIS, these calculations are both much quicker and more accurate. Furthermore lengths and areas data can be stored as attributes in a database and need to be measured only once. Beside this spatial data can be converted from one unit of measurement to another in a GIS. Lengths captured in feet mey be converted to metres, acres to square miles or hectares, and so on (Gilfoyle & Thorpe, 2004; Kleynhans, Coppin, & Queen, 1999).

At the end of the geographic operation outputs are best visualized as a map, tables, geographical summaries or reports, text either in hard-copy (such as paper) or in soft-copy (electronic file) format, graph. The sophistication of GIS software and the output capabilities of the hardware/software system determine quality and diversity of options that will be generated. To generate graphic output, generally in the form of maps, a GIS must have a wide variety of symbol and format options. Most systems offer various symbols for representing geographical phenomena, as well as text options for labeling output. Geographical and tabular summaries are common types of GIS output. Because these summaries are based on map analysis they differ from summaries generated by traditional database query (Kleynhans, Coppin, & Queen, 1999).

2.2.5.2 Analytical Functions of GIS

Data analysis is very important in transforming data into information and in all GIS packages there is several functions available to do these analysis. The main difference between GIS and mapping is that GIS's ability to do query and analysis.

Spatial analysis function distinguishes GIS from other types of information systems. These functions use spatial and attribute data to answer questions about the real world. The power of a GIS lies in its ability to analyze spatial and attribute data together (Aronoff, 1995).

Analytical functions of GIS that will be handled in this section are:

- Performing queries on a database
- Proximity analysis
- Integrating data using map overlay
- Network analysis
- Statistical analysis
- Surface analysis

GIS offers many query and analysis tool. For example, if one wanted the GIS to show all of the cities with a population of at least five hundred thousands in Turkey, GIS's query capabilities can be used; it would highlight all of the cities meeting that criterion. This simple query would allow one to see the distribution of highly populated states in Turkey. Are they concentrated in a particular part of the country, or are they spread out? This is the kind of spatial query that GIS provides an analyst.

Other tools allow the user to click on a data point to access all of the data linked to that point in the original data table. For example, if a database of student information is geocoded and mapped, it is possible to click on a point on the map and retrieve all of the data relating to that student in the original data table. Furthermore GIS can also show patterns or relationships that might be concealed in data tables. For example, a map created in a GIS could show that malaria is the most common across the particular river in the country, or condition of road is switching to the forested area in a city (Jardine & Teodorescu, 2003).

Performing queries on a database is an important part of GIS analysis. Presentations of the current data (such as, map of a forest area), pattern in the current data (such as, all parcels valued at over $200.000) and a prediction of what the data could be at a different time or place (for example, predicting the areas that will be affected in the flood case) all are answers provided by GIS (Aronoff, 1995).

Queries that can be done with GIS can be summarized as follows (Jardine & Teodorescu, 2003; Kleynhans & Queen, 1999; Lo & Yeung, 2002):

- Location: What is at a given location? This question seeks to find out what exists at a particular location. A location can be described as a place name or address. Mapped data primarily indicate where objects are located but cannot explain why. For example, an aerial photograph may show that an eucalyptus are growing in certain sections of a nursery, but can't explain why the species doesn't grow well in other areas. But GIS analysis may show relationship between tree growth, soil type and available water by simultaneously examining computerized tree, soil and moisture maps.

- Condition: Where does something occur? Using spatial analysis this question seeks to find a location where certain conditions are satisfied (e.g. an unforested section of land at least 2000 square meters in size, within 100 meters of a road and with soils suitable for supporting buildings).

- Patterns: What a spatial patterns exist or mapping where things are? This question might be asked to determine whether cancer is a major cause of death among residents near a nuclear power station. In mapping where things are, maps are used to identify individual features or to look for the pattern in the distribution of features. For example, one could see whether the rising average price of housing market nearby university is impeding students from living close the campus. Spatial analysts seek patterns in mapped data. They want to know if two or more events change similarly in space. For example, they may want to know if there is proportionately small number of accidents on gravel roads than on clay roads. If so, other questions, such as which stretches of roads are the most hazardous, may be asked.

- Modelling: What if …? These type of questions lead to scenario building in GIS and are posed to determine what happens, for example, if a new road is added to a network, or how will traffic be affected? Or what would happen to coastal areas if global temperatures increased, the ice caps partially melted and sea level rose? Here the user utilizes a model designed to forecast and map the potential impact of climatic changes on sea level in coastal areas. Application of such a model allows the user to generate a hypothetical situation and forecast the outcome.

- Mapping change: Both one's perception of the world and the world itself are constantly changing. GIS allows analysts to map changing conditions in a place over time. Analysts want to map how much or how fast a place has changed. Rather than mapping the conditions at two times, they usually calculate the difference between the values of a feature. The magniude of change can be expressed as an amount, or percentage. For example, an analyst may study the relationship between changing land-use practices and settlement law changes over many years. A GIS can perform these temporal analyses by storing and comparing maps with different dates.

With GIS both spatial and non spatial query can be performed. Nonspatial query involves questions about the attributes of features. For example the question concerning type of schools is a nonspatial query because neither the question nor the answer requires analysis of the spatial data component. But the question like, 'Where are the forest areas in İzmir?' is a spatial query because this requires information about 'where' and the location of forests will be reported and could be presented in map form. Moreover, users can query a map on the computer screen or browse through databases. Queries that satisfy two or more spatial and nonspatial criteria can also be done, such as, 'Where are the forest areas which have more than one hundred animal species in Canada?'. Queries can be made more complex by using boolean operators, such as, and, not, or.

Proximity is a measure of distance between features. It is commonly measured in length units but can also be measured in other units. In order to measure proximity four parameters must be specified: target location (e.g. a road, a hospital), measurement unit (e.g. distance in meters, travel time in minutes), a function to calculate proximity (straight line distance, travel time), and the area to be analyzed (Aronoff, 1995).

Buffer zone generation is one type of proximity analysis. A buffer is an area that is created around a spatial feature. It is a zone with a specified width surrounding a spatial feature. This feature can be point, line or polygon. That is a buffer zone is an area of specified width drawn around one or more map elements. Buffering is the process of creating areas of calculated distance from a point, line or area object and is used to identify a zone around an entity, or set of entities. For a point buffer, it is a circle with a specified radius drawn surrounding the point. For a line buffer, it is a band with a specified distance created on both sides of the line. For a polygon buffer, it is a belt of a specified buffer distance from the edge of the polygon surrounding the polygon and conforming to its shape (Heywood, Cornelius, & Carver, 2002; Lo & Yeung, 2002).

In the raster data model, the concept of spatial feature does not apply because individual features are not represented as independently identifiable entities, but as a collection of contiguous raster cells having the same attribute values. Therefore in raster-based data a buffer is defined as the raster cells that are at a specific distance from a particular cell or a cluster of cells (Lo & Yeung, 2002).

Like its raster-based counterpart, vector-based buffering is used primarily for neighborhood analysis that aims to evaluate the characteristics of an area surrounding a specific location. The objective of buffering is to delineate concerned area for a neighborhood analysis to search spatial features that fall inside or outside of interested area and analyze their spatial patterns and spatial relationships.The question like, which hotels are within 200 meters of a main road or how many houses are within 400 meters of a proposed incinerator outlet and what are their addresses, can be approached by producing a buffer zone that identifies all land up to 200 meters from the main road or all houses within 400 meters of incinerator. Or buffer zone can be generated around forest areas where logging is not permitted (Aronoff, 1995; Gilfoyle & Thorpe, 2004; Heywood, Cornelius, & Carver, 2002).

Figures 2.9 and 2.10 show examples of query and buffering operations, respectively.

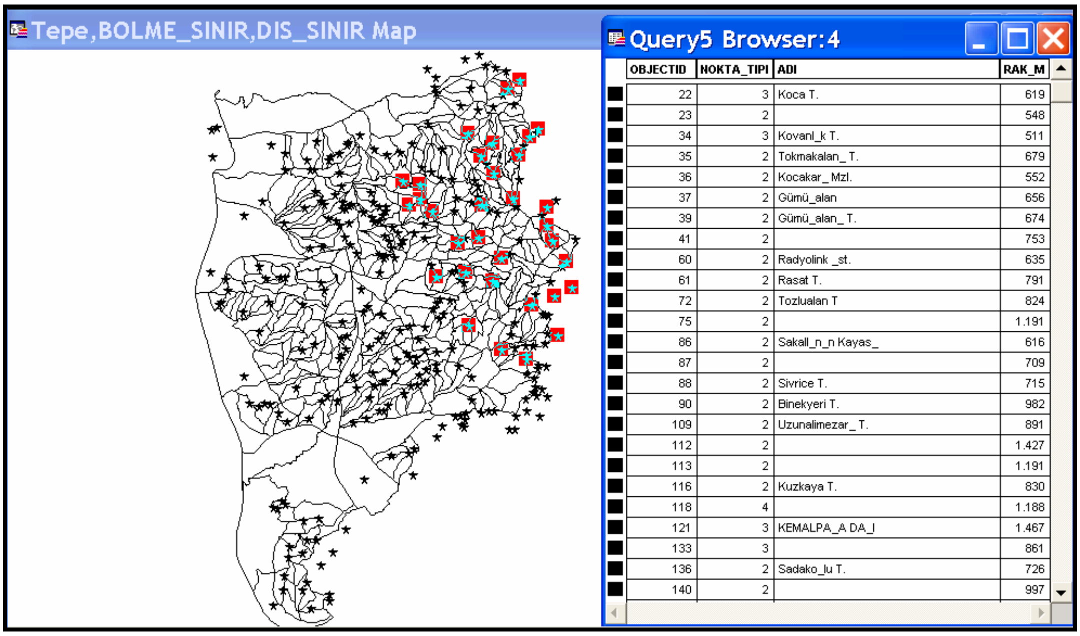

Figure 2.9 Altitude query of hills greater than 500 meters (Source, Author).

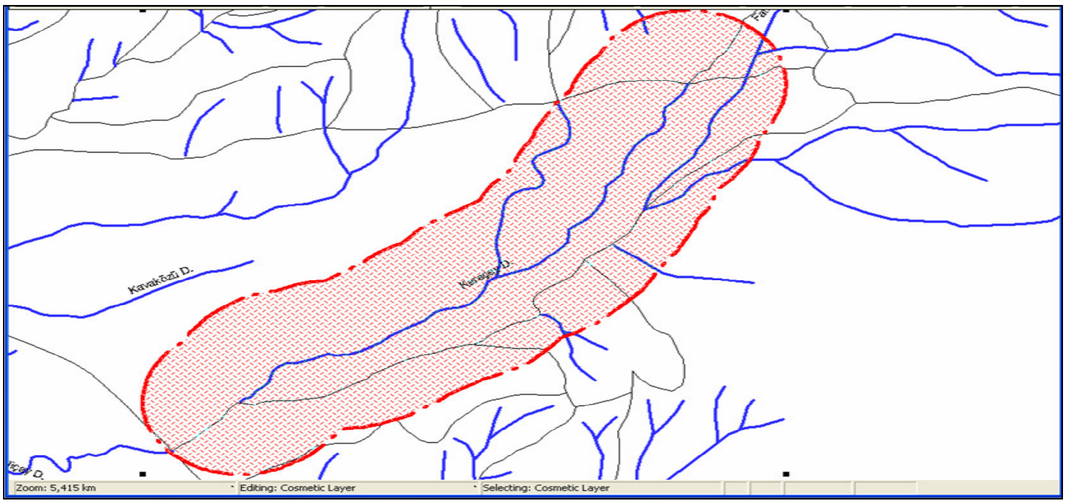

Figure 2.10 Buffer zone generation that identifies all areas up to 500 meters along Karaçay Stream in İzmir Forest Administration Chief Office Forest Boundary Map (Source, Author).

It is stated by Heywood, Cornelius, & Carver (2002) that perhaps the key GIS analysis function is the ability to integrate data from two sources using map overlay. With GIS it is possible to take two different thematic map layers of the same area and overlay them one on the top of the other to form a new layer.

Map overlay has many applications. In visual overlaying, map overlays can be used for the visual comparison of data layers. Visual overlays allow the user to view spatial relationships between the various layers in graphical form rather than seeking specific mathematical relationships. The visual display of these overlays doesn't create a new layer in the database, it simply provides visual cues of the relationships between them. For example, results of the hotel query, 'Where are all the luxury hotels?' may be overlaid on a map of road network to give some spatial context to the results. In this case no new data are generated (Heywood, Cornelius, & Carver, 2002; Kleynhans & Queen, 1999).

GIS can build map layers and evaluate relationships between them. Arithmetic and logical overlay operations are part of all GIS packages. Arithmetic overlay includes addition, subtraction, division and multiplication of each value in a data layer by the value in the corresponding location in a second layer. These arithmetic operations are done to combine two or more map layers. A logical overlay involves finding those area where a specified set of conditions occur (or don't occur) together. For example, desirable areas for cottages might be defined as those areas that have a forest vevetation cover, have well-drained soils and have a south-facing exposure. If vegetation, soils and exposure are represented as seperate data layers in GIS, to identify locations where these conditions occur together a logical overlay operation can be used (Aronoff, 1995).

Logical overlay superimposes layers using logical functions and store the results in the GIS database as new layers of data. The relationship is determined by combining various data layers to create a composite data set. Because the layers have already been registered, they can be accurately placed over one another. In a typical GIS, the analysis may require that data from existing layers be combined to create new data or map layers. For example, streams (lines), and deer sightings (points) can be combined with forest stands (polygons) to cretae a new database that reveals the spatial relationships between all three in the form of habitat quality (Kleynhans & Queen, 1999).

Another analytical function of GIS is network analysis. In the context of GIS a network is a set of linear features that are interconnected and are commonly constituted to evaluate alternatives for the purpose of route optimization and resource allocation. This means locating the best route between two points (e.g., timber transport routes) or selecting service zones (e.g., fire service zones). Common examples of networks include highways, railways, rivers, transportation routes and utility distribution system (e.g., electricity, telephone, water supply). There are several network-type problems, including identifying shortest paths, travelling sales person problem, allocating modelling and route tracing. For example an analyst may concern with the finding the shortest route from fire station to fire sensitive areas, routing waste collection vehicles and so on (Heywood, Cornelius, & Carver, 2002; Kleynhans & Queen, 1999; Lo & Yeung, 2002).

Route optimization applications range from emergency routing of ambulance, fire and police vehicles to routing of bus services, mail delivery and municipal garbage collection. A common resource application is the division of of metropolitan area into zones that can be efficiently serviced by police and fire stations (Aronoff, 1995).

Basic components of network analyses are summarized by Aronoff (1995) as:

- A set of resources, such as goods to be delivered
- One or more locations where the resources are located, such as warehouse wher the goods are stored.
- A set of constraints that limit meeting of an objective, such as the maximum speed that vehicles can travel.

In the context of surface analysis the term digital terrain model (DTM) and digital elevation model (DEM) must be explained. DTM and DEM have developed that refer to digital elevation data and its derivatives. In GIS topography of land surface can be represented by digital elevation data. The term topography refers to the surface characteristics. The topography of a land area refers to the hills, valley and plains of which it is comprised. Digital elevation data are a set of measurements for locations distributed over land surface. They are used to analyze topography of an area (such as, surface features). Digital elevation data are used in engineering, planning and military applications (Aronoff, 1995).

DTM is used to explain a digital data set which is used to model a surface representing height data. That is, it is a digital model of topographic surface using height, slope, aspect information and other topographic features. To model a surface accurately it is necessary to store an infinite number of observations. Because this is impossible, a surface model approximates a continuous surface using a finite number of observations. Thus an appropriate number of observations must be selected, together with their geographical location. DEM is a data file containing an array of elevation values (Aronoff, 1995; Heywood, Cornelius, & Carver, 2002).

The two terrain parameters commonly used are slope and aspect. Slope is the rate of change of elevation. It is the steepness or gradient of a unit of terrain, usually measured as an angle in degrees or as a percentage. Aspect is the direction that a unit of terrain (or surface) faces, and expressed in degrees from the north (Heywood, Cornelius, & Carver, 2002).

One of the common uses of DTMs is visibility analysis, which is an identification of terrain areas that can be seen from a particular point on a terrain surface. For example, visibilty analysis could be used to determine resort areas that would be visible from the top of the proposed new ski piste. In visibility analysis, location of the observer is connected to each possible target location in the terrain (i.e., a line is drawn from the observer at the top of the ski piste to all other locations in the area). The line is followed from each target back to observer, looking for the locations that are higher. Higher points will obscure what is behind them. Thus through line tracing viewshed map, a map resulting from a visibility analysis showing all the locations visible from a specified viewpoint, can be built (Heywood, Cornelius, & Carver, 2002).

Statistical analysis can also be done with GIS. Descriptive statistics can be used to describe distribution of spatail phenomena. For example, a histogram may be used to show the distribution of land parcels with different sizes. Prescriptive statistics are used to ask ‘what if?’questions. They help with the prediction of what might happen in a particular situation. Predictive statistics are used to look at relationships between spatial phenomena. For example, to look at relationship between altitude and vegetation type regression analysis might be used. Geographical datasets of altitude and vegetation type can be overlaid in GIS to provide a scatterplot of paired observations that show the relationship between dependent variable (vegetation) and the independent variable (altitude) (Heywood, Cornelius, & Carver, 2002).

Figure 2.11 shows calculated statistics of selected compartment in İzmir Forest Administration Chief Offices.

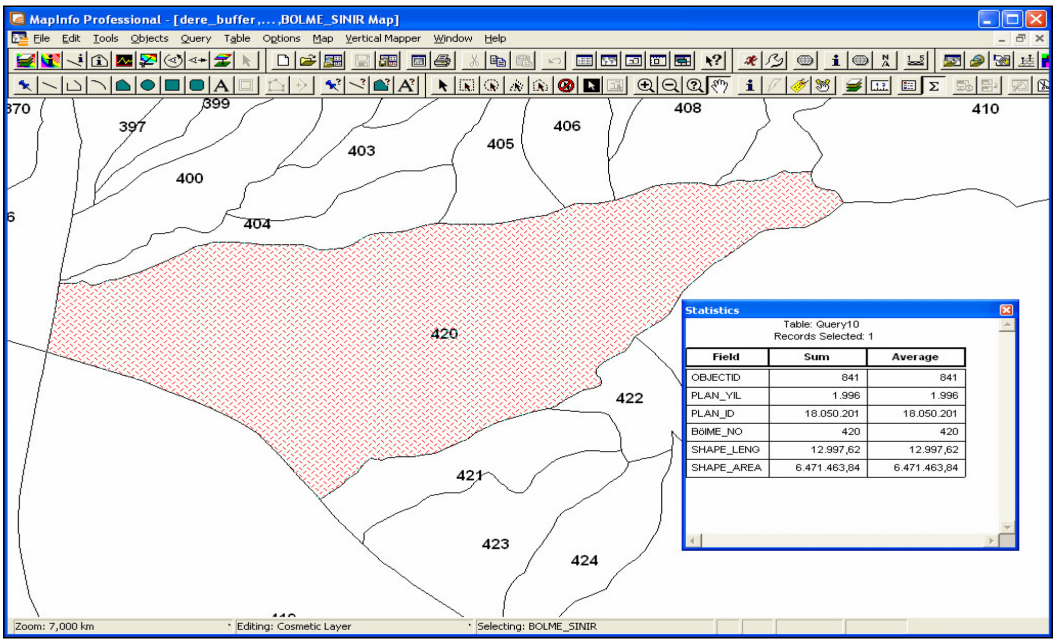

Figure 2.11 Statistical information of compartment 420 in İzmir Forest Administration Chief Office (Source, Author).

Other functions of GIS can be summarized as, transformation between map projections, edge matching, Thiessen polygons, interpolation, reclassification, viewshed analysis.

2.2.6 Importance of GIS

GIS has not only made the production and analysis of geographic information more efficient, it is changing the way geographic information is perceived and used. It is a technology that makes geographic data more easily shaped by the user into form best-suited to the application at hand (Aronoff, 1995).

GIS stores information about world as a collection of thematic layers that can be linked together by geography. This simple but extremely powerful and versatile concept has proven invaluable for solving many real-world problems from tracking delivery vehicles, to recording details of planning applications (Lang, 2001)

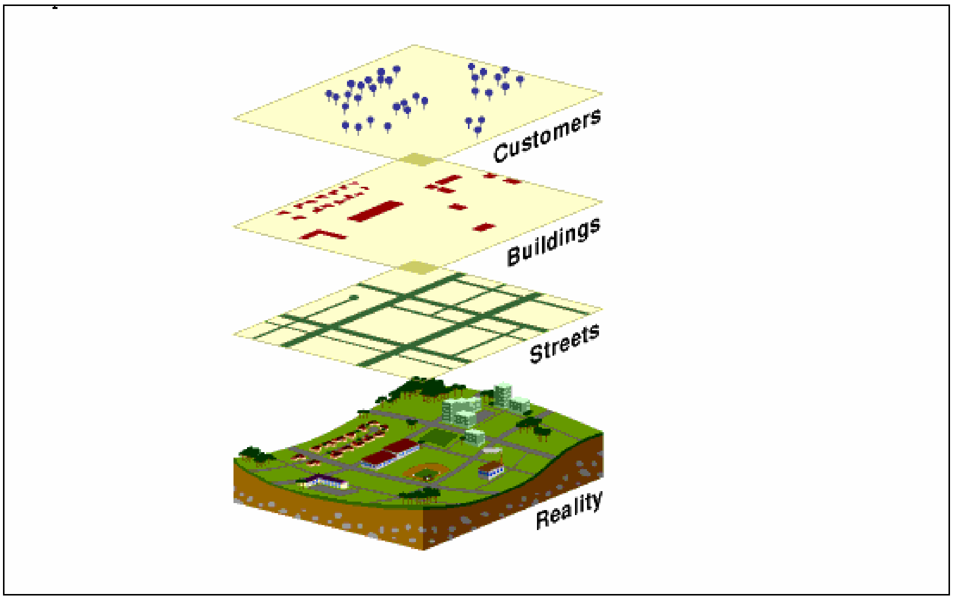

Figure 2.12 Different thematic layers (Lang, 2001).

Figure 2.12 shows different thematic layers. By overlaying streets, buildings and customers we obtain reality.

As stated by Aronoff (1995), the traditional map is like a snapshot of geographic data from which it was compiled. It represents a set of geographic information, usually at a single point in time. The map is updated at infrequent intervals, because of the time and cost to produce an updated version. In a GIS, the storage of the data is independent of mode of presentation. The physical map becomes a relatively inexpensive output product that can be generated quickly and customized for a single application. In addition, geographic database used to produce the map can be continuously updated.

Unlike to a paper map, a GIS map can combine many layers of information. To use a paper map, all we must do is to unfold it. The cities are represented by little dots or circles, the roads by black lines, the mountain peaks by tiny triangles, and the lakes by small blue areas. As on the paper map, a digital map created by GIS also have dots, or points that represent features on the map such as cities; lines that represent features such as roads. The difference is that this information comes from a database and is shown only the user chooses to show it.

In GIS the database stores where the point is located, how the long road is, and even how many square miles a lake occupies. Each piece of information in the GIS map bases on a layer, and the user turn on or off the layers according to their needs. One layer could be made up of all the roads in an area. Another could represent all the lakes in the same area. Yet another could represent all the cities.

With GIS we can turn on or off map layers according to our purpose as shown in Figure 2.13 and Figure 2.14. In Figure 2.13, there are three layers, Nokta, Tepe and Bölme Sınır. Supposing that researcher is interesed in Tepe and Bölme Sınır and wants to see only these layers. When Nokta layer is turned off Figure 2.14 is obtained.

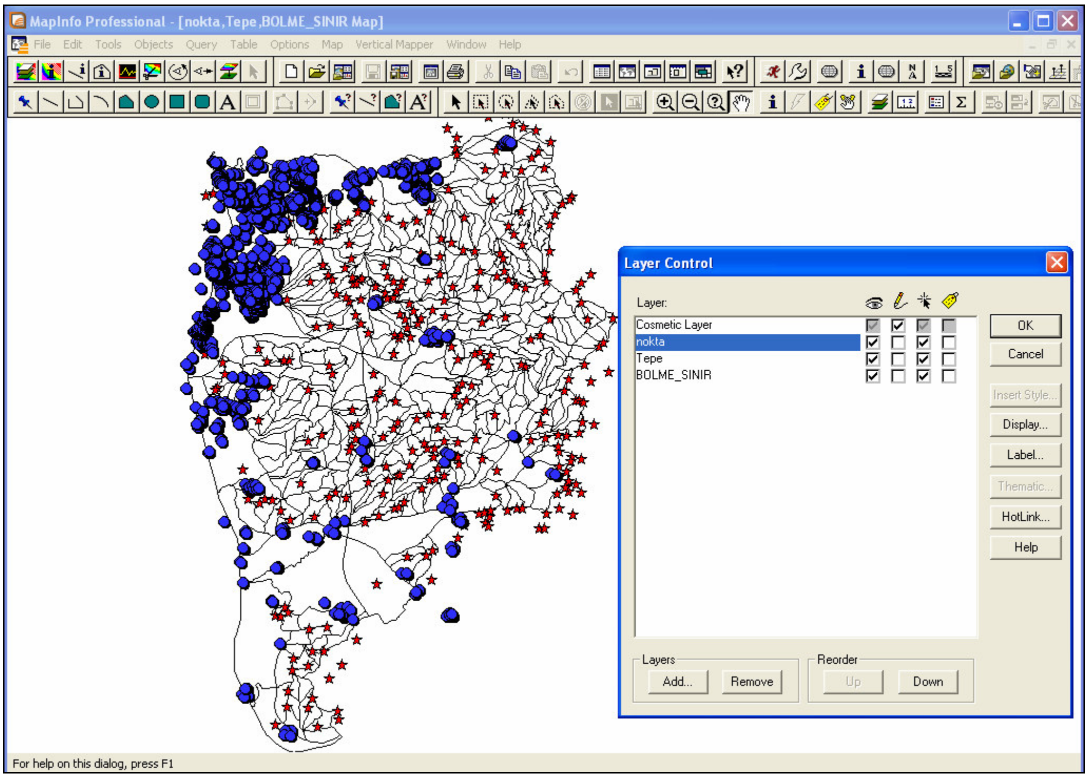

Figure 2.13 İzmir Forest Administration Chief Office map with different thematic layer (Source, Author).

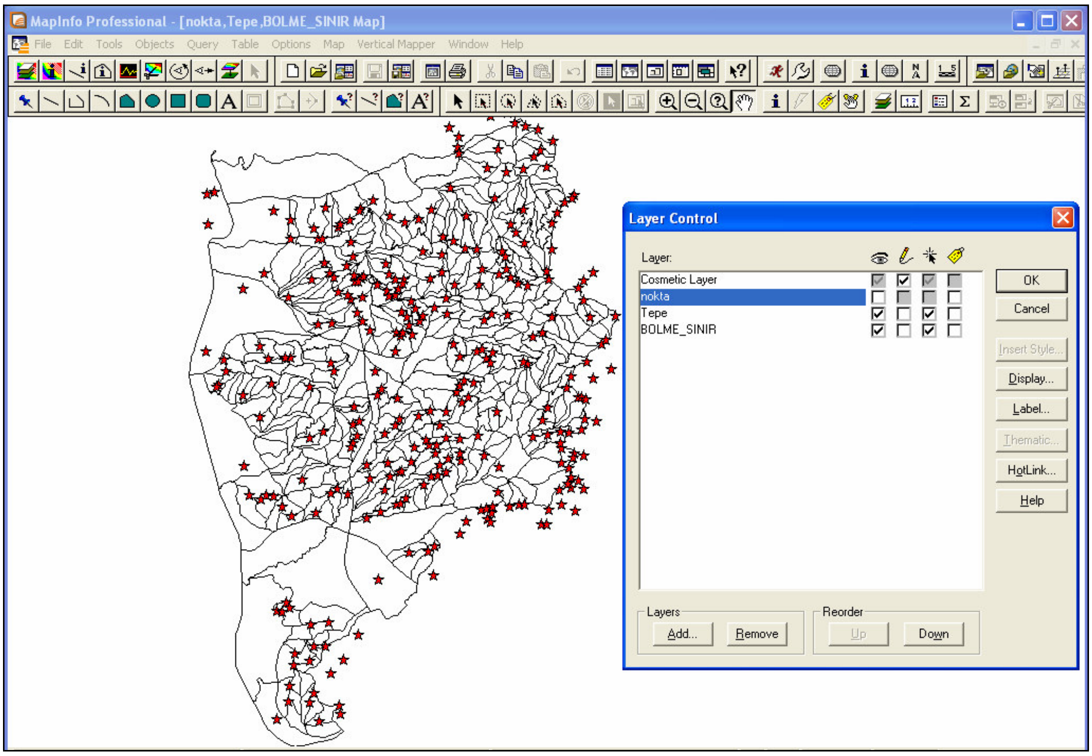

Figure 2.14 İzmir Forest Administration Chief Office Forest Boundary map with only Tepe and Bölme sınır layers (Source, Author).

GIS integrates spatial and other kinds of information within a single system. By putting maps and other kinds of spatial and non-spatial information into digital form, GIS allows us to manipulate and display geographical knowledge in new and exciting ways. GIS make connections between activities based on geographic proximity. Looking at data geographically can often suggest new insights, explanations. For example we can link toxic waste records with school locations through geographic proximity. Furthermore site selection procedure can also benefit from appopriate use of GIS. Classification function of GIS is one of the GIS capabilities for searching suitable sites (Lang, 2001; Vatalis & Manoliadis, 2002).

Main difference between GIS and computer cartography is their primary goals. Computer cartography has a primary goal of producing maps. Systems have advanced tools for map layout, placement of labels, large symbol and font libraries. However it is not an analytical tool. Therefore unlike data for GIS, cartographic data does not need to be stored in ways which allow, for example, analysis of relationships between different themes such as population density and housing prices.

Rather than locking researchers into a single representation, GIS could serve as a toolkit for estimating and exploring alternative geographic representations and their analytical possibilities for a given geographic phenomenon or problem. Spatial analysis capabilities of the computer based GIS distinguish it from related graphics-oriented systems like computer-aided design and drafting. The analysis of complex, multiple spatial and non-spatial data sets in an integrated manner constitute the major part of a GIS's capabilities. This function can not be done effectively with manual methods or with computer-aided design and drafting systems (Aronoff, 1995; Miller & Wentz, 2003).

Stated by Longley (2004) that, the wide adoption of GIS made traditional procedures of two dimensional paper map production obselete by replacing paper base mapping with digital framework data. But a GIS is more than digital encoding of paper maps. It has profound effects through spatial analysis. GIS also take into account digital representation across time and space.

2.2.7 Application Areas of GIS

Human societies have become increasingly dependent for their well-being on the ability to collect and analyze geographic information. The world becoming more crowded and resources are becoming scarcer. A new urban subdivision or a waste disposal sites are projects scrutinized by diverse regulatory agencies and frequently subject to public opposition. At the international scale, nuclear fallout, acid rain, toxic chemicals and deforestation have become widely recognized problems that direcly affect economic and social well-being of the global human population. Geographic Information Systems are a powerful resource for analyzing the interrelated systems involved in these types of problems. They provide flexible methods for exploring relationships among geographic data assisting experts from diverse fields in gathering their knowledge to solve complex problems (Aronoff, 1995).

Although GIS have been used for several years in the natural resources, forestry and environmental studies only recently they have begun to be used for a broader array of business and management functions such as logistics, site and facilities management, marketing, decision making and planning. The reason businesses and public sector organizations have begun to use GIS is, much of the data used by them include significant spatial component. Because of this reason, an increasing number of businesses have begun to make substantial use of GIS for a variety of routine decision support and analysis applications (Mennecke, 1997).

The use of GIS as a management tool has increased especially in the late 20th century. GIS has facilitated procedures which are once burdensome by simplifying exchange of data, spatial data management and modelling.

Some of the application areas of GIS are summarized by Heywood, Cornelius,& Carver (2002) and Lo & Yeung (2002) as follows:

Socio-economic/government activity applications:

- Federal government- national topographic mapping, resource and environmental management, population census, election and voting.
- State/provincial government- land and resource management, highway planning and management.
- Local/municipal government- land registration and property assesment, water and wastewater services.
- Health
- Local government
- Transport planning- roads selection for goods delivery, public transit, vehicle tracking
- Urban management

Commerce and business activity applications:

- Market share analysis
- Banking and insurance
- Real estate- sales and renting services, building management
- Direct marketing
- Target marketing
- Retail site selection

Environmental management:

- Landfill site selection
- Mining and mineral exploration
- Pollution monitoring

- Forestry- forest resource ınventory, harvest planning, wildlife management and conservation
- Flood plains management
- Agricultural land management
- Water quality management

2.3 GIS as a Decison Support System

A Decision Support System is commonly defined as computer application which '…assists management decision making by combining data, sophisticated analytical models and tools, and user-friendly software into a single powerful system…'. DSS have proven helpful in a wide range of fields, including business planning, medical diagnosis, and transportation (e.g. our air traffic control system). In the forestry sector, they have been used extensively for timber harvest scheduling (Gordon, Johnson, Reynolds, Crist, & Brown, 2004).

The ultimate objective of a Decision Support System (DSS) is to assist decision-makers (e.g., managers, planners, public officials, scientists, and the general public) in planning and the decision-making processes by giving the decision-makers useful and scientific information. A DSS may consist of a number of subsystems, each with a specific task. In forest ecosystem management (FEM), a DSS may contain a user interface, database, geographical information system (GIS), knowledge base, simulation and optimization models, data visualization and decision methods (Potter, Liu, Deng, & Rauscher, 2000).

Thousands of new GIS-based systems have and are currently being installed. Many of them are playing an important role in decision making at various level, both in government and private organizations. Decision making is a complex process, influenced by several factors. GIS applications can not make decision for people, but it is able to provide many simulated results, that can help the decision makers to make the decision and answer some of the questions such as (Diah, 1997):

- Where is the most polluted area in the Industrial Area and how much is the total?
- Where is the exact location of the polluted rivers and total of factory along the river?

By looking at these questions we can see the important roles played by GIS technology. The main advantage of GIS is its ability to manage and integrate with the existing database. Therefore, at any time it is possible to see not only spatial data but also databases.

GIS is gaining importance and widespread acceptance as a tool for decision support in land, infrastructure, resources, environmental management and spatial analysis, and in urban and regional development planning. With the development of GIS, environmental and natural resource managers increasingly have at their disposal information systems in which data are more readily accesible, more easily combined and more flexibly modified to meet the needs of environmental and natural decision making. Thus the decision process is expected to be better informed (Sharifi, 2002).

GIS help decision makers by gathering small pieces of information as a whole and showing them the big picture. In this regard GIS can be used as a decision making tool. GIS combine and analyze data from a wide range of different resources. The integration capability of GIS allows to pull together different datasets and to create a complete picture of a situation. This enables organizations to make better and informed decisions based on all relevant factors. An important benefit of GIS is its ability to integrate and analyze spatial data to support decision making process. The use of a common database in GIS eliminates the differences in presentation, evaluation and decision making based on using different types of data (Shamsi, 2005).

GIS related research is beginning to make an appearance at conferences associated with DSS. For example a GIS based session is organized at the annual Hawaii International Conference on System Sciences, a conference associated with

DSS rather than GIS based applications. There is increasing evidence of interest in GIS at Operations Research conferences, where applications integrating GIS and Operations Research techniques are discussed. Academic journals associated with the DSS field are beginning to publish GIS related papers. For example a recent paper by Crossland, Wynne and Perkins (1995) presented empirical evidence of the usefulness of a spatial approach to decision making. GIS techniques are beginning to have an impact on DSS applications. The survey by Eom, Lee and Kim (1993) identified marketing and routing as important areas of DSS application. These fields are recognised as areas of GIS application. Figure 2.15 shows DSS concept (Terfai & Schrimpf, n.d.).

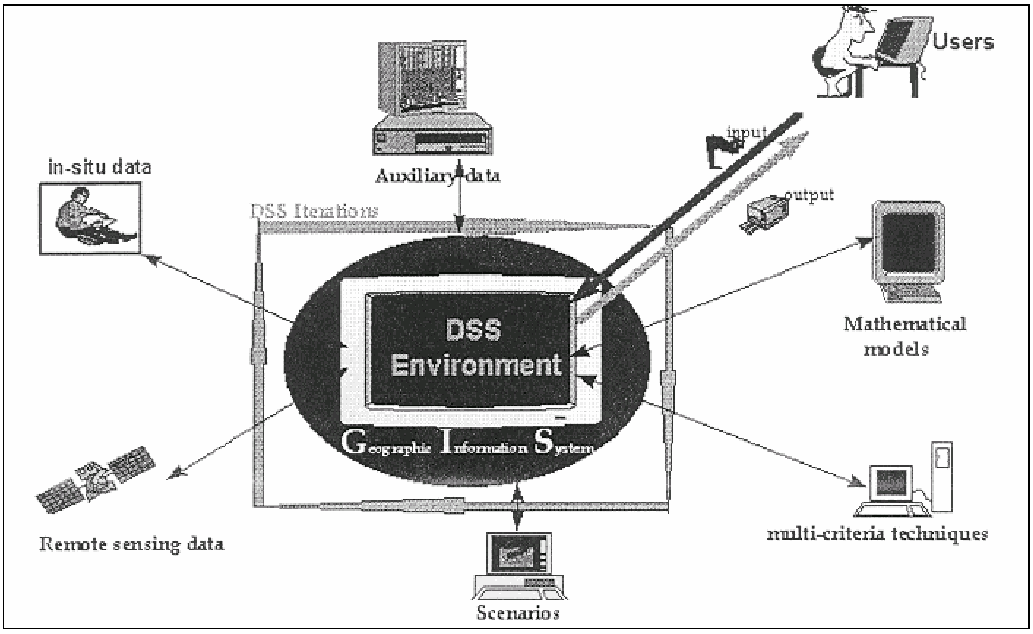

Figure 2.15 Decision support system concept (Terfai & Schrimpf, n.d.)

2.4 Fundamentals of Remote Sensing (RS)

Remote sensing (RS) is the analysis and interpretation of images gathered through techniques that don't require direct contact with the subject. It can be defined as the science of deriving information about an object without actually coming into contact with it. Remote sensing may also be defined as the detection, recognition, or evaluation of objects through distant sensing or recording devices. In this definition the most striking features of remote sensing are the conversion of the collected data to information and data interpretation which are represented by the words of 'deriving information' and 'detection, recognition or evaluation'. As stated by the developers of remote sensing, it is both technology and methodology. The term remote sensing is strongly associated with Earth-observing satellite technology. In general terms, remote sensing include all sensing with distant instruments Remote sensing uses aerial or space photographs, electronic scanners and other devices to gather data about earth's surface and subsurface. In the last two decades remote sensing has utilized digital techniques for collecting and processing spatial data. Remote sensing products have provided important input to geographic information systems (Antenucci et al., 1991; Franklin, 2001).

In the definition of remote sensing two different activities are involved. One of them is data collection by sensors designed to detect electromagnetic energy from positions on ground-based, aerial and satellite platforms. The other is the method of interpreting those data (Franklin, 2001).

As stated by Lo & Yeung (2002), remote sensing is not only a data collection process but also data analysis. In data analysis there are methods and processes to extract meaningful spatial information from remote sensing data to be direct input to GIS. The advantage of remote sensing is its ability to provide bird's eye view or synoptic view of study area. But adoption of remote sensing doesn't eliminate in situ data collection, it only helps minimization of in situ data collection. Because in situ data collection is needed to verify accuracy of remote sensing data collected.

Remote sensing systems can be classified as passive and active. Passive remote sensing systems sample emitted and reflected radiation from ground surfaces when the energy source is independent of the recording instrument. Camera is the example of passive remore sensing and without illumination from the sun no photographs can be taken with camera. On the other hand active remote sensing systems can send out their own electro magnetic radiation at a specified wavelength to the ground and then sample the portion reflected back to the detecting devices as in the example of imaging radar (Lo & Yeung, 2002).

Lo & Yeung (2002), mentioned that passive remote sensing systems can be further subdivided into analog and digital types. Aerial camera, which can produce high quality aerial photographs for topographic and thematic mapping at varying scales, is passive analog remote sensing system. Aerial photographs are very important source of data for GIS applications. Passive digital remote sensing systems contain multispectral scannsers, linear and area array scanners and spectroradiometers. But digital cameras are not commonly used in aerial photographic missions for topographic mapping purposes because the camera format is smaller and spatial resolution is much poorer than those of the analog aerial cameras.

Remote sensing systems can be classified on the basis of type of imaging platform used. Both aerial and space platforms have been used to obtain geographic data. Aerial platforms utilize small aircraft while space platforms include space shuttles and satellites (Lo & Yeung, 2002).

2.4.1 Growth of RS

The development of remote sensing as we know it today began with aerial photography. The term remote sensing was coined by geographers in the Office of Naval Research of the United States in the 1960s. It refers to the acquisition of informaton about an object without physical contact. The term usually refers to the gathering and processing of information about Earth's environment, particularly its natural and cultural resources, through the use of photographs and related data acquired from an aircraft or a satellite (Lo & Yeung, 2002).

The remote sensing technology originated from interpretation of aerial photographs. Aerial photography was the first method of remote sensing and interpretation of aerial photographs had been operational since the First World War. Aerial photography is the capturing of images from a position above the Earth's surface, without contact with the interested objects. It is a snapshot of the Earth at a particular instant in time and differs from a map, which is a model of the Earth's surface and contains only a selection of data. Aerial photograph contains mass of data and to make effective use of information portrayed it must be interpreted. In 1968 aerial photointerpretation drew attention of scientists in many disciplines and this young science was sharply challenged. New imagery and sensing techniques emerged based on various computer technologies, engineering designs and developments in sensor science. The use of term remote sensing began as a way of describing some of the new imagery and analysis techniques acquired alongside aerial photography (Franklin, 2001; Heywood, Cornelius, & Carver, 2002).

The use of aerial photography allows the collection of data describing the continuous change in phenomena from one place to another. This type of remote sensing relies on the use of aircraft to carry a photographic device designed to sense and record portions of electromagnetic spectrum. The user may abstract information on land use, vegetation type, moisture or heat levels or other aspects of the landscape from the photograph. Aerial photograhs are useful especially in monitoring change because repeated photographs of the same area are relatively inexpensive and they are valuable data source for GIS because of their wide availability, low cost (compared with other remotely sensed images), wide area views, time-freezing ability and three-dimensional perspective (DeMers, 1997; Heywood, Cornelius, & Carver, 2002).

Aerial photography has been generally used to cover a small area such as a county area for map revision purposes. The photographic scale is usually large, not smaller than 1: 25.000 (Lo & Yeung, 2002).

Another type of remote sensing is satellite images. Unlike aerial photography satellite images cover a very large area in very small scale and hence revealing large spatial patterns in the landscape. Satellite images are collected by sensors and then sent to Earth as a series of electronic signals. There are large numbers of satellites orbiting the Earth continuously, collecting data and returning them to ground stations all over the world. Some satellites, such as Meteosat, are stationary with respect to the Earth while others orbit the Earth to provide full coverage over a period of few days, such as Landsat and SPOT (Heywood, Cornelius, & Carver, 2002).

As stated by Lo & Yeung (2002), to monitor Earth continuously and image it from pole to pole at a fixed interval of time, an unmanned polar orbiting satellite carrying a digital multispectral scanner system is preferred. The satellite altitude, which determines the frequency of the repeat cycle of satellite, varies from 700 to 900 km. Examples are, Landsat 1 through 3, Landsat 4 and 5, and most recently Landsat 7 which use multispectral scanner technology to obtain images of earth. Each Landsat scene covers an area of 185x185 km. Unlike aerial photography, satellite images cover a very large area of Earth in very small scale and reveal large spatial patterns in the landscape. Thus, in data collection aerial photography and satellite remote sensing complement each other. A common application of remote sensing images and aerial photograhs is land use and land cover mapping because human activities are best revealed by the use of land and the changes to the land cover that have occured.

2.4.2 RS and GIS Integration

The success of any GIS application depends on the quality of the geographic data used. Therefore it is important to collect high quality geographic data for input to GIS. Traditionally, environmental data can be collected directly in the field in situ methods. This type of data collection makes use of an instrument that measures a phenomenon directly in contact with the ground, such as the pH value of soil, the temperature of the water in a lake, the angle of a slope. Although human and instrument errors occur data collected in the field are normally regarded as high quality. In situ data collection can be expensive because it is labour-intensive and time consuming. The data collected from a distance are termed remotely sensed data. Today remote sensing is the preferred method to use if environmental data covering a large area are required for a GIS application (Lo &Yeung, 2002).

Most natural resource mapping is done using remote sensing. Aerial photographs are very important source of data for GIS applications. Aerial photography has been used to produce virtually all topographic maps and most forestry, geology, land use and soil maps. More recently, airborne radar and scanner data as well as satellite imagery are being used for these types of mapping applications. Remote sensing techniques are used extensively to gather measurements. Aircraft-based remote sensing measurements of gamma radiation and magnetism are used routinely for geological exploration and mapping. Satellite-based systems can measure phenomena that cover large, inaccessible areas and change continuosly over time (Aronoff, 1995; Heywood, Cornelius, & Carver, 2002).

The use of remote sensing data, such as satellite imageries and aerial photos, allows to map the variabilities of terrain properties, such as vegetation, water, geology, both in space and time. Satellite images give a synoptic overview and provide very useful environmental information, for a wide range of scales, from entire continents to detail of a few meters. Many types of disaster, such as floods, droughts, earthquakes, etc. have certain precursors that satellite can detect. Remote sensing also allows monitoring the event as it occurs (Smara, Belhadj-Aissa & Aissa, 2005).

For GIS, remotely sensed data offers many advantages. First, images are always available in digital form, so it is not a problem to transfer them to a computer. However, some processing is usually necessary to ensure integration with other data. Second, there is the opportunity to process images or use different wavebands for the collection of data to highlight features of particular interest, for instance water or vegetation. The repeated coverage of the Earth is another advantage, allowing the monitoring of change at regular intervals. Some advantages of remotely sensed data for GIS applications in natural resource management can be summarized as low cost relative to other sources of data, currency of images, accuracy, and completeness of data (Heywood, Cornelius, & Carver, 2002).

The need for integration is driven by the urgent necessity to make environmental choices. The complexity of environmental problems implies that there is a growing quantity of spatially referenced information to be considered and an increasing number of factors that can and should be addressed dealing with such complex problems. This is where integrating different techniques/methods such as Multiple Criteria Aid Decision, different types of data such as Remote Sensing Imagery Data and Spatial Analysis can provide great assistance in understanding, examining and managing environmental problems and, hopefully, in leading to the final decision (Terfai & Schrimpf, n.d.).

As Earth changes constantly, remote sensing from an orbital platform in space provides the easiest means to keep up the GIS database up to date. Remote sensing images and aerial photographs have to be interpreted or analyzed prior to useful data can be added to GIS database. Aerail photographs represent versatile, detailed and relatively inexpensive data source for many GIS applications. For instance, local governments may organize aerial coverage of their districts to monitor changes in the extent of building development. At a larger scale photographs can be used to provide data on drainage or vegetation conditions within individual parcels that could not be obtained from conventional topographic maps (Heywood, Cornelius, & Carver, 2002; Lo & Yeung, 2002).

The use of remote sensing as data sources is possible in GIS. Natural resource analysis and environmental assesment are among remote sensing applications. Many natural features can be determined by various remote sensing techniques, such as infrared photography.

As stated by Naesset (1997) that, many GIS software packages provide procedures for raster to vector conversion and vice versa. Therefore combined use of remotely sensed data and vector data is possible in GIS. GIS is a convenient tool for merging remotely sensed data and various kinds of other geo-referenced data.

CHAPTER THREE
OPERATIONS RESEARCH AND GIS IN FORESTRY

The third chapter firstly introduces forestry and then examines the forest management and sustainable forest management concepts. Following these introductions forestry in Turkey is overviewed. OR applications in forestry are discussed. RS and GIS integration in forestry in the world is examined. Finally OR and GIS integration in forestry is discussed. Figure 3.1 summarizes outline of this chapter.

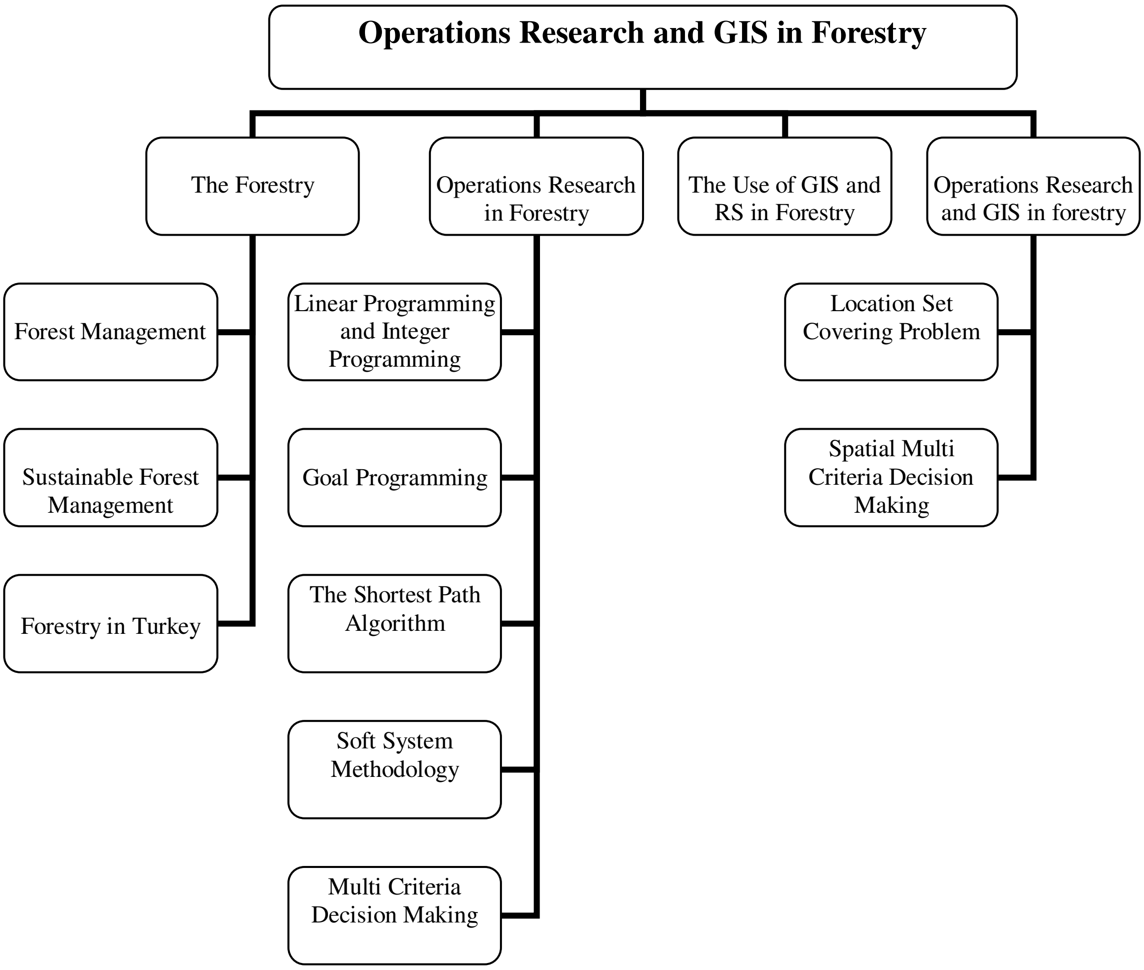

Figure 3.1 Outline of the third chapter.

3.1 The Forestry

Relation of human being with forests is as ancient as people's history. People have benefited from forests over the history and used forests to protect themselves to shelter and for fuelwood. Because of the necessity to carry on his life, relation of people with forest increased gradually over time. Forests provide not only raw material for wood processing industry but also habitat for wildlife, resources for water and soil conservation, oxygen and food chain. However, forestry face problems such as deforested areas, mismanaged forests, broken sructure and health, nonwarrantied sustainability, decreased biodiversity, and destructed forests. Furthermore, global warming and environmental pollution and fast growing industrialization have caused deforestation process to speed up. During the period 1990 to 1995, forests area in industrialized countries increased annually by about 1.75 million ha. At the same time, area covered by natural or seminatural forests in developing countries decreased every year by 13.7 million ha. During this period, the earth lost total of 56.3 million ha of forests, 0.33 % of total forest cover (Mısır & Başkent, 2002).

Forest managers and policymakers increasingly are involved with the interdependency of socioeconomic trends and changing forest landscapes. Increasing human populations and incomes, people's life-style choices and other socio-economic factors inevitably lead to greater demands for residental, commercial and industral building sites and conversion of some forestlands to developed uses. Resulting landscape changes can effet changes in forest goods and services that are valued by society, including long-term timber production, wildlife habitat, recreation and open spaces that contribute to people's quality of life (Kline & Alig, 2005).

Forestry encompasses the management of a wide range of natural resources. In addition to timber, forests provide resources such as grazing land for livestock, recreation areas, wildlife habitat and water supply resources. As a result, the public agencies responsible for forestry management typically have broad mandates. In this context, forest management involves management of harvesting, wildlife habitat, grazing leases, recreational areas, minig activities and the protection of endangered species and archaeological sites. Management of forest resources is a complex task due to their multi-functional nature. Therefore, forest management and planning problems usually involve decisions, which have to be made in the presence of multiple objectives. Forest ecology and forest management are dealing with ecosystems that develop over time. Models of forest growth and development are indispensable tools for understanding ecosystem behaviour (Aronoff, 1995; Kazana, Fawcett, & Mutch, 2003; Mohren, 2003).

Because of the increased demand for forest products and services multi-objective planning is necessary in forestry. In the past forests were managed to produce wood products. But management objectives shifted toward water conservation, prevention of soil erosion landscape conservation and recreation.

3.1.1 Forest Management

Forest ecosystems exhibit complex dynamics over time and space. Management of forest ecosystems involves the need to forecast future states of complex systems that are often undergoing structural changes. This in turn requires integration of quantitative science and engineering components with socio-political, regulatory, and economic considerations. The amount of data, information and knowledge involved in the management process is often overwhelming. Integrated decision support systems may help managers make consistently good decisions concerning forest ecosystem management (Potter, Liu, Deng, & Rauscher, 2000).

Forest management problems are multiscale and linked to society's need to measure, preserve and manage for multiple forest values. Population growth, climate change and human activities threaten the continued physical existence, biodiversity and functioning of forests. Compared to previous forest management approaches all new forest management strategies will require more record keeping, wider access to information and integration of new spatial information technologies, such as GIS, remote sensing, computer modeling and decision support systems. And major issue facing forest management is collection of data and interpretation of information extracted from those data. Thus remote sensing information needs to be integrated with other spatial and nonspatial data sets to form the information (Franklin, 2001).

Many forest management problems are result of management decisions applied to small areas. But there is a need to consider multiple scales, temporally and spatially, and remote sensing methods can provide these data. Increasing fragmentation caused by forest harvesting activities need to be monitored. To estimate net productive area is common problem among many timber producers. This problem can be overcome with multiscale and multitemporal remote sensing and accurate GIS database (Franklin, 2001).

Most forestry legislation stipulates that forest management must be conducted according to a general or strategic management plan. The need for a strategic or general forest plan is a common feature of forest management planning around the world (Harvey, Ngyuen-Xuan, Bergeron, Gauthier, & Leduc, 2003).

A forest management plan is a guide and a tool that help to make decisions, look at options, and plan for the future. Forest management planning is a process that helps to identify the resources and opportunities available on property and do planning for property. Forest management planning is a means of identifying what can be done to enhance and protect the values and aspects of forests. These aspects might include wildlife, recreation, aesthetics, timber, livestock ranching, inheritance values, and others (Perez, n.d.).

Hierarchical approach is very efficient means in tackling with forestry problems. In hierarchical approach seperate, but linked, planning models incorporating appropriate levels of spatial and temporal resolution are used. The first step in the process is strategic planning, involves determining the productive capability of the forest for the long term. The aim in this stage is, to determine the kinds of silvicultural interventions needed over time to produce a desired mix of benefits and outputs from the forest. Details about specific locations of activities or operational details are unnecessary at this level of analysis. At the tactical level of planning, the analyst must rationalize long term objectives and activity schedules with the physical realities of forest. At this stage geographic location of stands becomes important. Planning horizon for tactical planning is far shorter. Details become important at the operational level of planning. At this stage scheduling of activities goes from a periodic basis to a yearly or monthly basis and the planning horizon is reduced to a few years (Walters & Feunekes, 1994).

In general, planning begins with strategic policies, goals, and objectives, which are translated into tactical activity schedules, which in turn are rendered into specific operational actions on the ground. For instance, setting the level of the annual allowable cut (AAC), the amount of old-growth forest, and recreational opportunity priorities are all strategic decisions. Tactical planning takes these objectives and creates a schedule of management activities in space and over time that is most likely to achieve these goals. Such a schedule will typically project road building, and the sizes, locations, and timing of harvesting activities 2– 10 years into the future. The schedule of tactical activities is then used as the foundation from which operational planners create more specific plans involving the choice of harvesting options, and the design of silvicultural operations. Shortly, strategic level covers large areas and time horizons. Strategic plans allocate resources by zoning land use and setting sustainable targets. The tactical level operates within smaller areas and time frames, such as a single watershed for 5 to 20 years. Tactical plans schedule the order of activities, such as harvests and branch roads. Operational plans are the smallest planning unit, covering single activities for perhaps less than one year, detailing exactly how activities will take place (Andison, 2003; Boyland, 2003).

3.1.2 Sustainable Forest Management

The concept of sustainable forest management (SFM) arises from the notion of sustainable development that has gained increasing recognition worldwide since the late 1980s. Modern discussion of sustainability began with the Brundtland Commission’s (World Commision on Environment and Development, WCED 1987) statement, ‘Sustainable development is development that meet the needs of the present without compromising the ability of future generations to meet their own needs’. In the last decade of the 20th century, many conferences, discussion papers and books explored the several dimensions of sustainable development as applied to forestry. The principle of sustainability was adopted in March of 1992 as part of Canada’s National Forest Strategy (CFS) by the Canadian Council of Forest Ministers (CCFM) The idea of SFM has evolved over the past three centuries, originally in central Europe. It concerns providing products and services that are needed by present forest stakeholders without endangering the ability of future generations to get these products and services. SFM generally refers to the ways and processes of managing forest resources to meet society’s varied needs, today and tomorrow, without compromising the ecological capacity and the renewal potential of the forest resource base (Adomowicz & Burton, 2003; Gamborg &Larsen, 2005; Hickey&Innes, 2005; Wang, 2004).

The fundamentals of sustainability can be broken into three relatively simple concepts: equity, wealth and substitutability. First, sustainability implies a form of equity over all future generations. In this definition sustainability implies that future generations will be provided an environment that is no worse than the one we enjoy today. Interpreted in an ecological sense, this means that ecological conditions will not be degraded to the point that productive capacity is reduced, species are lost or irreversible losses occur. Social and economic sustainability have also been interpreted in similar fashion, that is, the productive capacity of the economic system and function of social system in resolving conflict and developing institutions, will be no worse in the future than it is today (Adomowicz &Burton, 2003).

Second component of sustainability is wealth. In sustainability wealth is considered in terms of environmental assets and services as well as community attributes that contribute to people’s well-being. An approach to assesing wealth is to consider the capital that generates wealth such as human capital (knowledge), nature capital (forests, biodiversity), constructed capital (infrastructure) (Adomowicz & Burton, 2003).

Substitutability is the third component of sustainability. We must answer following questions to understand the meaning of sustainability: Can we substitute constructed capital for natural capital to enhance wealth? To what extent such substitutions occur? Current discussions of sustainability raise concerns about the irreversible loss of species, culture and knowledge. Are there substitutes for these items? (Adomowicz & Burton, 2003).

Conservation of forest ecosystems, protection of soil and climate, production of timber and other products, and the provision of recreational and other social comforts are considered as important concepts in sustainable forest development. All these functions are interdependent, e.g. protecion function is an integral part of production function (Gamborg & Larsen, 2005).

Generally SFM aims to ensure securing continuum of forest products and services while meeting society's present demands for forest products and services.

3.1.3 The Forestry in Turkey

According to forest inventory evaluation results forests cover 26.6 percent (20.703.122 ha) and 27.2 percent (21.188.747 ha) of Turkey's land area in 1997 and 2004, respectively. While productive forests area is 10.548.000 ha in 1997, it increased to 10.621.221 ha in 2004 (Orman varlığımız, n.d.).

Approximately 91.6% of forests is natural forest and the remaining 8.4% consists of plantations. Forests, with high biodiversity value, are generally located on mountainous areas. The country has 9000 plant species most of which are located in forest areas. Forests in Turkey are also home to most of 120 mammals, 454 birds and 93 reptiles found in the Country. Almost half of the country's total forests are unproductive and needs to be rehabilitated and protected, only 51% of the forest area is productive. Deciduous forests are prevalent at moderate elevations along northern Turkey. Forested areas in the country are not evenly distributed and some parts of the country are totally poor of forest resources. By Forest Law Turkish forests are divided into three categories according to their functions. These are: Protection forests, national parks and production forests. Protection forests cover around 355.545 ha, being dispersed over 52 different sites. They perform various functions such as, erosion prevention, climatic and society health defence (Forestry Outlook Study for Turkey, 2005; Türker, Pak, & Öztürk, 2005).

Currently, 99% of forests and their resources are still owned by the state and are under the control of the Treasury. The protection, preservation and management of these areas are supervised by the General Directorate of Forestry (GDF). The remaining 1% of forest land is owned by private institutions. Forest management plans are prepared and implemented by the GDF, aim principally at conservation of existing forest resources and at development of forest tree vegetation and adequate wood production (Forestry Outlook Study for Turkey, 2005; Türker, Pak, & Öztürk, 2005).

Most of the forests in Turkey are located in fire sensitive areas. Forest fire issues are prime concern of the public. Therefore GDF allocates most of its capital and human resources to forest fire management. For the last ten years, yearly average number of forest fires is 2.063, and yearly average burned area is 12.581 ha. Most of the causes are human rooted. Cause of more than half of the fires is ignorance (Forestry Outlook Study for Turkey, 2005).

There are about 50 harmful insects that affect 2 million ha of forest in Turkey. GDF continuously monitors pest and diseases and combats 500.000-800.000 ha infected area each year, through mechanic, chemical, bio-technique and biological methods. The annual cost of this work is around 2-4 million USA$ (Forestry Outlook Study for Turkey, 2005).

Approximately half of the total forest area is degraded, mainly due forest fires, overgrazing and illegal settlement. Between 1937 and 1999, forest fires affected about 1.5 million hectares. Grazing is one of the major threats to forests, causing serious degradation and increases soil erosion especially on step slopes. Illicit woodcutting and encroachment for farming are other important causes of degradation and productivity decrease. Other challange facing forests is, poverty in forest areas. The 15% of Turkish population lives in or around forests, distributed among about 20.080 villages. Many of these villages are situated in remote areas, far from markets and hindered by generally outdated means of transport and inadequate communications, health care and education services and they are far poorer than the national average. Forest villagers depend on forest for wood used for heating and cooking, and for animal fodder and grazing. A large share of wood is illicitly cut by the villagers (Forestry Outlook Study for Turkey, 2005; Türker, Pak, & Öztürk, 2005).

Other challenge for the sustainability of forest management area is the lack of clear ownership boundaries in forest areas. Vague boundaries have led to a multitude of ongoing disputes among stakeholders. Disputes have been exacerbated by revisions of the legal definition of forest, whereby revisions are followed by removal of areas from the forest regime, thereby necessitating renewal of cadastral surveys. Many stakeholders believe that these changes in legal definition serve rapid urban expansion into forest areas (Forestry Outlook Study for Turkey, 2005).

Forestry practices are carried out by the national forestry plan in Turkey and forests are managed for a single objective, wood production. Forest management plan is the physical plan that determines the amount of wood for harvest over time. As a result of this, 97% of Turkey forests are managed as wood production and the rest is classified as National Park. But multi-objective planning must be contained in contemporary forest management planning Multi-objective planning must involve wood production, nonwood production and social values. And in this process GIS must be used in every step from data collecting, the first level of multi-objective planning, to preparing forest value map (Mısır & Başkent, 2002).

Forest management planning system is a very prestigious discipline in forestry. All forests have to be managed according to management plans. Since the first management plan in 1917, the planning system has evolved in terms of techniques used. Several methods used, among them Mut-Gazipaşa Model has resulted in satisfactory outputs but the model applied to certain places and it has not been replicated. German GTZ Project aimed to solve silvicultural problems of broadleaved forests and gained a lot of support from forestry quartes, but intense inventory and cost of planning has brought about difficulties in expanding the implementation. Another model was developed through a Finnish Project, and this model introduced effective use of GIS in planning. GIS model was developed on GTZ planning system and now the works are continuing to use it in classic planning system (Forestry Outlook Study for Turkey, 2005)

Development in the technologies will effectively contribute to forestry. Particularly GIS technology is developing very fast. In the next 20 years it is expected that GIS will be expanded largely due to its low cost, easy use, and its ability as a tool in effective planning, management, conservation and sustainable development of forest resources. When combined with the developments in communication systems and Internet, the informational need of stakeholders as well as public will largely be met (Forestry Outlook Study for Turkey, 2005)

According to priorities and strategies in Turkish forestry set towards 2023, the aim of strategy is: 'Conservation, development, expansion and sustainable management of forests in Turkey'. To implement this strategy several objectives and goals are determined. Among them GIS related objectives and goals are: In solution of ownership conflicts, GIS based forest land registry, all forest land will be registered and recorded to a GIS system, will be developed. To improve information on, and awareness of forestry issues, GIS and satellite technology will be used widely, Databases will be established and made accessible to public, Internet applications will be expanded comprehensively (Forestry Outlook Study for Turkey, 2005).

3.2 Operations Research in Forestry

Considerations of alternative uses of the forest and its product nearly always raises the question, 'What is the best way?'. Because of the number of alternatives, the complexity of product interactions, and the conflicting desires of the public, an optimum answer may be impossible to find. Some help has been provided for forest managers by the decision tool known as Operations Research (OR). Over the past few decades, several factors have altered the practice of forest land management. As population and resource utilization increase, many forest-based outputs are approaching or exceeding sustainable levels of use. People are increasingly aware of the need to preserve the forest ecosystem, to sustain threatened and endangered species, wildlife habitat, scenic beauty and biodiversity. As a result forest land managers, especially on public lands, are shifting their emphasis from the production of goods and services towards the maintenance of forest health, biodiversity, and productivity. On private timberlands this trend is tempered by need to remain competitive in the global market place (Sianturi, 2000).

Both classes of ownership have created new challenges for the OR community. On public land, the shift toward an ecology system model has necessitated the development of a new set of OR models that incorporate spatial relationship, ecological relationship, resource protection issues, and consideration of a wide spectrum of natural resources beyond timber. In the private sector, increase in open, global markets has encouraged forest product companies to improve productivity and managerial efficiency while being cognizant of environmental and ecological values (Sianturi, 2000).

In forestry, resource allocation, road construction and forest products are very important concepts. Proper allocations of resources, such as labour, equipment and land management can save a lot of time and money. In the construction of a road network in a forest, economic and environmental impacts must be considered. One of the main issues when considering forest product is to obtain maximal profit from selling the tree. In this regard, cutting patterns must be carefully designed in advance (Sianturi, 2000).

When literature is examined it is found that some foresters and operational researchers have attempted to use operations research techniques in forestry problems focusing on resource allocation, spatial consideration, and road construction.

In the 1960s, researchers developed the first linear programming forest-planning models. One, widely used by the USDA Forest Service, was the timber resources allocation model (RAM). It concentrated mainly on timber production, treating such other aspects as recreation, wildlife habitat preservation, and water quality only through limiting constraints. It did not explicitly include spatial considerations involving roads and the proximity of different habitat types and cutting units within an area. Weintraub and Bare (1996), highlighted the extensive use of large linear programming models for forest level planning. In the 1980s, it became apparent that existing models did not address some of the concerns of forest managers and the public. Because with the OR tools used spatial factors could not be easily treated. As a consequence forest researchers developed many OR/MS tools to look at implementing forest-wide plans. In the 1990s, public concern for resource sustainability, biodiversity, and habitat and endangered species protection caused a shift toward ecosystem management-largely on public lands. New OR/MS models have been reported in the literature. Systems under development by USDA Forest Service include Spectrum (USDA Forest Service 1994) and RELMdss (Church, Murray, and Barber 1995; Church, Murray, and Figueroa 1995). Both are optimization-based software tools intended to facilitate ecosystem management at several levels in decision hierarchy. They are designed as flexible tools to be used for trade-off analysis within what-if environment. Both models interface with GIS to enhance the analysis of spatial relationships in the land management process (Wientraub&Bare, 1996).

Davis and Johnson (1987) give an excellent introduction to forest management practices in the United States. Their study deals with the use of OR for strategic forest management planning. Bare, Briggs, Roise, & Schreuder (1984), made a comprehensive survey that traced the development of OR in forestry from the late 1950s to the mid 1980s and focussed on timber production at the stand and forest levels as well as manufacturing aspects of forest product industry. They draw attention to the OR and forestry. Martell (1982), reviewed OR approaches to forest fire management comprehensively (Martell, Gunn, &Weintraub, 1998).

Traditional OR has much to offer to those who seek to improve the management of forests. But it is clear that traditional OR alone will not suffice. Forestry is rich in what Checkland (1988) refers to as problems that '… cannot be solved once-and-for all, and call for a problem-and process-oriented, rather than technique-oriented research.' Checkland and Scholes (1990) describe soft system methodology (SSM) with its emphasis on the cycle of model formulation, action, and learning that was developed for complex systems with important social dimensions (Martell, Gunn, &Weintraub, 1998).

Kouchi (1996), proposed a forest road planning technique using topological considerations in conjuction with analytic methods. Typical objectives of planning a forest road network are to minimize the length of the roads in the network or to minimize cost. The objective considered by Kouchi is planning a road network with shortest possible length (Sianturi, 2000).

As a result it is clear that operations research techniques were and will be very essential tool for decision maker in developing sustainable forest management plans.

3.2.1 Linear Programming and Integer Programming

Linear programming (LP) is one of the most widely used methods for solving long term forest management problems. One reason for this is the computational efficiency of LP.

There has been a long and successful association between Management Science (MS)/Operations Research (OR) models and problems in forestry goes back to the mid 1950s. One of the earliest application of MS/OR method to a forestry problem was the use of Linear Programming (LP) to solve the paper trim problem, that is, the problem of how to best cut rolls from a machine into sizes that are demanded by customers. A few applications were suggested in the 1950's and early 1960's. Many of these early suggestions were for problems such as optimizing harvest schedules, production mixes and product distribution. These applications were followed by the famous Lanchester prize-winning work of Gilmore&Gomory (1961, 1963) in which the column generation technique was developed to solve cutting stock problem. Over the last four decades, MS/OR methods have been applied to a diverse set of problems in forest management and in the forest products industry. Optimization and simulation have been used to solve problems in two major areas: Forest management (including problems in nursery operations, stand management, and the protection of forest stands) and forest products (including problems in harvesting trees, transporting forest products, lumber manufacture and manufacturing finished goods). Finding an optimal solution to a linear programming model is important but it must be expanded. There is a tremendous amount of sensitivity analysis, information about what happens when data values or parameters of problems are changed. (Duangsathaporn & Prasomsin, 2005; Golden & Wasil, 1994; Sianturi, 2000).

Over the last 20 years, the U.S. Forest Service has used a wide variety of MS/OR tools to perform forest-level planning. For example, in the early 1970s, the Forest Service developed Timber RAM (Resource Allocation Method) - a mathematical programming system designed to address timber production, to model and solve timber harvest scheduling problems. In 1976, Congress passed the National Forestry Management Act which required the Forest Service to prepare comprehensive land management plans every 10 years for the 154 national forests in the U.S.. Developing these plans is a formidable task, due to the sheer size of the National Forest Systems and due to the multi-use capabilities of the nation's timberlands. After regulations were issued in 1979, the Forest Service designated FORPLAN (FORest PLANing) as the primary analysis tool. FORPLAN is a large-scale LP system that consists of a matrix generator, an interface to a commercial mathematical programming (FMPS), and a report writer. Field, reviews much of the history surrounding the development of FORPLAN and the use of MS/OR models at the Forest Service until the early 1980s. Kent, Bare, Field&Bradley concluded that the use of FORPLAN has been significant in helping managers translate multiple-use policies into action at the forest level (Golden & Wasil, 1994).

Mathematical optimization techniques such as LP and Integer Programming (IP) seek to find the maximum level of economic value for timber harvesting and ecological and social value from the forest composition subject to some management and policy constraints. LP is the first optimization technique widely used in forest management planning. Some applications include, timber harvest scheduling, product optimization, optimization of stumpage value and multiple use forest management planning (Başkent & Keleş, 2006).

Although application of LP in forest management is common in developed countries, in Turkey few studies have been done. So it is needed to present foresters LP based harvest scheduling models (Başkent & Keleş, 2006).

Transportation of logs from the forest to the landings with minimum losses of quality and quantity with minimum damage to the environment is very important matter in forestry. So it is needed to minimize total cost during logging operations, can be done by LP (Acar, Gül, & Gümüş, 2000).

Forestry problems have become more complex due to considerations of environmental impacts, recreational and other needs from the forests. Spatial consideration is one of the central issues that foresters have to take into account in their decisions. This means that harvesting is restricted to a certain area. Therefore, forests should be blocked into contiguous areas so that, for example, adjacent blocks cannot be harvested in the same period of time. Remedy to this concern is using integer 0-1 programming, with 1 indicates harvesting and 0 indicates not harvesting.

Similarly in resource allocation problems, integer variables can be used to indicate decisions such as the amount of equipment to buy (Sianturi, 2000).

As stated by Martell, Gunn, & Weintraub (1998) that spatial relationships have always been important in forest management planning. But in the early forest management models decisions concerning road constructions, and timing of the specific stand harvest were handled indirectly. Road building decisions call for mixed integer models with 0-1 variables that denote timing and standards (gravel, dirt, pavement, one lane, two lanes) of potential roads.

3.2.2 Goal Programming

LP can only optimize one objective. To solve multiobjective problems, multiobjective optimization techniques are needed. The most common technique used in forestry management is Goal Programming. Multiple-use forest resource problems involve a consideration of multiple conflicting goals and objectives such as: increased net revenue from timber resources, improved water quality, protection of wildlife, preservation of natural beauty and increased recreational opportunities. Managing multiple-use resources requires more complicated decision making in which there are several alternative courses of action. To choose among them, managers must know both the trade-off between one course of action and another, and the relative desirability of the goods and services. For example, if the decision makers want to provide 20 % more recreation in the forests, they must answer questions such as what quantity of timber products must be relinquished, and is there enough money and land to provide the desired recreation? (Sianturi, 2000).

3.2.3 The Shortest Path Algorithm

Transportation systems in forests are one of the most crucial decisions that have to be made. The determination of the shortest route (or path) through a network of available routes is often an important step in planning transportation. A system of forest routes may be described as a network, a collection of interconnected links.

Each link describes a unique path between two adjacent nodes. A node is any feature that might be treated as the point of departure or destination of some path through the network. Nodes are also commonly used to indicate points at which road design standards change or there is a marked change in grade or curvature. Such changes would be expected to influence costs of hauling logs and therefore very important in solution of many transportation problems. Planning a network for transportation in a forest is also very important because we can reduce transportation costs by having an efficient network. Before deciding on a permanent system of forest roads, usually a network road plan is created and on each road link cost values are put. Then the network road planning is analyzed to get a more efficient alternative road network. The shortest path algorithm is commonly used for this purpose (Sianturi, 2000).

3.2.4 Soft System Methodology

In the real world, problems can be categorized as well-defined and ill-defined problems which are also known as hard problems and soft problems, respectively. In hard problems objectives are quite clear, there is an algorithm for finding a solution and it is dealth with "how problems can be solved?" in these type of problems. Hard problems are problems that can be defined well. There is a definite solution and it can be defined number of specific goal to be accomplished. On the other hand, soft problems are difficult to define. Soft problems are problems that deal with "what to do". These problems are dynamic problems that include human factor.

Hard system thinking originated in engineering to generate solutions to technical problems and assumes that making a choice between alternatives to achieve a known objective can solve problems. Hard system approach involves a series of steps involving, problem definition, choosing objectives, analyzing alternative systems, prototyping and system development and engineering. Soft system approach emerged when modeling complex human activity processes. These systems express a perceived problem in terms of structure and study the relation between two. Soft problems have obscure goals and if goals can be identified they may be in conflict with each other. Soft systems are applicable when problem definition is itself a problem. This approach involves a seven-stage process of analysis (Nidumolu, Bie, Keulen, Skidmore, & Harmsen, 2006).

Classical OR techniques, named as hard OR, such as linear programming and integer programming, are tangible, easy to explain and easy to use, whereas soft OR is somewhat intangible, not easy to explain and not easy to use.

For solving soft problems Peter Checkland developed soft system methodology (SSM) during 1970s while at Lancaster University. This methodology arose out of attempts to apply system engineering principles to business problems. System engineering emphasizes measurable system objectives. When applying system engineering to human activity systems Checkland found number of problems. Organization goals were matter of controversy, in particular most investigators assumed that all members of the organization accepted goal set by top management. But this is not the case. Formal methods usually begin with a problem statement. Checkland found that fixing the problem too early made investigators unlikely to see different problems. To overcome these problems he proposed SSM and his first book on SSM was published in 1981. SSM is a philosophical system concept formulated specially as a tool for solving management problems. It is a systems-based approach in the management field that is designed to address complex problematic situations involving human activity. It informs a process by which iterative operation of the methodology promotes learning and stimulates action for desirable and feasible change in the situation (Bunch, 2003; Pešl & Hřebiček, 2003).

As stated by Winklhofer (2002), SSM was conceived as a framework for the inquiry into ill-structured situations. It provides a general concepts and an intellectual framework for articulating the search for images of reality which are relevant to taking purposeful action within some problem situation.

SSM is structured around a comparison between real-world problem situation and conceptual models of relevant systems of purposeful activity. The approach is designed to allow human element of such systems to be incorporated into system design work. Checkland’s argument is that conventional system analysis, which he terms hard system nanalysis, is inadequate vehicle to investigate human systems (Nidumolu et al., 2006).

Figure 3.2 and explanations regarding it describe conventional seven stage model of SSM.

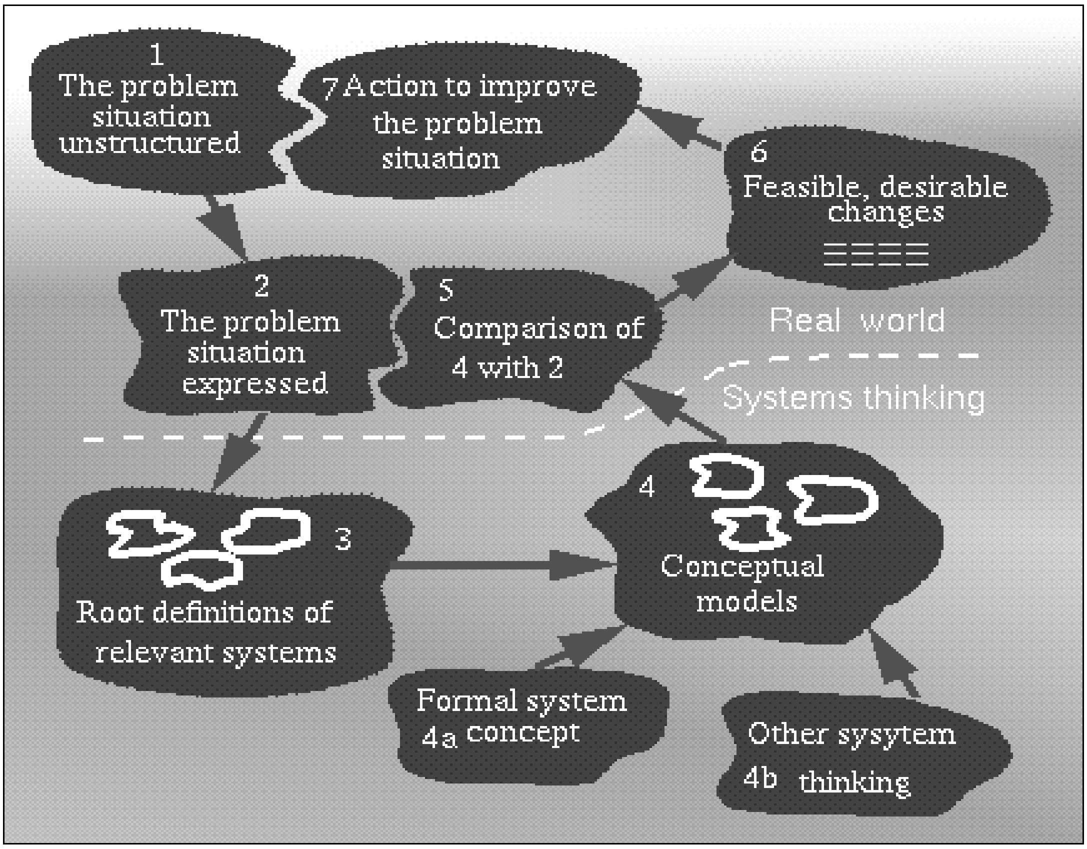

Figure 3.2 The conventional seven stage model of SSM (Brown, Cooper, & Pidd, 2006; Checkland & Scholes, 1990).

Stage 1: The problem situation is unstructured: SSM thinks the term problem as inappropriate because it narrows the view of the situation. Soft system believes that problem situation is more appropriate since there might be many problems which are perceived need to be solved. The purpose of this stage is to gain a general understanding and a wider view of the problem. Information is gathered about who is involved, what their perception of the situation are, what are the organization structures are, and what processes are going on.

Stage 2: The problem situation expressed: In this stage information is collected and sorted and some description of the problem situation is done. The structure of the organization, transformations which are carried out within the system and issues that are felt by organization members are some of the information searched in this stage. Stage 1 and 2 are an expression phase during which it is attempted to build the possible rich picture of the problem situation. In Stage 2 to understand features of the problem situation some analyses tools are used. These are, intervention analysis, social and cultural analysis, political analysis and rich picture. Rich pictures show the people involved, their stated purposes, and their desires and fears. These pictures are used to provide a model for thinking about the system and to help the analyst to gain an appreciation of the problem situation. The rich picture does not attemp to model the system in any precise way. It provides a representation of how we can look at and think about system. It can be refined as our understanding of the system becomes clearer. Rich pictures should represent structure, processes and issues of the organization relevant to the problem definition.

Stage 3: Naming of relevant systems: In this stage root definitions and CATWOE analysis are done. Root definition expresses the core purpose of purposeful activity system. That core purpose is expressed as a transformation process that takes some entity as input, changes or transforms that entity, and produces a new form of the entity as output. The root definition is one way of describing what is the system, how the system will work and why this system is needed. Root definitons are sentences that elaborate a transformation. There are six elements that make up a well formulated root definition which are summed up in the mnemonic CATWOE.

C: Customers: The victims or beneficiaries of the T.

A: Actors: The actors perform the activities defined in the system, those who would do T.

T: Transformation process: The conversion of input to output.

W: Weltanschauung: The German expression for world view. This world view makes the transformation process meaningful in context.

O: Owner: Those who could stop or start up the process.

E: Environmental constraints: External elements exist outside the system which it takes as given. These constraints include organizational policies as well as legal and ethical matters.

Stage 4: Conceptual models: The conceptual model is the core of SSM. A conceptual model is a human activity models that is used to show each operational activity that is necessary to carry out the process described in the root definition. In other words these models are human activity models that strictly conform to the root definition using the minimum set of activities. In building a conceptual model different activities that must be implemented are thought to fulfill root definition. Formal system thinking is applied to the development of the conceptual model. After then it is need to monitor a system. In monitoring a system measure of performance is defined. For measurement of operational system any or all of three E's can be used. Efficacy, "does the system do what it is supposed to do?". Efficiency, "are minimum resources used?". Effectiveness, "are the high-level aims of the system being met?".

Stage 5: Comparing conceptual models with reality: This stage deals with comparison of the conceptual models developed in Stage 4 with the real world expression at Stage 2. The purpose of this stage is to analyse the similarities and differences between the model and the real world in a structured manner.

Stage 6: Implementing feasible and desirable changes: The purpose of this stage is to define changes that are the most feasible and desirable. Feasible and desirable changes are identified and discussed and they will be put in action in Stage 7. The pupose of comparison stage is to generate debate about possible changes. These changes include changes in structure, changes in procedure and changes in attitude. For each proposed change, reason for change, nature of change, means to bring about change and potential long-term effects of change must be considered.

Stage 7: Take action to improve the problem situation: This stage include the actual starting of the change process. It is important to note thet introduction of the action may change the situation and new problems may arise.

Forest management has evolved from optimizing timber harvesting to finding satisfactory solutions related to ecosystem health. As mentioned before in addition to timber, forests provide various resources like grazing land for livestock, recreation areas, wildlife habitat and water supply resources. In this context, forest management involves management of harvesting, wildlife habitat, grazing leases, recreational areas, minig activities and the protection of endangered species and archaeological sites (Aronoff, 1995; Kazana et al., 2003; Mohren, 2003). But forest management planning involves uncertainty. Fires, insects and diseases, changes in markerts, manufacturing technologies, and government policies lead to this uncertainty. So it is clear that traditional OR will not enough to tackle with these uncertainties. These uncertainities necessiate the inclusion and application of soft OR methods, SSM, combined with hard OR methods in forestry.

3.2.5 Multi Criteria Decision Making

Different problems encountered in the life can be considered as multi criteria decision making (MCDM) problems. As stated by Vassilev et al. (2005), multi criteria decision making problems can be divided into two distinct classes. In the first class of problems a finite number of alternatives are exlicitly 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 problems or multi criteria optimization problems. Multi criteria analysis problems can be divided into three types, such as, problems of multi criteria choice, problems of multi criteria ranking and problems of multi criteria sorting.

The techniques used in the different approaches of decision analysis are called multi criteria decision methods. These methods include preferences of decison-makers whose statements are defined explicitly. Multi criteria decision methods have been classified in a number of ways. One of them differentiates multi attribute decision making (MADM) from multi objective decision making (MODM). MADM methods are designed for selecting discrete alternatives. MADM deals with choice from a moderate/small size set of discrete actions. However, MODM methods are more suitable for dealing with multi-objective planning problems, when an infinite number of continuous alternatives are defined by a set of constraints on a vector of decision variables. MODM deals with the problem of design in a feasible solution space bounded by the set of constraints (Jankowski, 1995; Mendoza&Martins, 2006).

Pairwise comparisons, ranking method and rating methods are some of the methodogies used in MCDM. Pairwise comparison technique is based on the method developed by Saaty called the Analytic Hierarchy Process (AHP). Analytic Hierarchy Process is a decision making technique developed by mathematician Thomas L Saaty. It is a an Eigen value approach to the pair-wise comparisons and a mathematical decision making based on, building hierarchy of criteria and at each node of hierarchy weighting is performed (Saaty, 1980; Saaty; 1986; Yaralıoğlu, 2004).

Some key and basic steps involved in this methodology are (Saaty, 1980; Vaidya & Kumar, 2006):

1. State the problem.
2. Broaden the objectives of the problem or consider all actors, objectives and its outcome.
3. Identify the criteria that influence the behavior.
4. Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

5. Compare each element (pairwise comparisons) in the corresponding level and calibrate them on the numerical scale. The scale has values range from 1 to 9 as shown in Table 3.1 (Saaty, 1980).

Table 3.1 Scale for pairwise comparison

Intensity of importance	Definition
1	Equal importance
2	Equal to moderately importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

6. Perform calculations to find the maximum Eigen value (λ), consistency index (CI), consistency ratio (CR), and normalized values for each criteria/ alternative. λ reperesents average value of the consistencey vector, CI provides a measure of departure from consistency, CI and CR are calculated as shown in Formula 3.1 and Formula 3.2, respectively:

$$CI= (\lambda_{max} - n) / (n-1) \quad (3.1)$$

$$CR = CI / RI \quad (3.2)$$

Where RI is the random index and depends on the number of elements being compared as shown in Table 3.2 (Saaty, 1980):

Table 3.2 Random inconsistency indices (RI) for n=1, 2, ……., 15

n	RI	n	RI	n	RI
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

If $CR < 0.10$, the ratio indicates a reasonable level of consistency in the pairwise comparison, however, if $CR \geq 0.10$, the values of the ratio indicates inconsistent judgements.

7. If the maximum Eigen value, CI, and CR are satisfactory then decision is taken based on the normalized values; else the procedure is repeated till these values lie in a desired range.

In forest management, Mendoza & Prabhu (2000) used multicriteria decison making methods in assesing forest sustainability using criteria and indicators. Mendoza, Campbell, and Rolfe (1986), Tarp and Helles (1995), Hayashi (2000), Kangas, Kangas, Leskinen, and Pykäläinen (2001) dealed with the application of MCDA to natural resources management problems. Bare and Mendoza (1988) applied MCDA in forest land management planning. Pukkala and Miina (1997) used MCDA in the multi-objective optimization of stand management, d'Angelo, Eskandri, and Szidarovsky (1998) examined selection of the best forestry treatment method according to MCDA applications.

3.3 The Use of GIS and RS in Forestry

Human activities have an impact on the world's forest ecosystems. Much of the original forest cover has been cleared for agriculture or otherwise impacted by various resource extraction activities, such as logging and mining. Over the last several decades, the rate of forest change has increased substantially. Various studies continue to document the ongoing loss of forest ecosystems. As a result, undisturbed, intact forest ecosystems are becoming increasingly rare and unevenly distributed across the world.

According to Global Forest Resources Assessment 2005 and State of The World's Forest 2007 report, total forest area is estimated at 3.952 million hectares, 30 percent of total land area. This corresponds to an average of 0.62 ha of forest per capita. From 1990 to 2005, the world lost 3 percent of its total forest area, an average decrease of some 0.2 percent per year. Forest area is unevenly distributed. For example, 64 countries with a combined population of 2 billion have less than 0.1 ha of forest per capita. The ten most forest rich countries account for two-thirds of total forest area, while seven countries have no forest at all, and 57 countries have forest less than 10 percent of their total area (Global Forest Resource Assesment 2005, 2005; State of The World's Forest 2007, 2007).

Deforestation caused by conversion of forests to agricultural land is 13 million hectares per year. South America suffered the largest net loss of forests in the period 2000-2005, about 4.3 million hectares per year. South America is follewed by Africa, which lost 4 million hectares annually. North and Central America and Oceania each had a net loss of about 350.000 ha while Asia reported a net gain of 1 million ha per year from 2000 to 2005 as a result of large scale afforestation. Forest areas in Europe continued to expand although at a slower rate than in 1990s (Global Forest Resource Assesment 2005, 2005; State of The World's Forests 2007, 2007).

An estimated 36 percent of total forest area is classified as primary forests, in which there are no clearly visible human activity indicators. About 6 million hectares of these forests were lost or modified each year since 1990. This rapid decrease stems both from deforestation and from modification of forest due to selective logging and other human interventions (Global Forest Resource Assesment 2005, 2005).

Most deforestation occurred in natural tropical forests, which lost 14.2 million hectares a year over the last decade. Africa and South America have suffered the most deforestation. Africa, which lost 5.3 million hectares of forest per year in the 1990s, was the region with the highest deforestation in the world. (Facts on forests around the world, n.d.).

About 2 percent of the world's forests are certified as being managed in a sustainable manner, with about 92 percent of these forests lying in temperate, industrialized countries. Areas under forest management plans are also increasing. At least 6 percent of the total forest area in developing countries is covered by a formal, nationally approved forest management plan. Some 89 percent of the forests in industrialized countries are managed according to formal or informal management plans (Facts on forests around the world, n.d.).

Europe accounts for one-quarter of total forest area, followed by South America and North and Central America with 21 and 18 percent respectively. Ten countries with largest forest area, with million hectares, are, the Russian Federation (809 million ha.), Brazil (478), Canada (310), the United States (303), China (197), Australia (164), the Democratic Republic of the Congo (134), Indonesia (88), Peru (69) and India (68) (Global Forest Resource Assesment 2005, 2005; State of The World's Forest 2007, 2007).

The usefulness of criteria and indicators as tools to monitor and assess forest conditions and trends is recognized worldwide. They continue to increase understanding of sustainable forest management by generating better information, improve the development and implementation of forest policies, programmes and practices, strengthen stakeholder involvement in decision making, and enhance collabration on forest issues at the local, national, regional and international levels. Criteria define the essential elements against which sustainability is assessed. Each criterion relates to a key element of sustainability, and may be described by one or more indicators. Indicators are parameters which can be measured and correspond to a particular criterion. They measure and help monitor the status and changes of forests in quantitative, qualitative and descriptive terms (State of the World's Forest 2005, 2005).

Sustainable forest management comprises seven elements (State Of the World's Forests 2007, 2007,):

- Extent of forest resources
- Biological diversity
- Forest health and vitality

- Productive functions of forest resources
- Protective functions of forest resources
- Socio-economic functions
- Legal, policy and institutional framework.

To assist developing countries with national forest programmes, a number of international organizations and donors, including Food and Agriculture Organization (FAO) and National Forest Programme Facility are helping to link the programmes with broader agendas, address governance issues, develop national capacity and make knowledge available to those involved in the process. The national forest programme provides a global framework to address forestry issues within the context of sustainable development. They are tools for the planning, implementing and monitoring forestry and forestry-related activities. National forest programmes follow a participatory planning and implementation approach that encourages the involvement of all forest-dependent actors at local, national and global levels and the development of a partnership between all stakeholders (State of the World's Forests 2005, 2005).

Technological changes are opening important opportunities to improve ways in which the forestry sector is governed and how administrations operate. Advances in information and communication technologies, including satellite imagery, spatial information and decision support systems offer the greatest potential to achieve gains. GIS technology has been widely accepted by public forestry agencies and private forestry companies. This has been a result of the clear benefits of current forest inventory maps (State of The World's Forests 2005, 2005).

The forest inventory is the primary management tool for timber production in North America. It is used to assess the existing forest resource and to develop harvest schedules and treatment programs. Information like species, age, height, structure and condition is derived from the airphotos and supporting field data. This information is entered into the GIS. Other data sets commonly included in forestry

GIS databases are soils mapping, the road network and drainage systems (Aronoff, 1995).

The conventional forest inventory was done progressively, a portion of the forest area being inventoried each year. However, to update thousands of forest cover maps could take many years. With a GIS, forest cover maps can be updated on a continual basis. In this way forest managers are provided with more current information. With GIS technology, the average age of information in the forest data base can be reduced from years to weeks. This factor alone has led to wide acceptance and demand for GIS technology in the forestry sector (Aronoff, 1995).

In itself the use of a GIS to update forest inventory maps is little more than automated cartography, using computer technology for an existing manual process. It is the analytical power of the GIS that sets it apart. The GIS can be used to store and analyze the forest information, model the spread of forest fires, or develop and evaluate alternative harvest plans. GIS allows to evaluate several alternatives relatively quickly. Plans can be proggressively refined and re-evaluated to optimize a solution. GIS has been widely used by the US Forest Service (Aronoff, 1995).

Managing forests requires up to date technology in ensuring sustainable resources utilisation. Much of the current forest management practices can be improved through the use of current technologies including GIS, RS, and GPS which may enhance any decision making process. The use of spatial data for forest resources management and planning has been recognised worlwide. However, the spatial data will be less useful if they are not transformable into information. Hence there is a requirement to transfer and keep spatial data related to forestry in a standard computer format, in a GIS environment. The use of GIS in forestry is becoming very important in which immense accumulation of data is unavoidable. Realising this fact, the Forestry Department (FD) Peninsular Malaysia has set up a Mapping and GIS Section in 1997, with a purpose to develop an operational GIS for more effective planning, management, conservation and sustainable development of forest resources (Hamzah, 2001).

GIS is an effective tool to capture, store, update, manipulate and analyze spatial and nonspatial forestry data. Designing forest database, including data such as forest cover type map, soil map, road network map, and attribute data, such as stand volume per hectare, tree species, and determining forest values are necessary in a comprehensive forest management plan. Data must be accurate, properly organized, detailed and should be ge easiliy and economically. Gathering spaial and nonspatial data and analyzing them determines the quality of forest management plans. Preparing age class maps, site class map, topographic map and harvest planning maps are managed easily by GIS (Mısır & Başkent, 2002).

The most common operational remote sensing applications in forestry entail vegetation mapping as a preliminary step in a forest inventory and for identifying the boundaries of habitats and ecosystems. Fire prediction, detection, response and burned area assesment is another area in which remote sensing has been used to a greater extent (Peterson, Resetar, Brower & Diver, 1999).

As stated by Franklin (2001), remote sensing application in forestry include, forest covertype characterization, determination of forest stand conditions and forest health, site characterization and fire monitoring. In Asian tropical forest management remote sensing is used for detection of deforestation, forest covertype mapping, general assesment of volume and cutting rates and fire monitoring. In India, remote sensing is used in forestry for timber volume estimation, species identification, estimation of biomass and productivity and biodiversity monitoring. In Oregon, three remote sensing applications are, forest cover mapping, measuring and monitoring structure, function and composition of vegetation and detecting change in these conditions over time.

GIS can be used as an analysis tool for timber harvesting, habitat protection, planning of scenic roads in forestry and predicting the behavior of a forest fire.

In America primary management tool for timber production is the forest inventory. It is used to access the existing forest resource and develop harvest schedules to project future timber supplies and for other operational planning activities. Forest inventory data is collected by remote sensing techniques (GIS and forestry, n.d.).

In Canada, almost every forest agency has either fulfilled or is in the process of fulfilling GIS technology. Before GIS, the forest databases were updated by aerial photography and field sampling methods. With GIS program, the forest maps were digitized and a forest inventory can be updated constantly. By GIS, forestry agencies manage and manipulate their databases. Landsat satellite is used to update the individual maps that need current information due to forest harvesting and fires (GIS and forestry, n.d.).

It is known that forest fires have an important effect on animals, plants, soil, air quality and vegetation cover. Forest fire effects can be estimated by developing forest fire model. In order to model forest fire, the techniques for getting, analyzing and visualizing spatial information are needed. GIS is used as a tool for modeling forest fires due to their spatial nature.

A fire simulation program, FIRE, has been developed using ARC/Info. Through the integration of fire behavior models with GIS models, new insights about fire danger situation can be gained. For instance the damage potential that arises from fires starting at a certain point to sensitive areas like buildings, railway lines. In these cases proximity is used in many GIS-related models. In the past, BEHAVE was used as a fire behavior prediction tool. It is a non-spatial tool that inputs fire fuel types, topograhy data and weather data. But it can’t give spatial output and is useful for predicting fire characteristics in a given area. It is unable to predict spread rates, flame lengths, and heat calculations when these parameters change. Whenever there is a change, the entire BEHAVE model must be recalculated and it is inefficient to model the behavior of forest fire. But with the use of GIS technology, the prediction of fire behavior has been very efficient and effective (GIS and forestry, n.d.).

Effective forest managers monitor changing conditions and make intelligent decisions for sustainability. GIS can be used to evaluate conditions through stand inventory, soil types, and land-use practices. Modeling enables users to test and consider options in temporal and spatial contexts (GIS best practices forest assesment, 2006).

The forest is a complex ecosystem. Making sure all of its rivers, streams, plants and wildlife remain healty, and can successfully coexist with human activities, is an immense task. More and more often, foresters are finding that GIS makes this task easier. It helps them organize and relate information to make better decisions about forest resources. For instance, Oregons's foresters use GIS, in tracking fires (GIS technology help them in pinpointing areas where fires have been frequent, identifying fire hazards, coordinate on-site fire-fighting resources, and deploy fire-fighting equipment and crews more effectively), in understanding how prevantable fires start (The Southwest Oregon Distict in Medford protects 1.8 million acres in Jackson and Josephine counties, an area that has about 250 fires a year. The district maintains historical dBASE data and makes it available over a local area network. This data includes when and where fires occured, how much acreage they burned, what they cost, and how they were started. Because the tabular dBASE files include latitude/longitude values for the location where each fire started, it is possible to position them accurately on a map. For example, near the town of Takilma, it has been determined that, there have been several fires caused by children. Identfying trends like this helps the district allocate funds for fire education programs in local schools) (Lang, 2001).

During the last few years, the forest fire management policy is mainly based on GIS. The objective of forest fire control is the minimization of fires' negative impacts on human being, private and public property and natural resources. This may be achieved either by detecting and attacking fires soon after they are reported or by controlling fires effectively. A standard practice throughout the world is to classify forest areas in terms of fire danger and in order to protect them appropriately. This classification is based on type of vegetation, time of the year, and weather conditions, etc. GIS is very useful in providing all data and manipulating the data effectively (Dimopoulou & Giannikos, 2004).

GIS is also used in tracking tree disease and other hazards in forests. (Forest managers in Oregon use GIS and GPS systems to track insect and disease infestations and schedule treatments. For example, in the case of some kind of plant disease foresters use GPS receivers to record the position of infected trees within stands. These positions are then uploaded to the GIS, where buffer zones are drawn around areas within affected stands. Then created map shows areas with infected trees. The foresters use it to schedule reforestation. Data collected about insects that damage timber, can also be entered into the GIS and used to plan.), in opening data to the public (The Oregon Department of Forestry provides GIS data and applications over the Internet. Users enter place name or latitude/longitude positions to view detailed maps of an area. By pointing to on-screen menu choices, they can view data layers, such as watersheds, average rainfall and elevation bands.) (Lang, 2001).

Following maps are some examples of usage of spatial information systems in forestry in the world (Converted and accessed forests in Canada, 2000; Low –Access Forests and Their Level of Protection in North America, 2002):

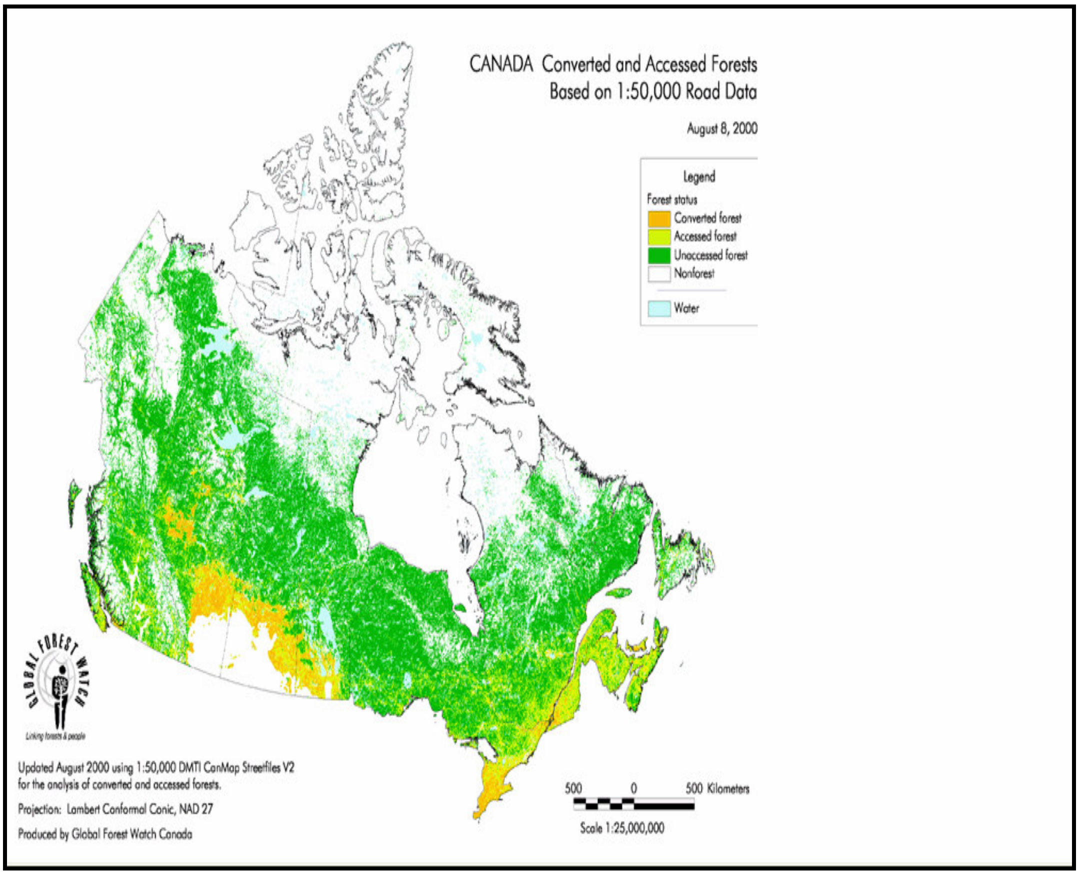

Figure 3.3 Converted and accessed forests in Canada.

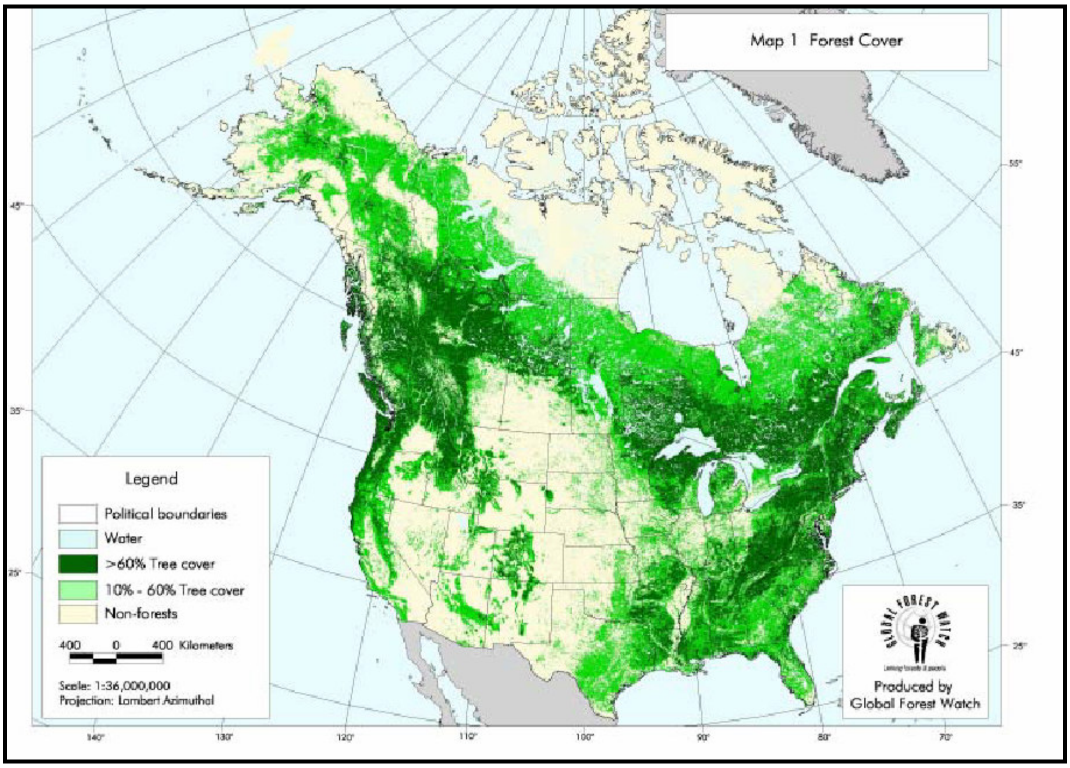

Figure 3.4 Forest cover in North America.

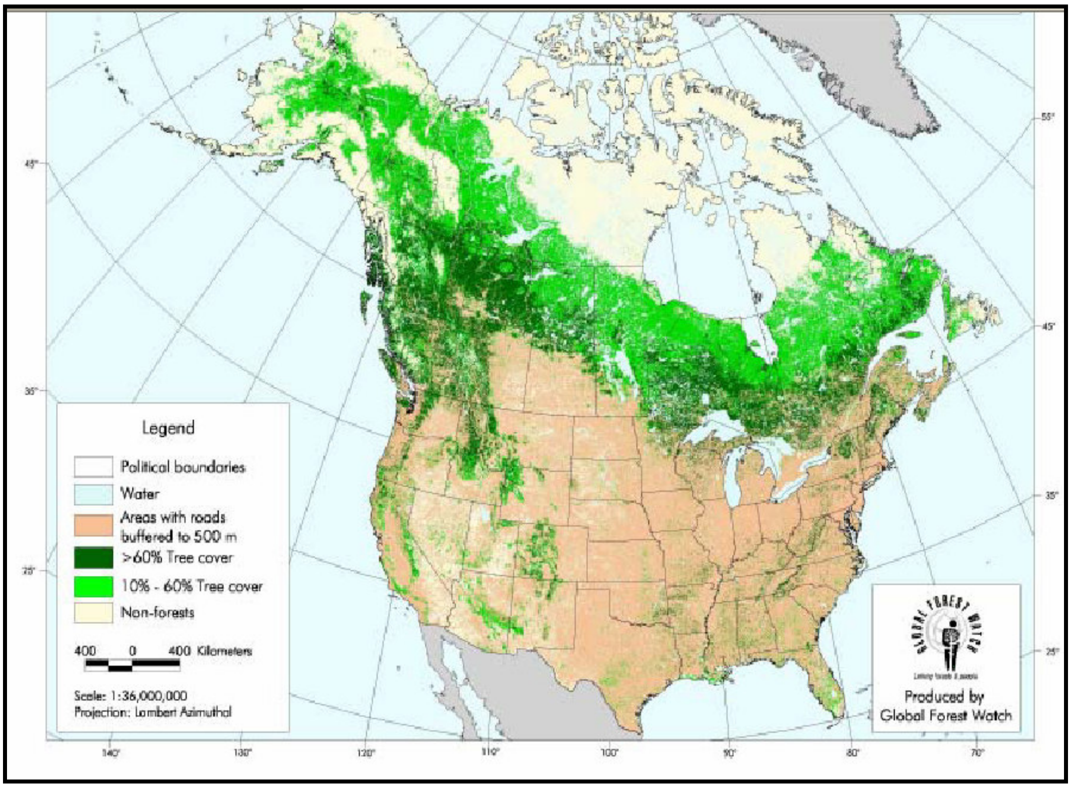

Figure 3.5 Forest cover with buffered area in North America.

3.4 Operations Research and GIS in Forestry

As the forest planning becomes increasingly complicated there is a need to assist planner with operative tool. As stated by Rönnqvist, Westerlund, & Carlsson (1999), OR techniques can be used to suggest e.g. routes or overall flows. But to use such techniques there is a need to get information about e.g. actual roads, supplies and orders. It also has to be easy to collect and update information. GIS provides that link to OR tools.

The ability to visualize OR methods' results spatially, via maps and remotely sensed land images, allows for producing spatial optimization systems. The combined use of GIS and OR techniques gives forest managers the chance to visualize solutions proposed by OR and to get a better understanding and a whole picture of the real problem they confront.

3.4.1 Location Set Covering Problem

It is very important to minimize damage caused by forest fire. This can be achieved by developing an efficient fire management system. Fire fighting planning is an important component of fire management system which is also an important component of forest management. Martell (1982), reviewed OR approaches in forest fire management comprehensively.

Questions of how many and which vehicles are going to be moved towards fire area and especially the assignment of fire crews to proper locations are very essential in fire fighting planning. In question such as, "how many facilities (fire crew, reservoir or pool) are required to meet fire zone (fire sensitive area) demand?" the concept of covering is important. Location Set Covering Model (LSCM) which is also known as Location Set Covering Problem (LSCP) can answer these questions. LSCP, seeks to assign facilities in such a way that all of the spatially distributed demand points are covered within a specified distance and the number of facilities is minimized. In other words, this problem finds the smallest number of needed facilities and their locations in a way that each demand point is covered at least once. (Church and Gerrard, 2003; Revelle et al., 1996). As Dimopoulou and Giannikos (2004) stated this model determines the locations of the minimum number of units required to cover a given set of points. Mathematical expression of the problem is given in Formula 3.3 (Church and Gerrard, 2003):

$$\textit{Minimize}\ \mathrm{Z} = \sum_{j=1}^{n} x_j \qquad (3.3)$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j \geq 1 \qquad \text{for each demand point i= 1, 2, ……,m}$$

$$x_j = 0,1 \qquad \text{for each site j= 1, 2, ……,n}$$

where

$$a_{ij} = \begin{cases} 1, \text{ if site j can cover demand i} \\ 0, \text{ if not} \end{cases}$$

$$x_j = \begin{cases} 1, \text{ if site j is selected for a facility} \\ 0, \text{ if not} \end{cases}$$

The objective is to find the minimum number of needed facilities and their locations in Formula 3.3. The objective function involves the minimization of the number of sites selected for facilities. First constraint requires that, for each demand i, the number of sites selected that can cover demand i must be greater than or equal to 1. The second constraint refers to the integer requirements of the site selection variables (Church and Gerrard, 2003).

3.4.2 Spatial Multi Criteria Decision Making

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

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. Spatial multi criteria analysis is different from conventional multi criteria decision analysis (MCDA). Spatial multi criteria analysis requires information on criterion values and the geographical locations of alternatives and the results of analysis depend not only on the geographical distribution of attributes, but also on the value judgements of decision maker (Jankowski, 1995; Malczewski & Ogryczak, 1996).

As stated by Carver (1991) and Jankowski (1995), two important components of spatial multi criteria decision analysis are Geographical Information Systems (GIS) component and Multi criteria decion making (MCDM) component.

Multi-criteria evaluation (MCE) and MCDM are very important concepts in GIS. Many spatial decison problems lead to GIS and multi criteria decision analysis (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, evaluating and prioritizing alternative decisions. GIS-MCDM integration can be thought of as a process that transforms and combines geographical data and value judgements to obtain information for decision making (Malczewski, 2006).

Antonie, Fischer and Makowski (1997), discussed land use analysis with multiple critera. Land-use planning has also been analysed including the integration of MCDA with GIS (Malczewski, 1999). In another study GIS-MCDM was handled to improve quality of landscape ecological forest planning (Kangas, Store, Leskinen, & Mehtätalo, 2000). Basnet, Apan, and Raine (2001), used GIS-MCDM integration to select suitable sites for animal waste application. Jumppanen, Kurttila, and Uuttera (2003) applied GIS-MCDM in spatial harvest scheduling approach for areas involving multiple ownership.

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 & Eastman, 2000).

Boolean analysis is used where only two states of variable are possible (criterion satisfied and criterion not satisfied). This analysis was developed by George Boole, who devised rules and methodologies for combining two-states variables. In boolean search it is generally concerned with the AND operator. The logical AND operator produces a true result from tha phrase “A AND B” only if 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”). When such boolean layers are multiplied together in an overlay operation, the only areas of ones in the output image occur where ones are present in both input images (i.e., 1 X 1 = 1, but, 1 X 0 = 0, 0 X 1 = 0, 0 X 0 = 0) (Eastman, 2003).

However in many problems decision making process can be more sophisticated. There are situations in which boolean analysis does not work effectively. Boolean approach requires that all of the criteria have equal importance in the solution. But situations in which multiple criteria have important role in determining areas that satisfy criteria some other techniques, such as AHP-GIS integration, must be used.

Forestry decision problems involve a lot of 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. MCDM and GIS integration can help to solve forestry based multi criteria decision problems spatially and represents results visually. In this study it is shown the areas that can cope with forest fires effectively according to distance from water resources, distance from streams and distance from settlement areas criteria by using Boolean Approach and AHP and the results are visualized on a digital map. IDRISI software package is used for analyses.

CHAPTER FOUR
THE USE OF OR AND GIS IN İZMİR FOREST ADMINISTRATION CHIEF OFFICE

4.1 The Aim of the Case Study

Purpose of this thesis is to implement forest management by using spatial information systems, GIS, in combination with OR techniques for our study area, İzmir Forest Administration Chief Office. Our aim is to generate a prototype study that integrates GIS and OR in order to facilitate forest management decision procees of directorates. Forests can not be managed without a forest management plan. Objective of thesis is to show to the forest manager how to plan forestry in the short and long-term by using GIS and OR techniques. Then we will show how to use new information tool for management.

4.2 The Study Area

İzmir Regional Directorate of Forestry has seven direcorates of forest administrations, as shown in Figure 4.1. Our study area is İzmir Forest Administration Chief Office which is subordinate to İzmir Directorate of Forest Administration. İzmir Directorate of Forest Administration has eleven forest administration chiefs, shown in table 4.1, our study area, İzmir Forest Administration Chief Office, is one of them.

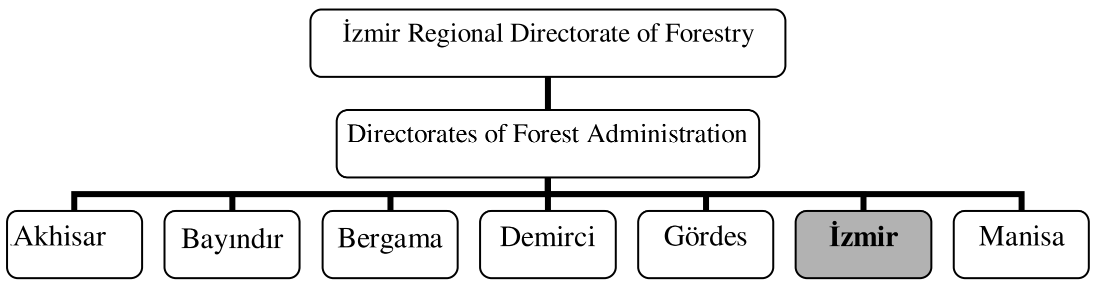

Figure 4.1 İzmir Directorates of Forest Administration (İzmir Orman İşletme Müdürlüğü, n.d.).

Table 4.1 shows forest administration chief offices subordinate to İzmir Directorate of Forest Administration (İzmir Orman İşletme Müdürlüğü, n.d.).

Table 4.1 Forest Administration Chief Offices of İzmir Directorate of Forest Administration

Chief Office	Foundation Date	Province	County	Center	Forest Area (ha)	Free Space (ha)
Gaziemir	04.06.1948	İZMİR	Gaziemir	Gaziemir	19360	16428
İzmir	**06.04.1951**	**İZMİR**	**İzmir**	**Karşıyaka**	**19983**	**19286**
Karabel	15.09.1982	İZMİR	Kemalpaşa	Kemalpaşa	6687.5	5575
Kemalpaşa	04.06.1948	İZMİR	Kemalpaşa	Kemalpaşa	13820	12029
Menemen	01.06.1948	İZMİR	Menemen	Menemen	28311	94446
Bornova	21.10.1949	İZMİR	Bornova	Karşıyaka	10601.5	15417
Gümüldür	19.04.1993	İZMİR	Gümüldür	Gaziemir	30455	21163
Seferihisar	04.06.1948	İZMİR	S.Hisar	Seferihisar	32465.5	24116
Urla	04.06.1948	İZMİR	Urla	Urla	44087.5	48919
Armutlu	15.02.1979	İZMİR	Kemalpaşa	Armutlu	1169.5	10328
Karaburun	23.12.1994	İZMİR	Karaburun	Karaburun	25824.5	20062

Figure 4.2 shows boundary map of İzmir Directorate of Forest Administration.

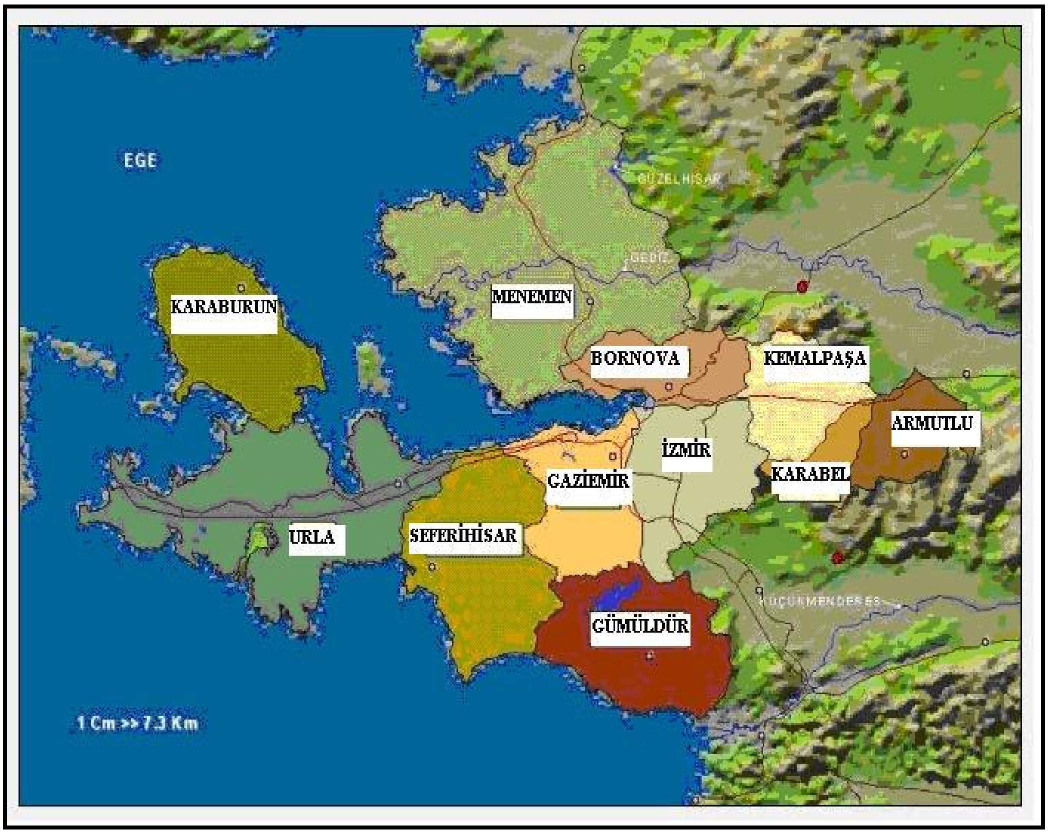

Figure 4.2 İzmir Directorate of Forest Administration boundary map (İzmir Orman İşletme Müdürlüğü,n.d.).

Figure 4.3 shows forest state of İzmir Forest Administration Chief Office. General area is 39270 ha and 50.88 % of this area is forest land. Total forest area is 19983.5 ha of which 11494.5 ha (57.52 %) is productive forest and 8489 ha is unproductive forest.

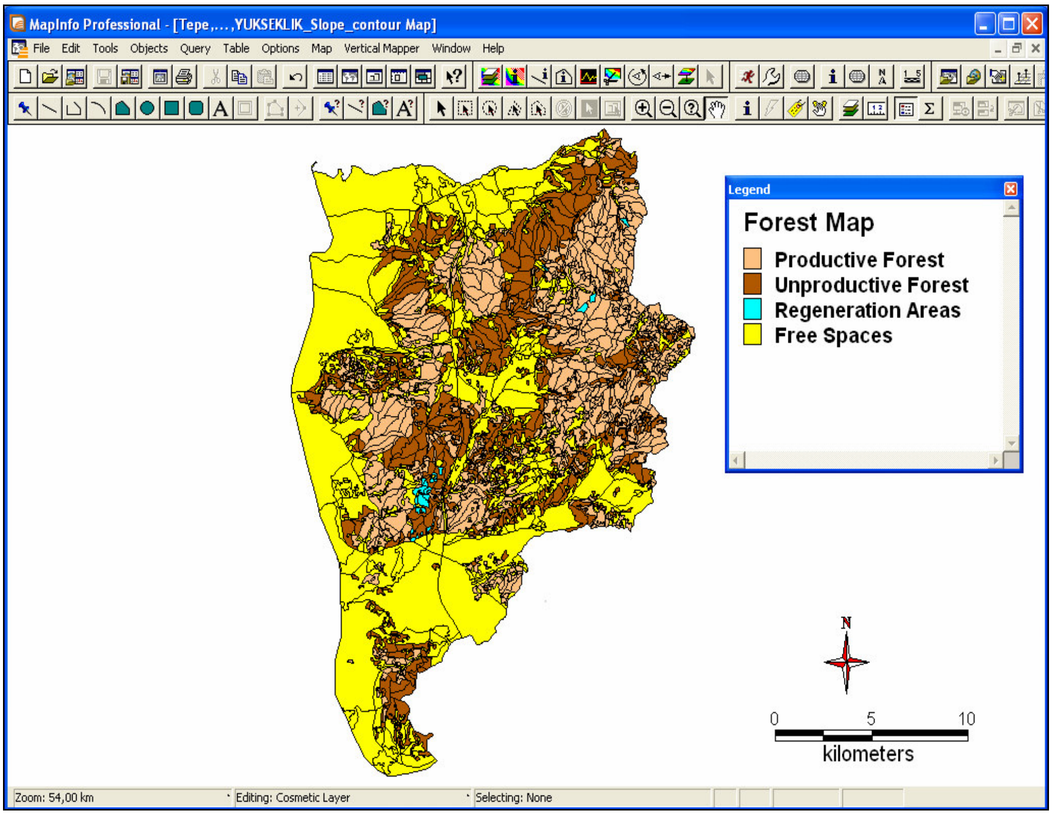

Figure 4.3 Forest state of İzmir Forest Administration Chief Office.

4.3 General Information About Data

At the beginning of the study data collection and database design were done. Data, data type, data format and source of data are shown in Table 4.2. With data obtained from İzmir Regional Directorate of Forestry some new data were produced as shown in Table 4.3.

Table 4.2 List of data used in this thesis.

Data	Data Type	Data Format	Software	Source of data
Stand	Map/Attribute	Vector data	ArcGIS	İzmir Regional Directorate of Forestry
Compartment data	Map/Attribute	Vector data	ArcGIS	İzmir Regional Directorate of Forestry
Sub-compartment data	Map/Attribute	Vector data	ArcGIS	İzmir Regional Directorate of Forestry
Stream data	Map/Attribute	Vector data	ArcGIS	İzmir Regional Directorate of Forestry
Hill data	Map/Attribute	Vector data	ArcGIS	İzmir Regional Directorate of Forestry
Settlement area	Map/Attribute	Vector data	ArcGIS	İzmir Regional Directorate of Forestry
Agricultural land	Map/Attribute	Vector data	ArcGIS	İzmir Regional Directorate of Forestry
Forest road data	Map/Attribute	Vector data	NetCAD	İzmir Regional Directorate of Forestry
Fire crew location data	Attribute	Text	-	İzmir Regional Directorate of Forestry
Water resources data	Attribute	Text	-	İzmir Regional Directorate of Forestry
Crew, vehicle, equipment data	Attribute	Text	-	İzmir Regional Directorate of Forestry
Contour data	Map/Attibute	Vector data	MapInfo	Vahap Tecim

Table 4.3. List of data produced from the data at hand.

Data	Produced Data	Produced Data Type	Produced Data Format	Software used
Fire crew location data	Fire crew location map	Map/Attribute	Vector data	MapInfo
Water resources location data	Water resources location map	Map/Attribute	Vector data	MapInfo
Settlement areas map	Distance map of settlement areas	Map	Raster data	IDRISI
Water resources location map	Distance map of water resources	Map	Raster data	IDRISI
Stream map	Distance map of streams	Map	Raster data	IDRISI
Contour data	Altitude and altitude contour map	Map	Vector data	Vertical Mapper
Contour data	3D, slope and aspect map	Map	Vector data	Vertical Mapper

Before starting analyses, all of the maps obtained from İzmir Regional Directorate of Forestry were transformed into MapInfo compatible format. After conversion many analyses were done. These analyses are discussed in the following section.

4.4 Analyses

Flowchart of the application process and analyses done are shown in Figure 4.4. Table 4.4 lists analyses done according to types of data.

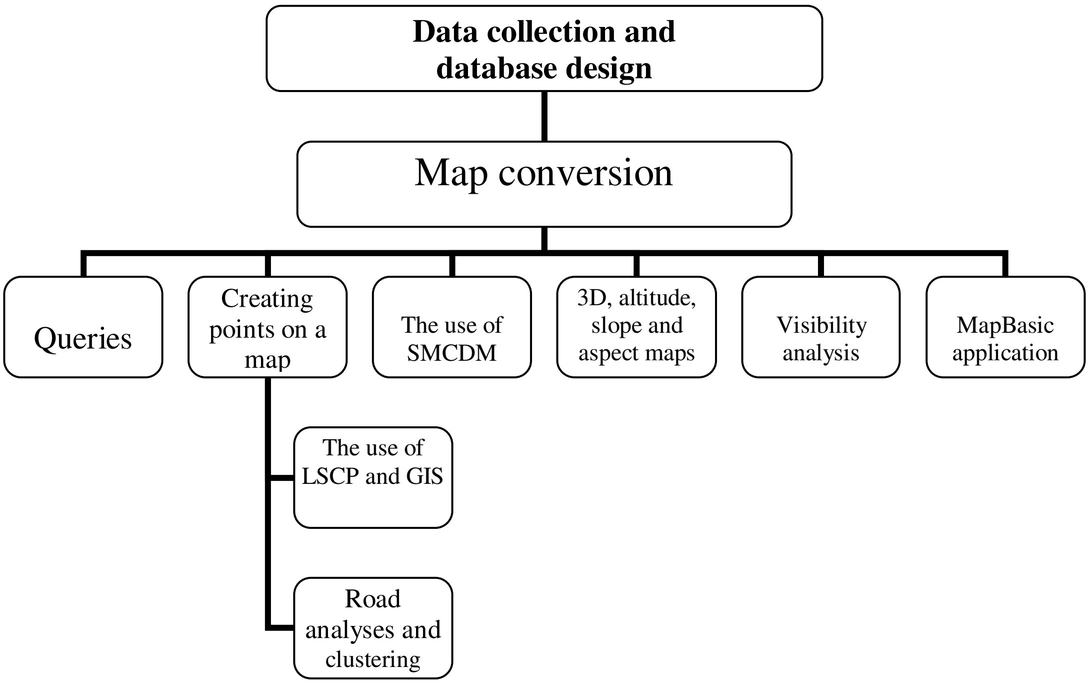

Figure 4.4 Flowchart of the application process.

Table 4.4 Data types and analyses done related to type of data

Data	Analyses
Stand	Thematic map by stand, query by stand,
Compartment data	Query by compartment number, LSCP
Sub-compartment data	Thematic map by state of forests
Stream data	Representation of streams, SMCDM
Hill data	Query of hills by altitude
Settlement areas	Query of settlement areas, SMCDM
Agricultural lands	Query of agricultural lands
Forest road data	Thematic map by roads, buffering analysis, clustering analysis, shortest path analysis
Fire crew location data	Representation of fire crews and related attribute data on a digital map
Water resources data	Representation of water resources and related attribute data on a digital map, SMCDM
Digital elevation models	3D map, altitude map, slope and aspect map, visibility analysis

In this thesis it was aimed to help decision process of directorates as shown in Figure 4.5.

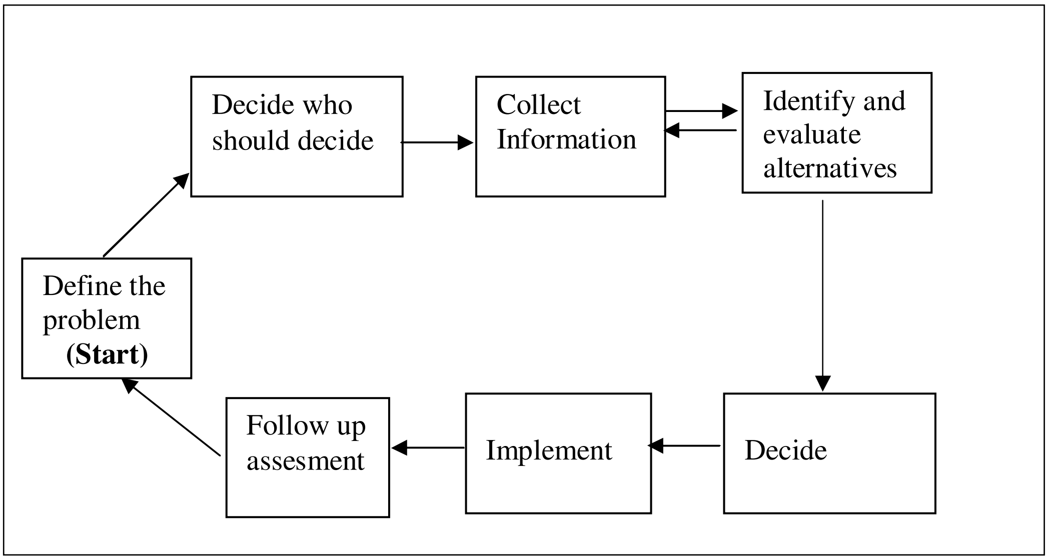

Figure 4.5 Decision process (Power, 2002).

In its the simplest form, the usage of GIS and OR in forest management by this thesis is shown in Figure 4.6.

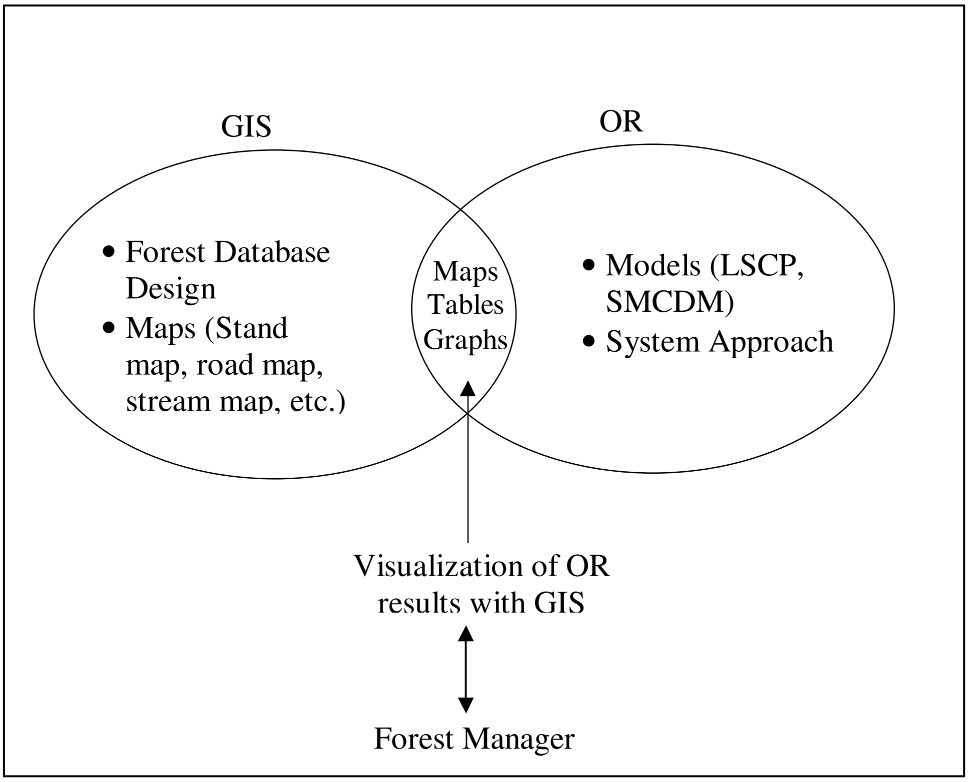

Figure 4.6 Combined use of GIS and OR in forestry.

4.4.1 Queries

Figure 4.7 shows analyses done with query function of GIS.

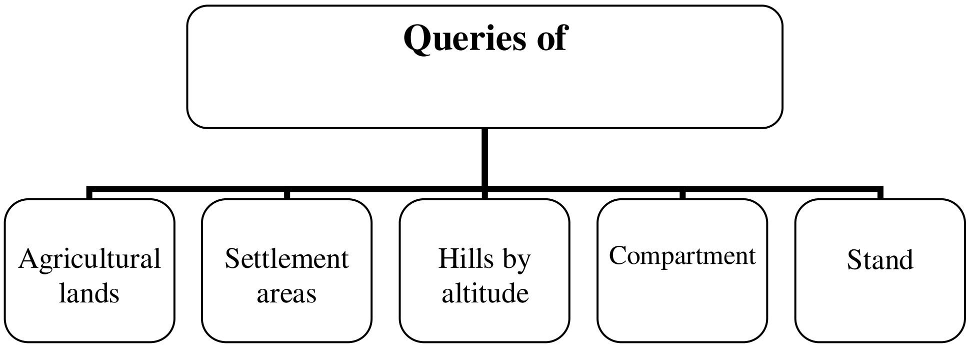

Figure 4.7 Query analyses done in this thesis.

In this part several queries were performed as shown in following figures. Figure 4.8 shows query menu in MapInfo. Figure 4.9 shows step followed in query function. Figures 4.10 and 4.11 represent settlement areas and agricultural lands of İzmir Forest Administration Chief Office by query function, respectively. Figure 4.12 demonstrates settlement areas and agricultural lands simultaneously. Figures 4.13 and 4.14 show hill maps and query of hills whose altitudes are greater than 500 meters, respectively. Figure 4.15 represents the query results.

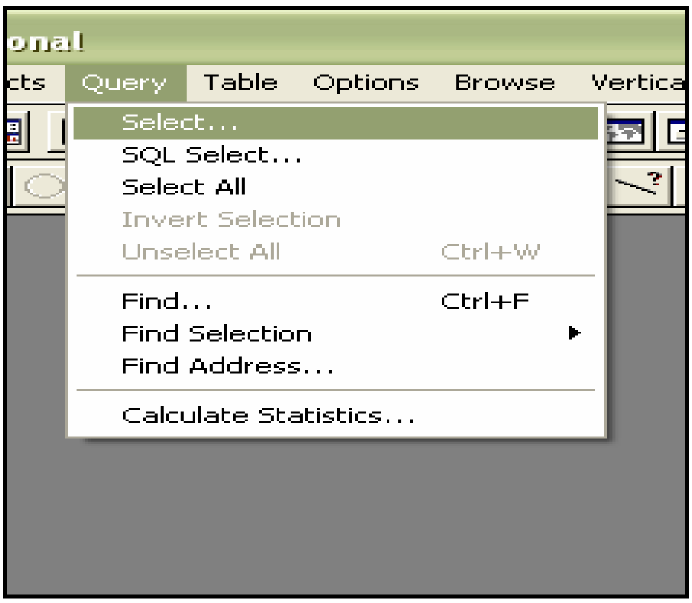

Figure 4.8 Query menu in MapInfo.

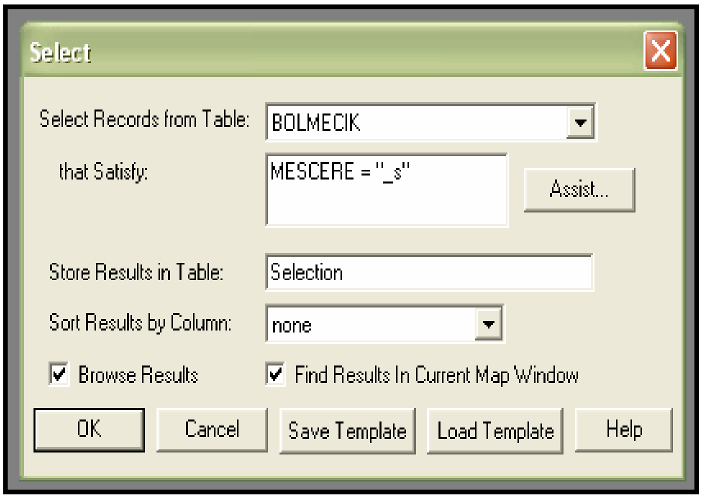

Figure 4.9 Step of query function.

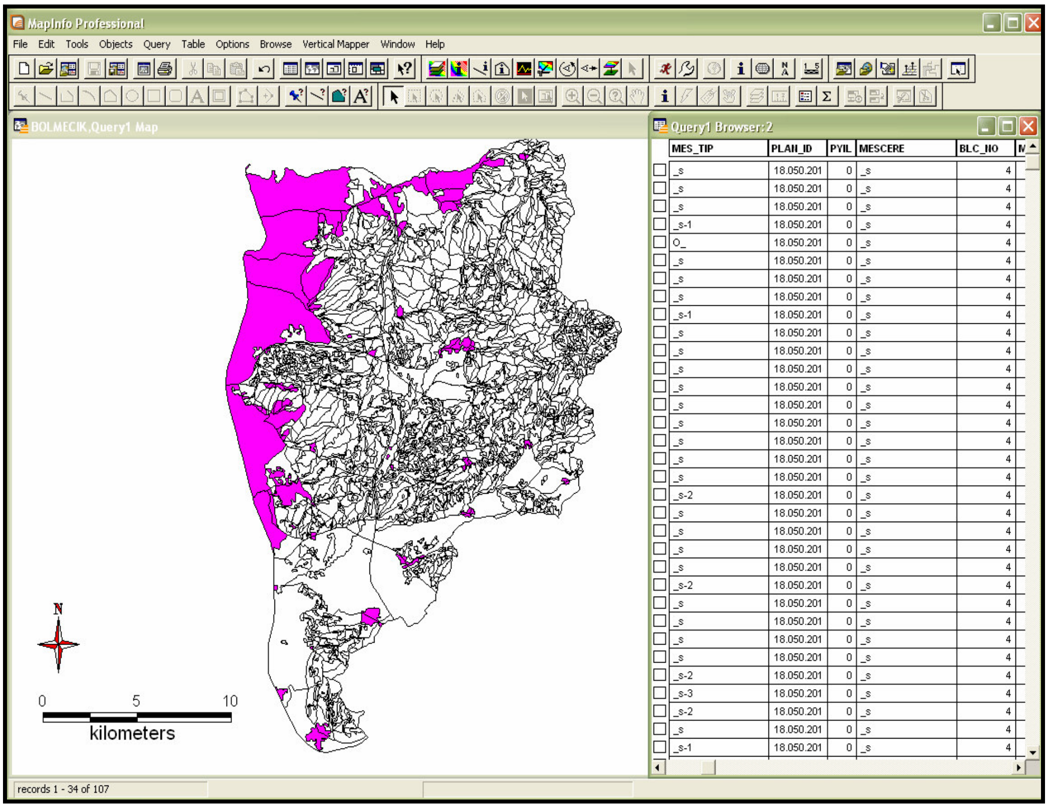

Figure 4.10 Representation of settlement areas by query function.

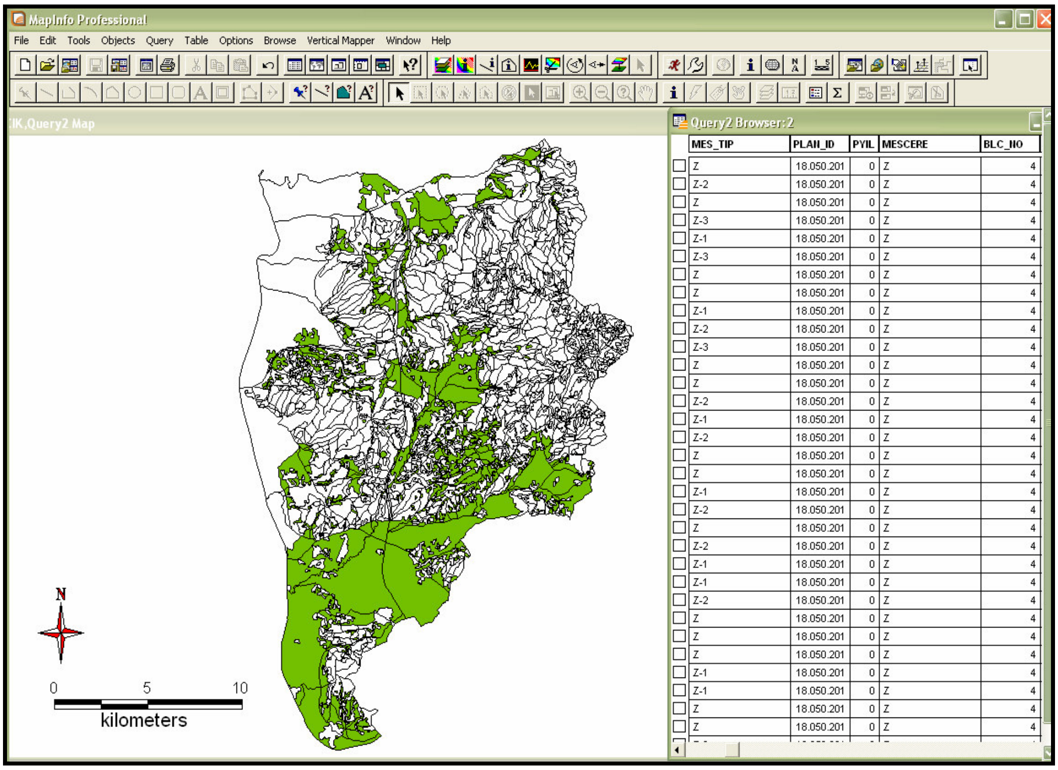

Figure 4.11 Agricultural lands.

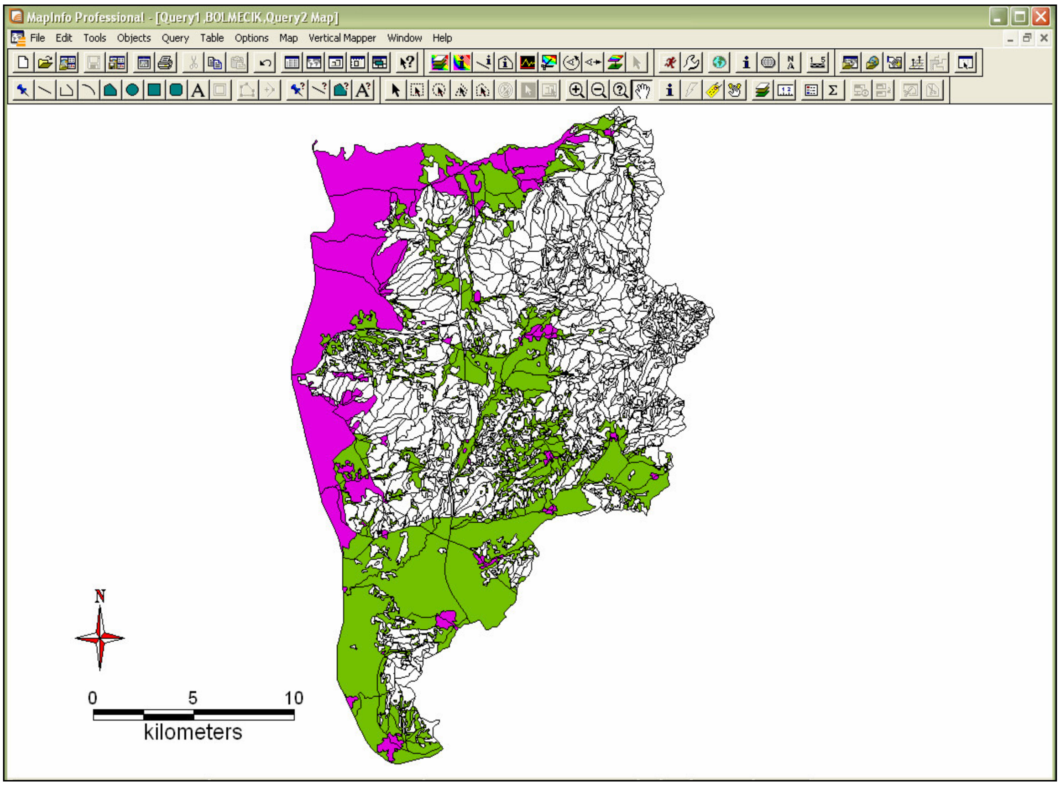

Figure 4.12 Settlement areas and agricultural lands.

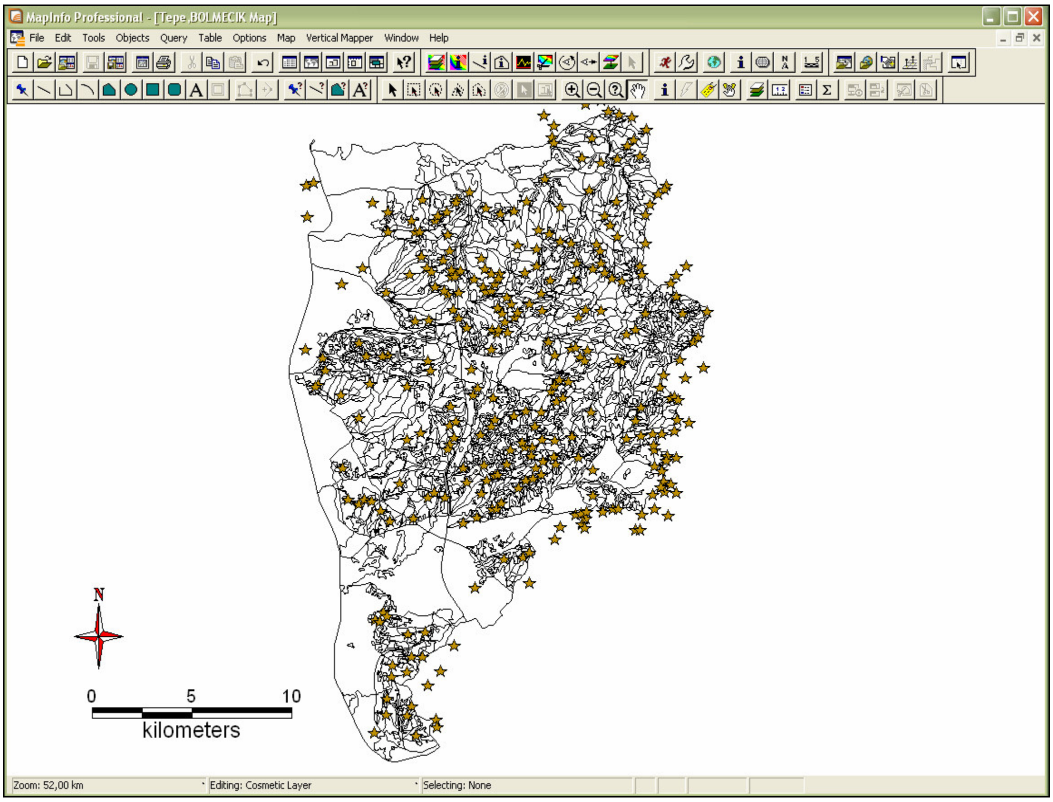

Figure 4.13 Hills of the study area.

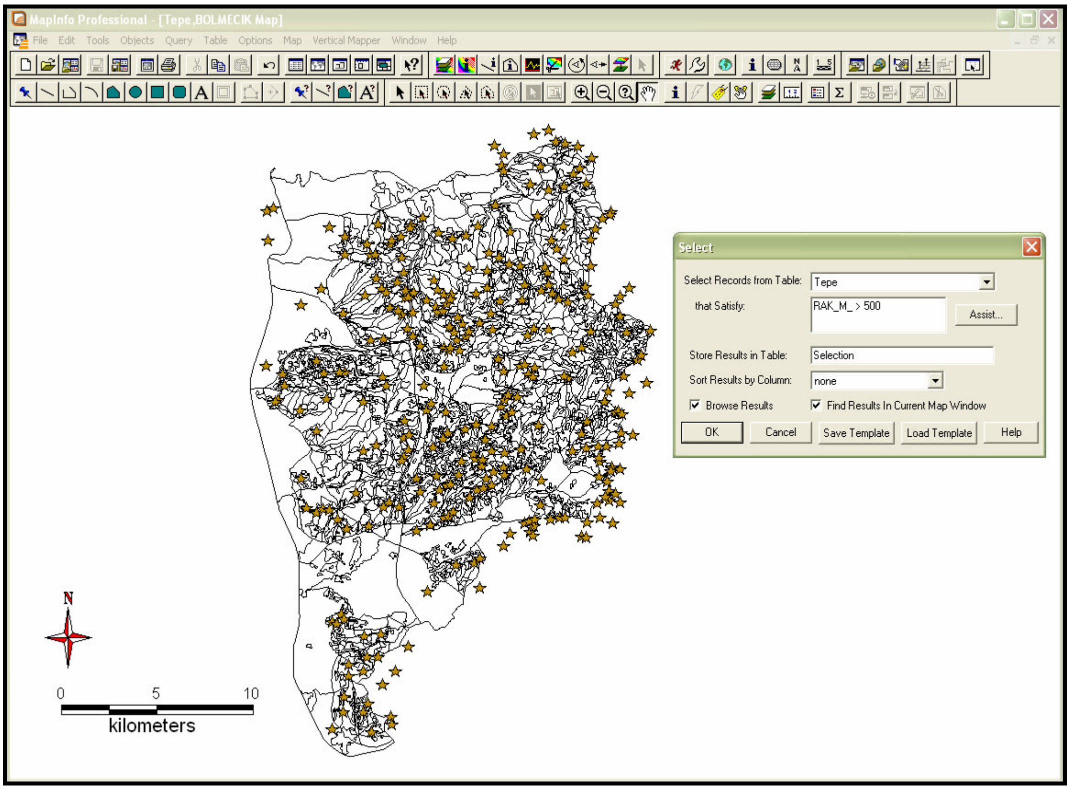

Figure 4.14 Query of hills whose altitudes are greater than 500 meters.

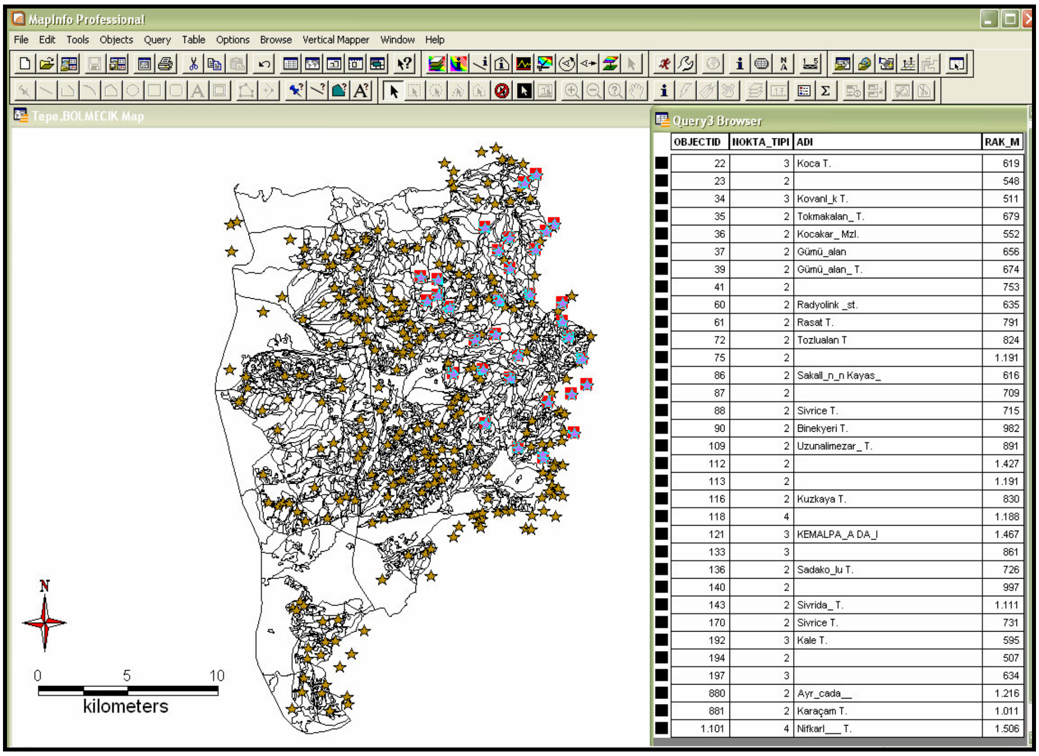

Figure 4.15 Query results.

İzmir Forest Administration Chief Office consists of 445 compartments. It is not practical to see all of them in a detailed way. So for example, if we want to find compartment 30 and general and statistical information of that compartment, results of analyses are shown in Figures 4.16 and 4.17, respectively.

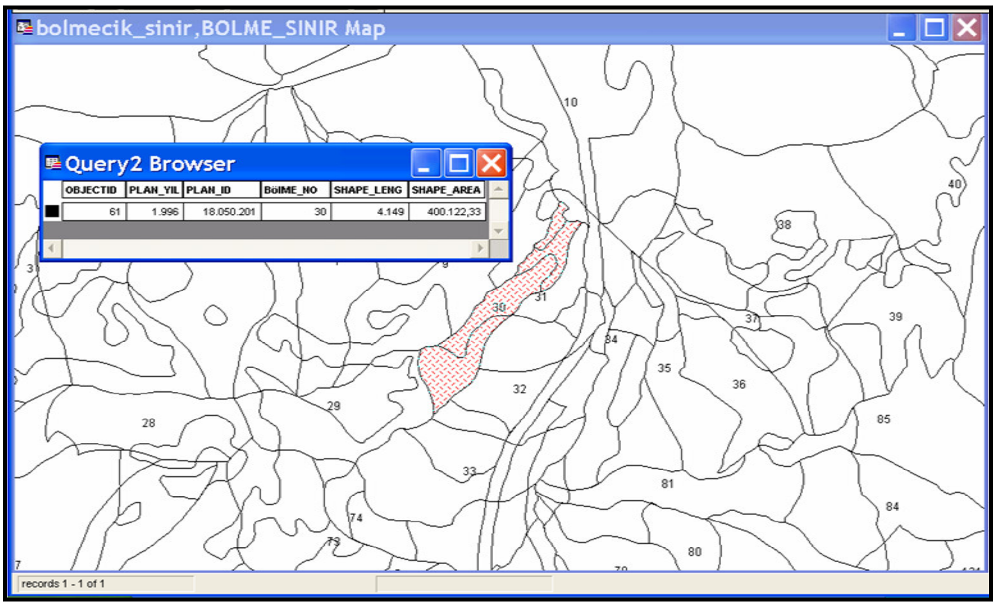

Figure 4.16 Query of compartment 30.

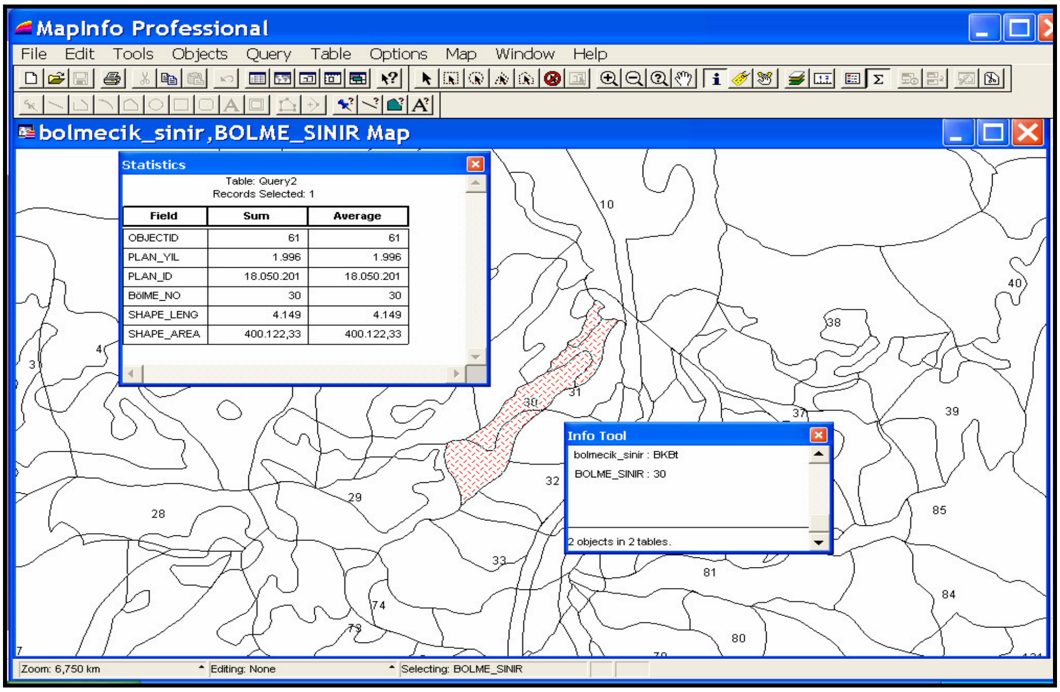

Figure 4.17 General and statistical information of compartment 30.

Figure 4.18 represents query of ÇzÇkcd2 stand. Figure 4.19 shows compartment number and stand type. Figure 4.20 demonstrates info tool for compartment 268.

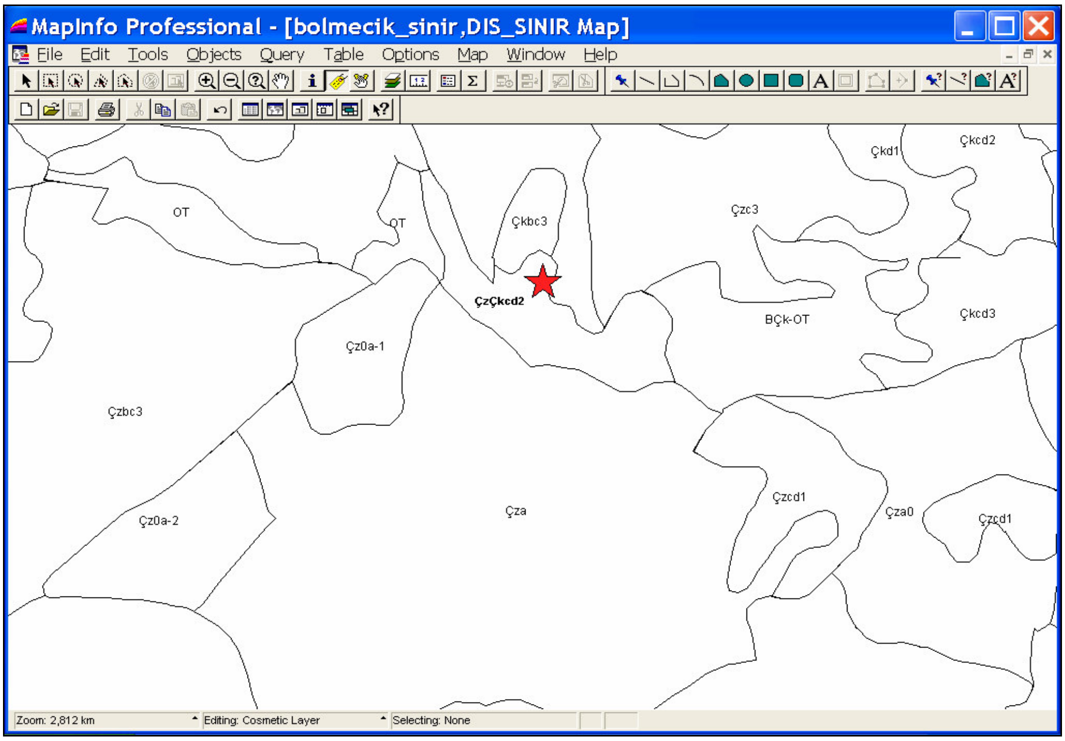

Figure 4.18 Query of ÇzÇkcd2 stand.

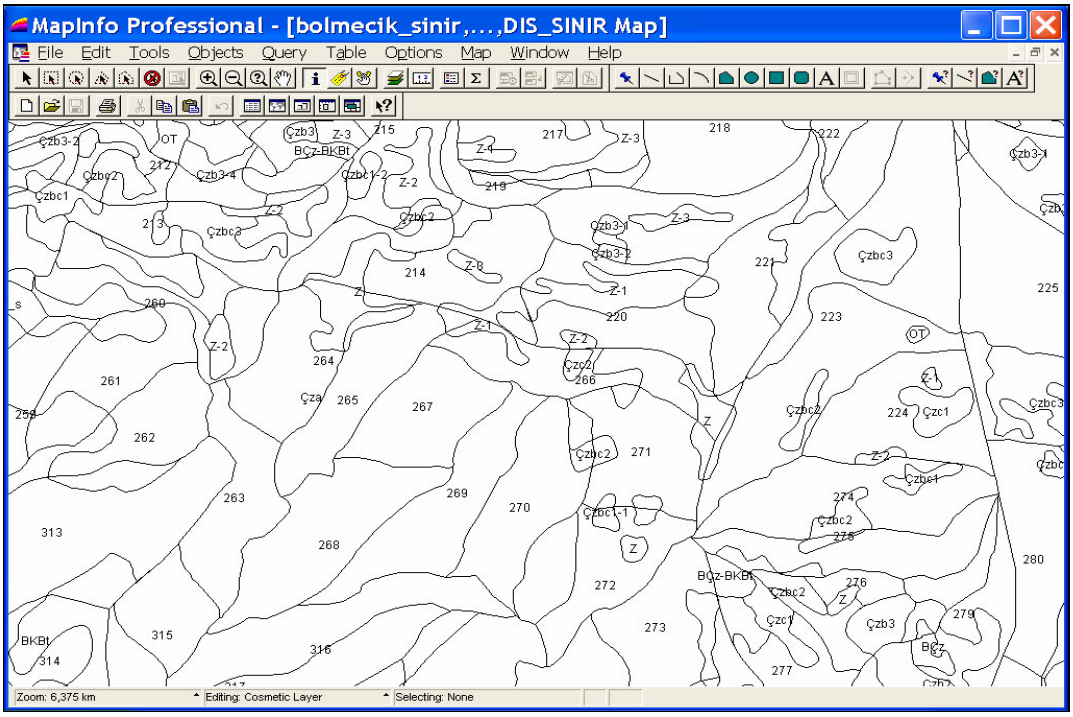

Figure 4.19 Representation of compartment number and stand type simultaneously.

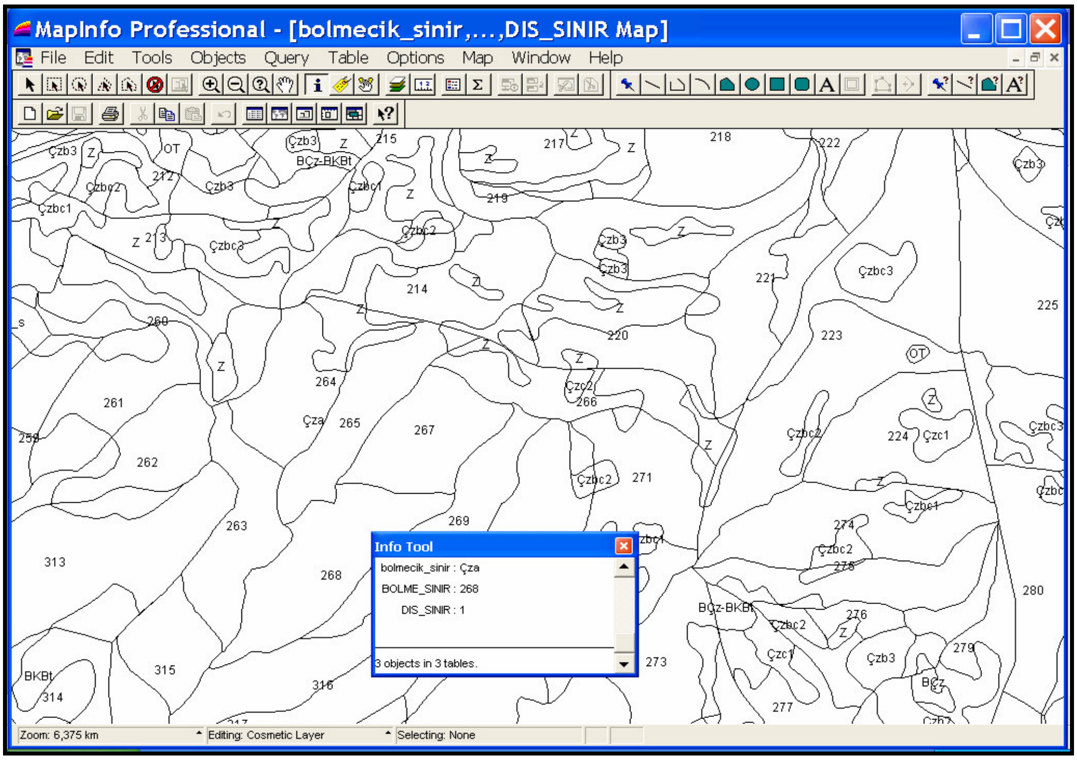

Figure 4.20 Info tool for compartment 268.

Figure 4.21 represents tabular data for selected streams. Figure 4.22 shows info tool, statistics and polyline object of Ayıtlı Stream.

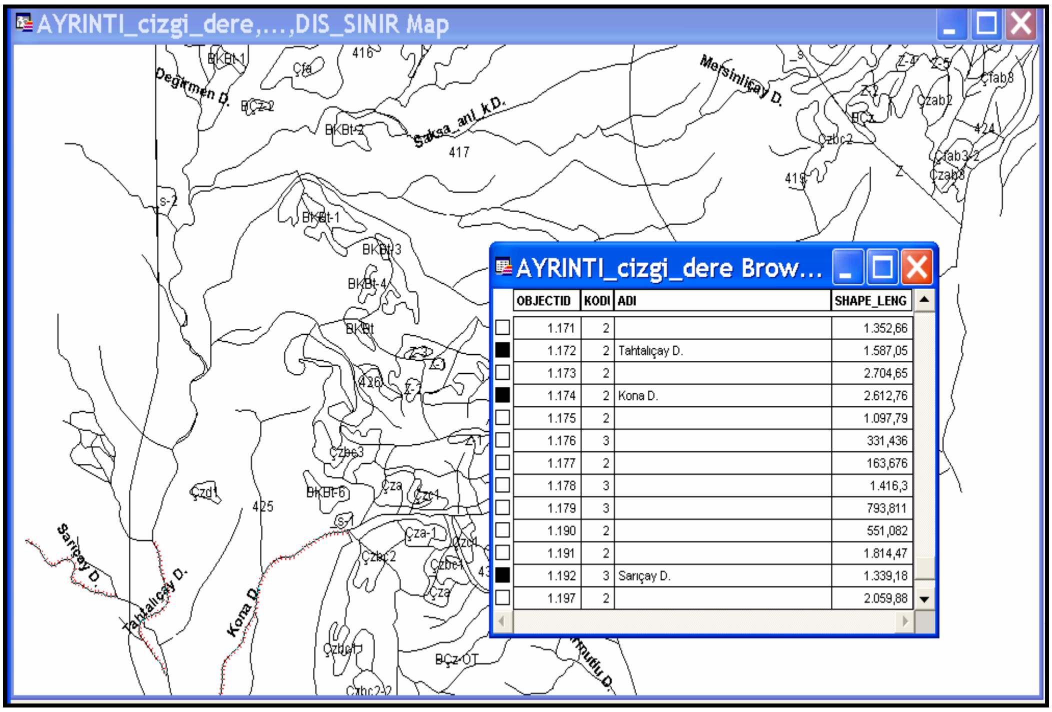

Figure 4.21 Tabular data for selected streams.

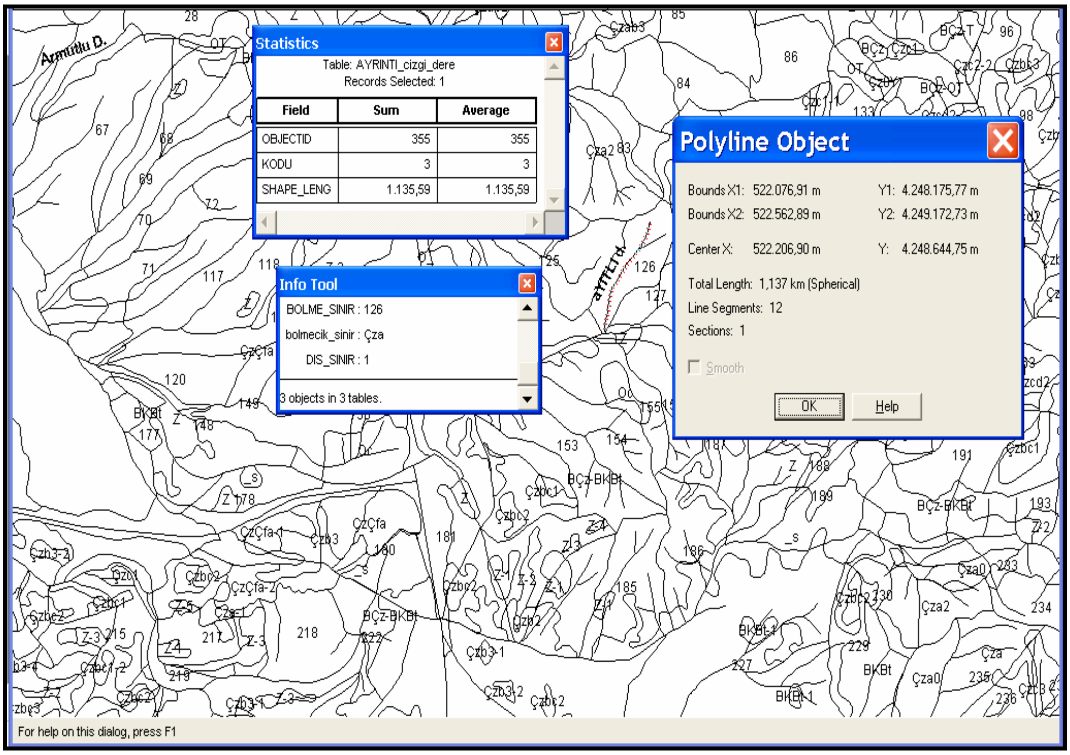

Figure 4.22 Info tool, statistics and polyline object for Ayıtlı Stream.

Figure 4.23 shows stream and compartment map. Figure 4.24 represents stream, stand and compartment map together. The information that Figure 4.24 gives is important to see which compartment contains which stand and to see closeness of streams to the compartment and stands.

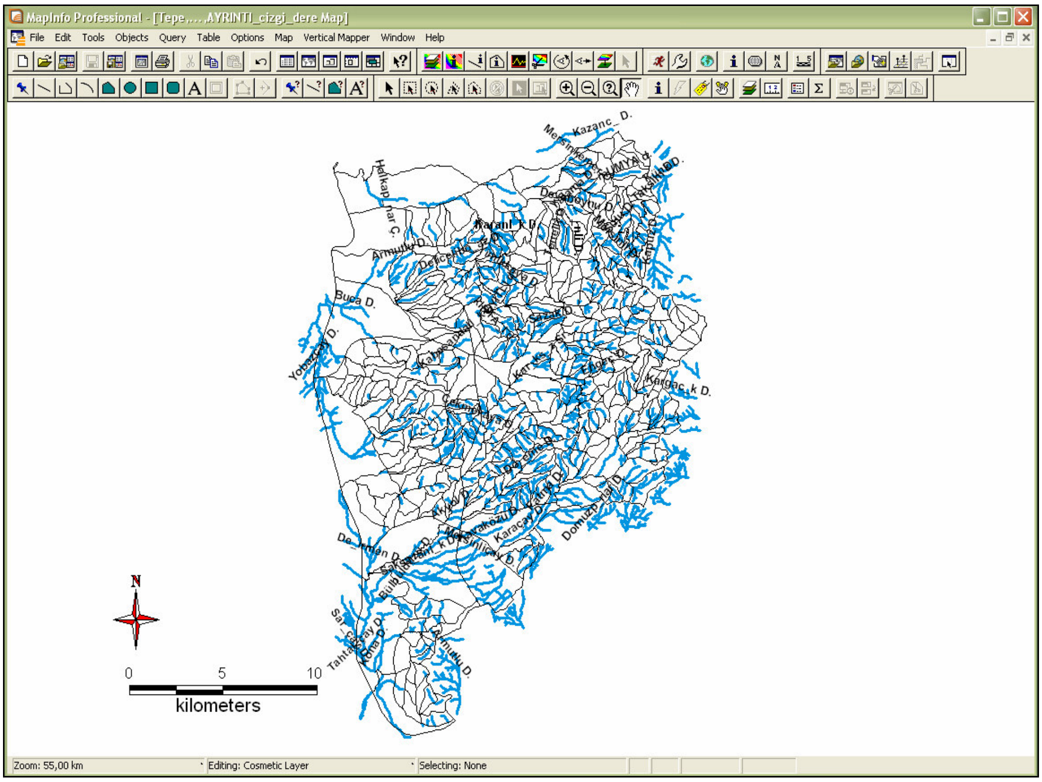

Figure 4.23 Stream map and compartment map.

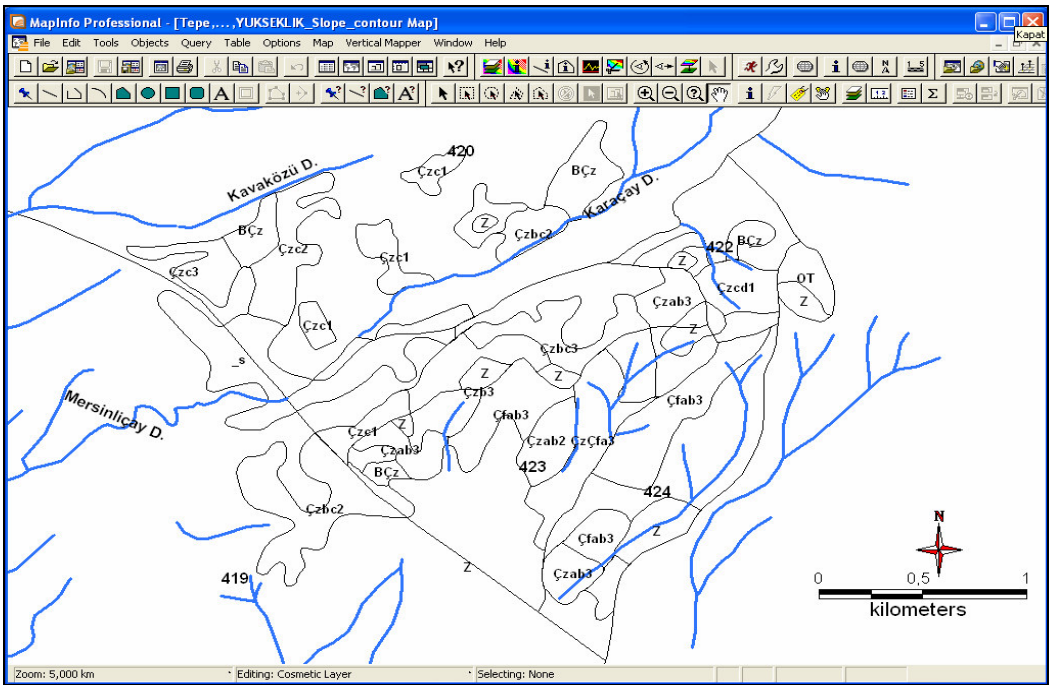

Figure 4.24 Stream map, compartment map and stand map.

4.4.2 Creating Points on a Map

It is very important and vital to minimize damage caused by forest fire. This can be achieved by developing an efficient fire management system. Fire fighting planning is an important component of fire management system.

Fire tower, fire crew, water resources and fire pool location, crew and equipment (helicopter, airplane, water tank and sprinkler) information, communication devices information are components of fire fighting planning.

Figure 4.25 shows database constituted for our study area, İzmir Forest Administration Chief Office, to manage forest and fire effectively.

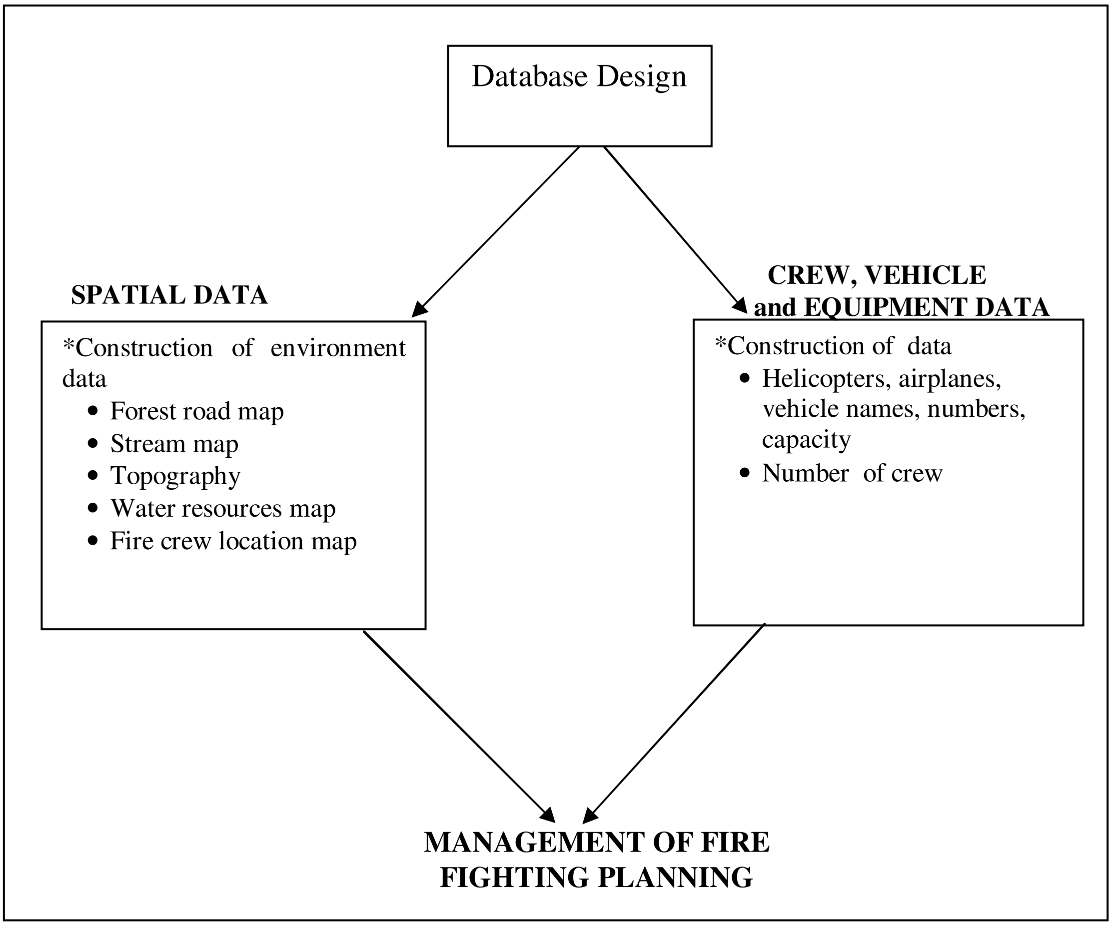

Figure 4.25 Construction of database to manage fire fighting planning.

Water resources and fire crew locations were only available as attribute data with coordinate information. In order to display these points on a map, firstly, coordinates of all water resources and fire crews were converted to decimal degrees and then to meters. East longitude and north latitude coordinates of water resources are, 27° 19′ 06″ and 38° 22′ 15″ for Kaynaklar, 27° 14′ 29″ and 38° 20′ 54″ for Buca Gölet, 27° 10′ 48″and 38° 16′ 53″ for Sarnıç Gölet, 27° 12′ 52″ and 38° 20′ 02″ for BP-Olduruk, respectively. Longitude and latitude coordinates of fire crews are, 27° 06′ 47″ and 38° 27′ 13″ for Karşıyaka, 27° 18′ 05″ and 38° 27′ 02″ for Belkahve, 27° 11′ 40″ and 38° 22′ 30″ for Buca. After converting these degrees to decimal and then to meter, attribute data related to these points were added to the database we constituted. Attribute data were, water resources capacity, crew number per month, number, code, license plate, brand of sprinkler, water tank, grader, helicopter and airplane number. This database was constituted in MapInfo and can be updated when new information must be added. All these attribute data were obtained from İzmir Forest Administration Chief Office handbook, Struggle with Forest Fires 2007 Activity Plan. Locations of fire crews and water resources were shown in Figure 4.26 and Figure 4.27, respectively. Figures 4.28 and 4.29 display spatial and attribute data for fire crews and water resources, respectively.

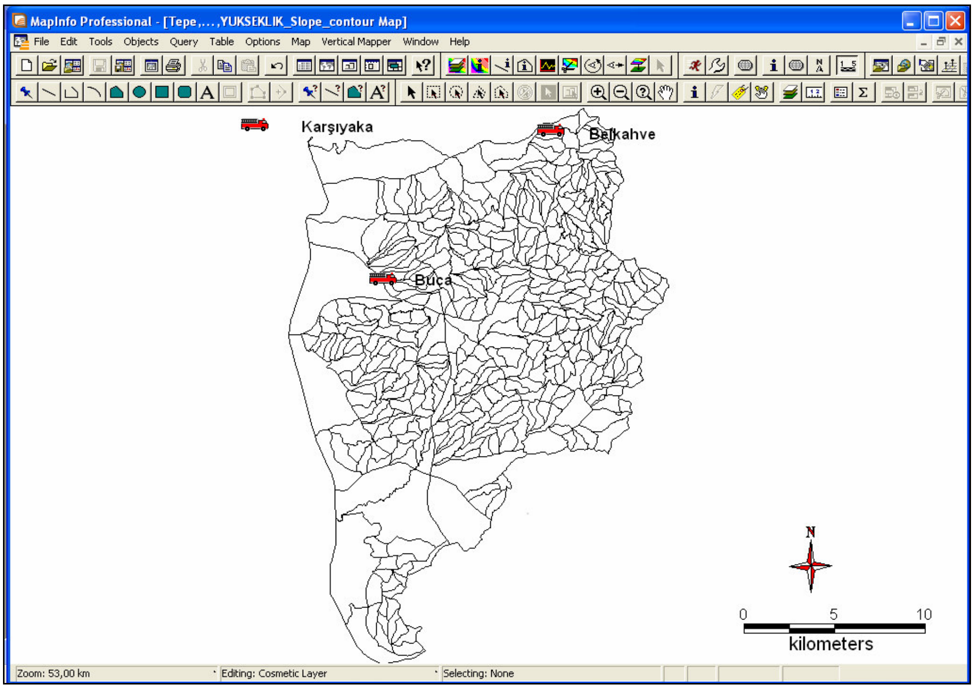

Figure 4.26 İzmir Forest Administration Chief Office fire crews location map.

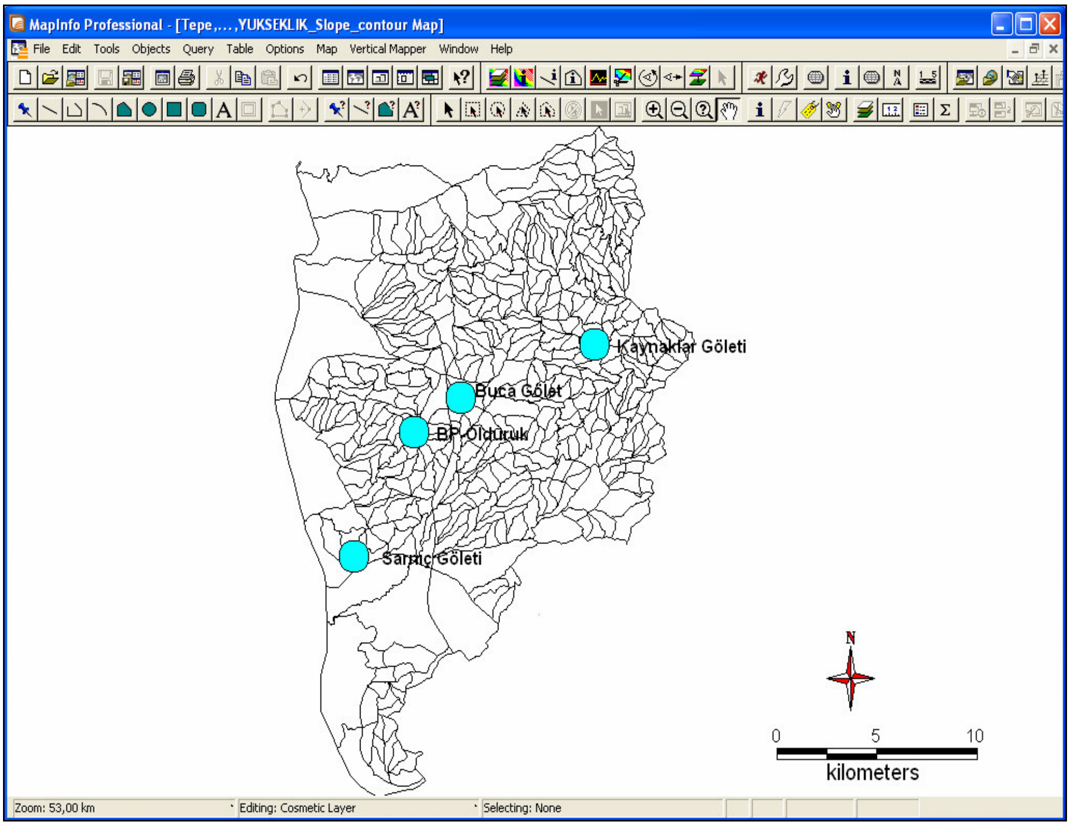

Figure 4.27 İzmir Forest Administration Chief Office water resources location map.

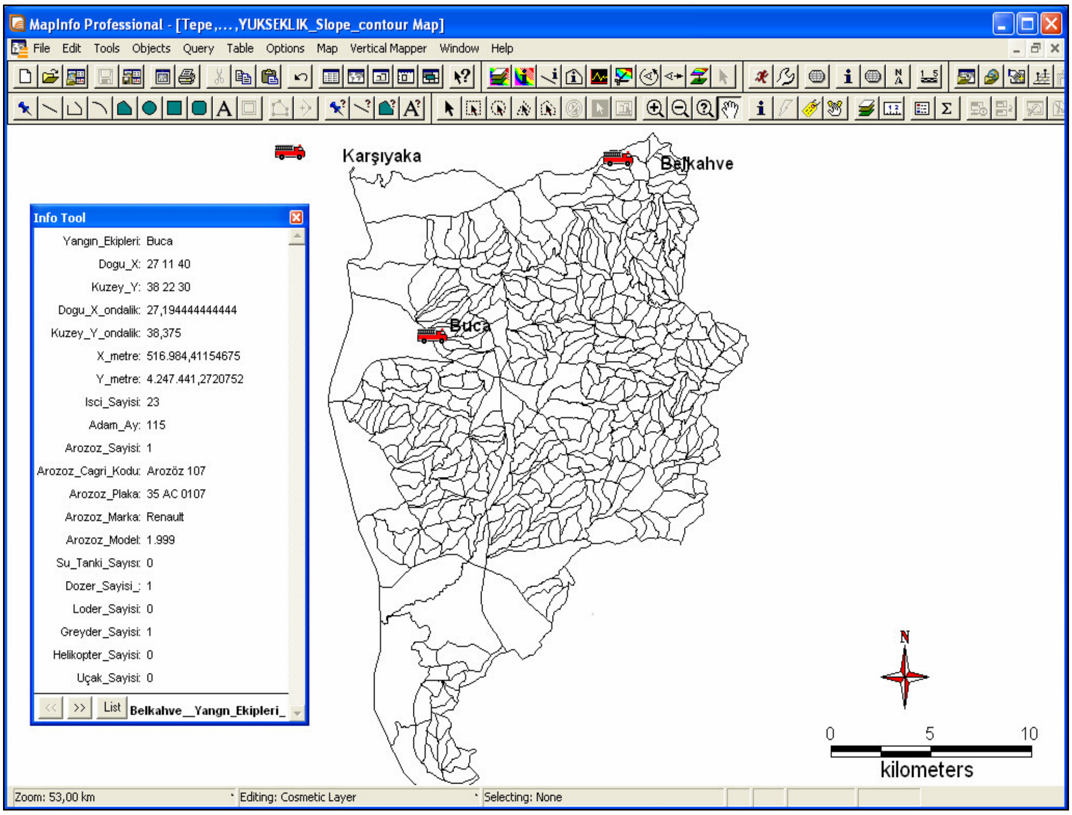

Figure 4.28 Spatial and attribute data for fire crews.

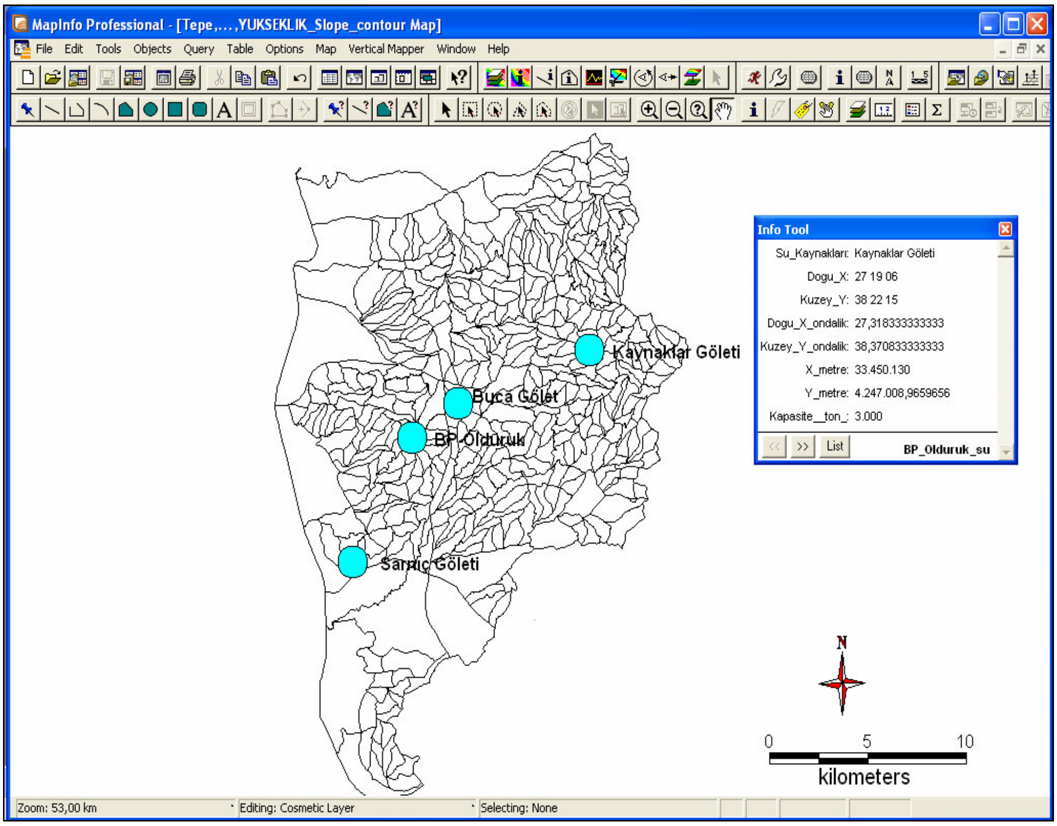

Figure 4.29 Spatial and tabular data for water resources.

4.4.3 Location Set Covering Problem and GIS

In this study it is tried to find minimum numbers of fire crews to cover demand of interested area in fire fighting planning by LSCP and to visualize results by GIS.

As perceived from Figure 4.26, the south region of the study area was deprived of fire crews. For this purpose, this region was selected to find the minimum numbers of fire crews that must be assigned to this area by LSCP.

In Figure 4.30 south region of the study area and the locations of current fire crews were displayed together. Figure 4.31 represents south region of the study area in a detailed way.

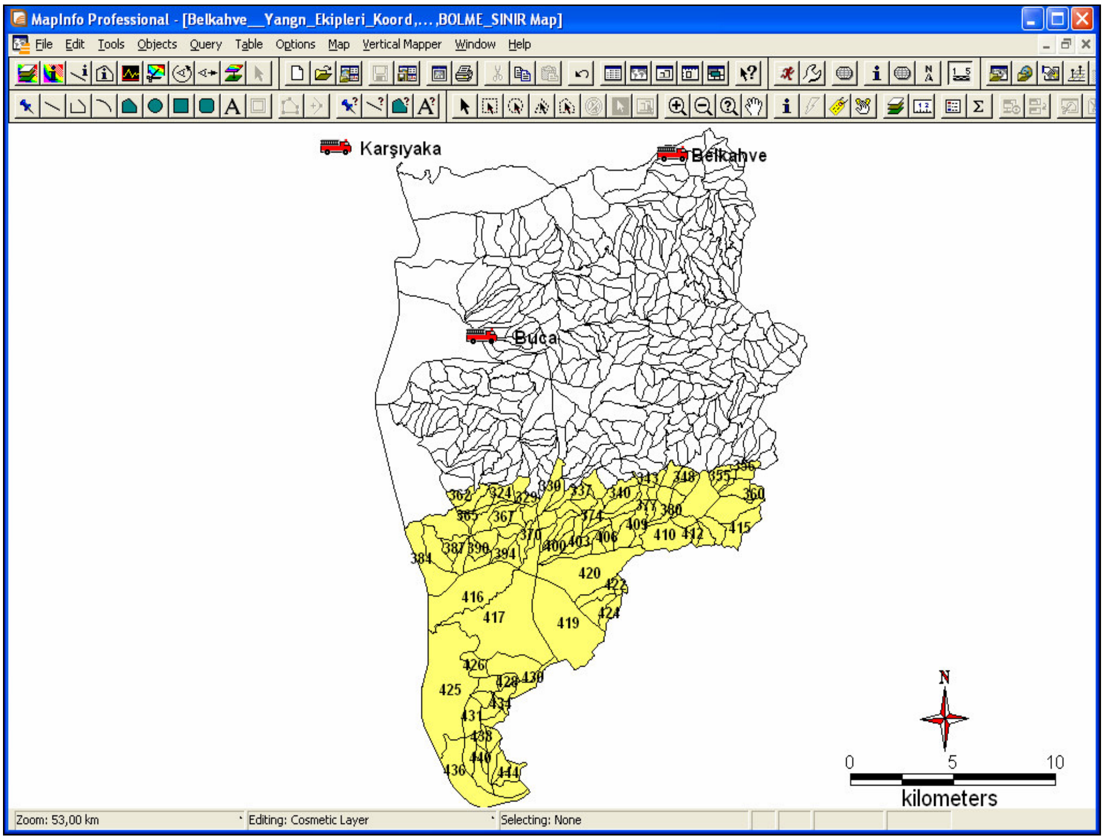

Figure 4.30 South region of study area and locations of current fire crews.

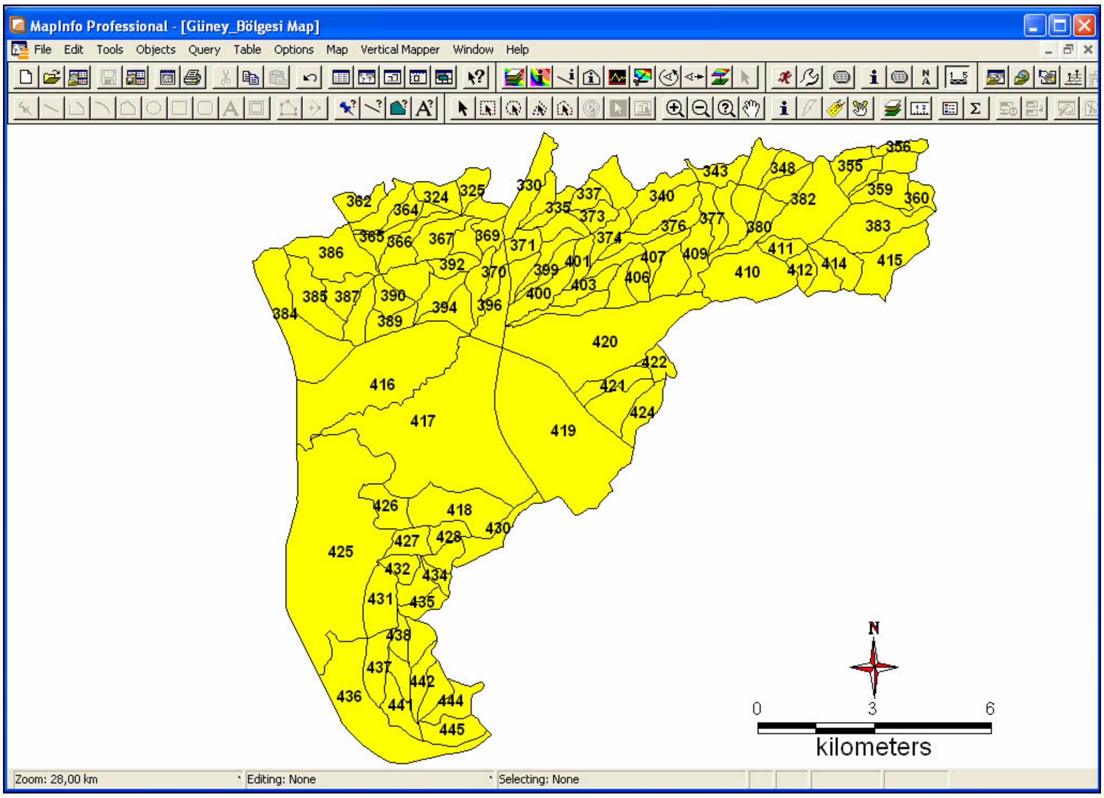

Figure 4.31 South region of İzmir Forest Administration Chief Office.

South region of the study area consists of 102 compartments. LSCP formulation consists of 132 decision variables and 102 constraints. Problem formulation is shown in Formula 4.1. Constraints are constituted according to the compartment numbers and their neighborhood relations. For example, the first constraint means that there must be fire crew either in compartment 324 or in its neighborhood. The objective is to minimize the numbers of compartments that fire crew will be assigned and thereby to minimize the numbers of fire crews.

x_j: compartment number that fire crew will be assigned.

Formula 4.1 is shown as follows:

Minimize $Z = x_{277} + x_{278} + x_{279} + x_{280} + x_{308} + x_{309} + x_{310} + x_{311} + x_{312} + x_{319} + x_{322} + x_{323} + x_{324} + x_{325} + x_{326} + x_{327} + x_{328} + x_{329} + x_{330} + x_{331} + x_{332} + x_{333} + x_{334} + x_{335} + x_{336} + x_{337} + x_{338} + x_{339} + x_{340} + x_{341} + x_{342} + x_{343} + x_{344} + x_{346} + x_{347} + x_{348} + x_{349} + x_{351} + x_{352} + x_{353} + x_{354} + x_{355} + x_{356} + x_{357} + x_{358} + x_{359} + x_{360} + x_{361} + x_{362} + x_{363} + x_{364} + x_{365} + x_{366} + x_{367} + x_{368} + x_{369} + x_{370} + x_{371} + x_{372} + x_{373} + x_{374} + x_{375} + x_{376} + x_{377} + x_{378} + x_{379} + x_{380} + x_{381} + x_{382} + x_{383} + x_{384} + x_{385} + x_{386} + x_{387} + x_{388} + x_{389} + x_{390} + x_{391} + x_{392} + x_{393} + x_{394} + x_{395} + x_{396} + x_{397} + x_{398} + x_{399} + x_{400} + x_{401} + x_{402} + x_{403} + x_{404} + x_{405} + x_{406} + x_{407} + x_{408} + x_{409} + x_{410} + x_{411} + x_{412} + x_{413} + x_{414} + x_{415} + x_{416} + x_{417} + x_{418} + x_{419} + x_{420} + x_{421} + x_{422} + x_{423} + x_{424} + x_{425} + x_{426} + x_{427} + x_{428} + x_{429} + x_{430} + x_{431} + x_{432} + x_{433} + x_{434} + x_{435} + x_{436} + x_{437} + x_{438} + x_{439} + x_{440} + x_{441} + x_{442} + x_{443} + x_{444} + x_{445}$

s.t.

$x_{323} + x_{324} + x_{325} + x_{363} + x_{364} + x_{365} + x_{366} + x_{367} \geq 1$ (Compartment 324 and its neighborhood)

$x_{277} + x_{323} + x_{324} + x_{325} + x_{326} + x_{327} + x_{329} + x_{366} + x_{367} \geq 1$ (Compartment 325 and its neighborhood)

$x_{325} + x_{327} + x_{328} + x_{329} + x_{330} + x_{366} + x_{367} + x_{368} + x_{369} \geq 1$ (Compartment 329 and its neighborhood)

$x_{278} + x_{279} + x_{280} + x_{327} + x_{328} + x_{329} + x_{330} + x_{331} + x_{332} + x_{333} + x_{334} + x_{335} + x_{369} + x_{370} + x_{371} \geq 1$ (Compartment 330 and its neighborhood)

$x_{330} + x_{331} + x_{332} + x_{333} + x_{334} + x_{335} + x_{371} \geq 1$ (Compartment 333 and its neighborhood)

$x_{330} + x_{333} + x_{334} + x_{335} + x_{336} + x_{337} + x_{371} + x_{372} + x_{373} \geq 1$ (Compartment 335 and its neighborhood)

$x_{335} + x_{336} + x_{337} + x_{338} + x_{372} + x_{373} \geq 1$ (Compartment 337 and its neighborhood)

$x_{336} + x_{337} + x_{338} + x_{339} + x_{340} + x_{373} + x_{374} \geq 1$ (Compartment 338 and its neighborhood)

$x_{338} + x_{339} + x_{340} + x_{341} + x_{343} + x_{374} + x_{375} + x_{377} \geq 1$ (Compartment 340 and its neighborhood)

$x_{340} + x_{341} + x_{343} + x_{344} + x_{347} + x_{375} + x_{377} + x_{378} + x_{379} \geq 1$ (Compartment 343 and its neighborhood)

$x_{343} + x_{344} + x_{346} + x_{347} + x_{348} + x_{349} + x_{378} + x_{379} \geq 1$ (Compartment 347 and its neighborhood)

$x_{347} + x_{348} + x_{349} + x_{351} + x_{379} + x_{381} + x_{382} \geq 1$ (Compartment 348 and its neighborhood)

$x_{351} + x_{352} + x_{353} + x_{354} + x_{355} + x_{356} + x_{357} + x_{382} \geq 1$ (Compartment 355 and its neighborhood)

$x_{308} + x_{309} + x_{310} + x_{311} + x_{354} + x_{355} + x_{356} + x_{357} + x_{358} \geq 1$ (Compartment 356 and its neighborhood)

$x_{355} + x_{356} + x_{357} + x_{358} + x_{382} \geq 1$ (Compartment 357 and its neighborhood)

$x_{356} + x_{357} + x_{358} + x_{359} + x_{382} \geq 1$ (Compartment 358 and its neighborhood)

$x_{358} + x_{359} + x_{360} + x_{382} + x_{383} \geq 1$ (Compartment 359 and its neighborhood)

$x_{359} + x_{360} + x_{383} \geq 1$ (Compartment 360 and its neighborhood)

$x_{312} + x_{319} + x_{361} + x_{362} + x_{363} + x_{386} \geq 1$ (Compartment 362 and its neighborhood)

$x_{319} + x_{322} + x_{323} + x_{324} + x_{362} + x_{363} + x_{364} + x_{386} \geq 1$ (Compartment 363 and its neighborhood)

$x_{324} + x_{363} + x_{364} + x_{365} + x_{386} \geq 1$ (Compartment 364 and its neighborhood)

$x_{324} + x_{364} + x_{365} + x_{366} + x_{386} \geq 1$ (Compartment 365 and its neighborhood)

$x_{324} + x_{325} + x_{329} + x_{365} + x_{366} + x_{367} + x_{390} + x_{391} \geq 1$ (Compartment 366 and its neighborhood)

$x_{324} + x_{325} + x_{329} + x_{366} + x_{367} + x_{368} + x_{391} + x_{392} \geq 1$ (Compartment 367 and its neighborhood)

$x_{329} + x_{367} + x_{368} + x_{369} + x_{392} + x_{395} \geq 1$ (Compartment 368 and its neighborhood)

$x_{329} + x_{330} + x_{368} + x_{369} + x_{370} + x_{371} + x_{395} \geq 1$ (Compartment 369 and its neighborhood)

$x_{330} + x_{369} + x_{370} + x_{371} + x_{395} + x_{396} + x_{397} \geq 1$ (Compartment 370 and its neighborhood)

$x_{330} + x_{333} + x_{335} + x_{369} + x_{370} + x_{371} + x_{372} + x_{396} + x_{397} + x_{398} \geq 1$ (Compartment 371 and its neighborhood)

$x_{335} + x_{337} + x_{371} + x_{372} + x_{373} + x_{398} + x_{401} \geq 1$ (Compartment 372 and its neighborhood)

$x_{335} + x_{337} + x_{338} + x_{372} + x_{373} + x_{374} + x_{401} \geq 1$ (Compartment 373 and its neighborhood)

$x_{338} + x_{340} + x_{372} + x_{373} + x_{374} + x_{375} + x_{376} + x_{401} + x_{402} \geq 1$ (Compartment 374 and its neighborhood)

$x_{340} + x_{343} + x_{374} + x_{375} + x_{376} + x_{377} \geq 1$ (Compartment 375 and its neighborhood)

$x_{374} + x_{375} + x_{376} + x_{377} + x_{402} + x_{407} + x_{409} \geq 1$ (Compartment 376 and its neighborhood)

$x_{340} + x_{343} + x_{375} + x_{376} + x_{377} + x_{378} + x_{380} + x_{409} \geq 1$ (Compartment 377 and its neighborhood)

$x_{343} + x_{347} + x_{377} + x_{378} + x_{379} + x_{380} \geq 1$ (Compartment 378 and its neighborhood)

$x_{343} + x_{347} + x_{348} + x_{378} + x_{379} + x_{380} + x_{381} \geq 1$ (Compartment 379 and its neighborhood)

$x_{377} + x_{378} + x_{379} + x_{380} + x_{381} + x_{382} + x_{409} + x_{410} + x_{411} \geq 1$ (Compartment 380 and its neighborhood)

$x_{348} + x_{351} + x_{379} + x_{380} + x_{381} + x_{382} \geq 1$ (Compartment 381 and its neighborhood)

$x_{348} + x_{351} + x_{352} + x_{355} + x_{357} + x_{358} + x_{359} + x_{380} + x_{381} + x_{382} + x_{383} + x_{411} + x_{412} + x_{413} + x_{414} \geq 1$ (Compartment 382 and its neighborhood)

$x_{359} + x_{360} + x_{382} + x_{383} + x_{414} + x_{415} \geq 1$ (Compartment 383 and its neighborhood)

$x_{312} + x_{384} + x_{385} + x_{386} + x_{388} + x_{416} \geq 1$ (Compartment 384 and its neighborhood)

$x_{384} + x_{385} + x_{386} + x_{387} + x_{388} \geq 1$ (Compartment 385 and its neighborhood)

$x_{312} + x_{362} + x_{363} + x_{364} + x_{365} + x_{366} + x_{384} + x_{385} + x_{386} + x_{387} + x_{390} + x_{391} \geq 1$ (Compartment 386 and its neighborhood)

$x_{385} + x_{386} + x_{387} + x_{388} + x_{390} \geq 1$ (Compartment 387 and its neighborhood)

$x_{384} + x_{385} + x_{387} + x_{388} + x_{389} + x_{390} + x_{416} \geq 1$ (Compartment 388 and its neighborhood)

$x_{388} + x_{389} + x_{390} + x_{391} + x_{393} + x_{394} + x_{416} \geq 1$ (Compartment 389 and its neighborhood)

$x_{366} + x_{386} + x_{387} + x_{388} + x_{389} + x_{390} + x_{391} + x_{393} \geq 1$ (Compartment 390 and its neighborhood)

$x_{366} + x_{367} + x_{389} + x_{390} + x_{391} + x_{392} + x_{393} \geq 1$ (Compartment 391 and its neighborhood)

$x_{367} + x_{368} + x_{391} + x_{392} + x_{393} + x_{395} \geq 1$ (Compartment 392 and its neighborhood)

$x_{389} + x_{390} + x_{391} + x_{392} + x_{393} + x_{394} + x_{395} + x_{416} \geq 1$ (Compartment 393 and its neighborhood)

$x_{389} + x_{393} + x_{394} + x_{395} + x_{396} + x_{416} + x_{417} \geq 1$ (Compartment 394 and its neighborhood)

$x_{368} + x_{369} + x_{370} + x_{392} + x_{393} + x_{394} + x_{395} + x_{396} \geq 1$ (Compartment 395 and its neighborhood)

$x_{370} + x_{371} + x_{394} + x_{395} + x_{396} + x_{397} + x_{400} + x_{404} + x_{416} + x_{417} + x_{419} + x_{420} \geq 1$ (Compartment 396 and its neighborhood)

$x_{370} + x_{371} + x_{396} + x_{397} + x_{398} + x_{399} + x_{400} \geq 1$ (Compartment 397 and its neighborhood)

$x_{371} + x_{372} + x_{397} + x_{398} + x_{399} + x_{401} \geq 1$ (Compartment 398 and its neighborhood)

$x_{397} + x_{398} + x_{399} + x_{400} + x_{401} \geq 1$ (Compartment 399 and its neighborhood)

$x_{396} + x_{397} + x_{399} + x_{400} + x_{401} + x_{403} + x_{404} \geq 1$ (Compartment 400 and its neighborhood)

$x_{372} + x_{373} + x_{374} + x_{398} + x_{399} + x_{400} + x_{401} + x_{402} + x_{403} \geq 1$ (Compartment 401 and its neighborhood)

$x_{374} + x_{376} + x_{401} + x_{402} + x_{403} + x_{405} + x_{406} + x_{407} \geq 1$ (Compartment 402 and its neighborhood)

$x_{400} + x_{401} + x_{402} + x_{403} + x_{404} + x_{405} \geq 1$ (Compartment 403 and its neighborhood)

$x_{396} + x_{400} + x_{403} + x_{404} + x_{405} + x_{420} \geq 1$ (Compartment 404 and its neighborhood)

$x_{402} + x_{403} + x_{404} + x_{405} + x_{406} + x_{420} \geq 1$ (Compartment 405 and its neighborhood)

$x_{402} + x_{405} + x_{406} + x_{407} + x_{408} + x_{420} \geq 1$ (Compartment 406 and its neighborhood)

$x_{376} + x_{402} + + x_{406} + x_{407} + x_{408} + x_{409} \geq 1$ (Compartment 407 and its neighborhood)

$x_{406} + x_{407} + x_{408} + x_{409} + x_{420} \geq 1$ (Compartment 408 and its neighborhood)

$x_{376} + x_{377} + x_{380} + x_{407} + x_{408} + x_{409} + x_{410} + x_{420} \geq 1$ (Compartment 409 and its neighborhood)

$x_{380} + x_{409} + x_{410} + x_{411} + x_{412} + x_{420} \geq 1$ (Compartment 410 and its neighborhood)

$x_{380} + x_{382} + x_{410} + x_{411} + x_{412} + x_{413} + x_{414} \geq 1$ (Compartment 411 and its neighborhood)

$x_{410} + x_{411} + x_{412} + x_{413} \geq 1$ (Compartment 412 and its neighborhood)

$x_{382} + x_{411} + x_{412} + x_{413} + x_{414} \geq 1$ (Compartment 413 and its neighborhood)

$x_{382} + x_{383} + x_{411} + x_{413} + x_{414} + x_{415} \geq 1$ (Compartment 414 and its neighborhood)

$x_{383} + x_{414} + x_{415} \geq 1$ (Compartment 415 and its neighborhood)

$x_{384} + x_{388} + x_{389} + x_{393} + x_{394} + x_{416} + x_{417} + x_{425} \geq 1$ (Compartment 416 and its neighborhood)

$x_{396} + x_{416} + x_{417} + x_{418} + x_{419} + x_{420} + x_{425} + x_{426} + x_{430} \geq 1$ (Compartment 417 and its neighborhood)

$x_{417} + x_{418} + x_{426} + x_{427} + x_{428} + x_{430} \geq 1$ (Compartment 418 and its neighborhood)

$x_{396} + x_{417} + x_{419} + x_{420} + x_{421} + x_{423} + x_{424} + x_{430} \geq 1$ (Compartment 419 and its neighborhood)

$x_{396} + x_{404} + x_{405} + x_{406} + x_{408} + x_{409} + x_{410} + x_{419} + x_{420} + x_{421} + x_{422} \geq 1$ (Compartment 420 and its neighborhood)

$x_{419} + x_{420} + x_{421} + x_{422} + x_{423} \geq 1$ (Compartment 421 and its neighborhood)

$x_{420} + x_{421} + x_{422} + x_{423} + x_{424} \geq 1$ (Compartment 422 and its neighborhood)

$x_{419} + x_{421} + x_{422} + x_{423} + x_{424} \geq 1$ (Compartment 423 and its neighborhood)

$x_{419} + x_{422} + x_{423} + x_{424} \geq 1$ (Compartment 424 and its neighborhood)

$x_{416} + x_{417} + x_{425} + x_{426} + x_{427} + x_{431} + x_{432} + x_{436} + x_{437} \geq 1$ (Compartment 425 and its neighborhood)

$x_{417} + x_{418} + x_{425} + x_{426} + x_{427} \geq 1$ (Compartment 426 and its neighborhood)

$x_{418} + x_{425} + x_{426} + x_{427} + x_{428} + x_{429} + x_{432} + x_{433} + x_{434} \geq 1$ (Compartment 427 and its neighborhood)

$x_{418} + x_{427} + x_{428} + x_{429} + x_{430} \geq 1$ (Compartment 428 and its neighborhood)

$x_{427} + x_{428} + x_{429} + x_{430} + x_{434} \geq 1$ (Compartment 429 and its neighborhood)

$x_{418} + x_{419} + x_{428} + x_{429} + x_{430} \geq 1$ (Compartment 430 and its neighborhood)

$x_{425} + x_{431} + x_{432} + x_{433} + x_{435} + x_{436} + x_{437} + x_{438} \geq 1$ (Compartment 431 and its neighborhood)

$x_{425} + x_{427} + x_{431} + x_{432} + x_{433} \geq 1$ (Compartment 432 and its neighborhood)

$x_{427} + x_{431} + x_{432} + x_{433} + x_{434} + x_{435} \geq 1$ (Compartment 433 and its neighborhood)

$x_{427} + x_{429} + x_{433} + x_{434} + x_{435} \geq 1$ (Compartment 434 and its neighborhood)

$x_{431} + x_{433} + x_{434} + x_{435} + x_{438} + x_{439} \geq 1$ (Compartment 435 and its neighborhood)

$x_{425} + x_{431} + x_{436} + x_{437} + x_{441} + x_{445} \geq 1$ (Compartment 436 and its neighborhood)

$x_{431} + x_{436} + x_{437} + x_{438} + x_{440} + x_{441} \geq 1$ (Compartment 437 and its neighborhood)

$x_{431} + x_{435} + x_{437} + x_{438} + x_{439} + x_{440} \geq 1$ (Compartment 438 and its neighborhood)

$x_{435} + x_{438} + x_{439} + x_{440} + x_{442} \geq 1$ (Compartment 439 and its neighborhood)

$x_{437} + x_{438} + x_{439} + x_{440} + x_{441} + x_{442} \geq 1$ (Compartment 440 and its neighborhood)

$x_{436} + x_{437} + x_{440} + x_{441} + x_{442} + x_{443} + x_{445} \geq 1$ (Compartment 441 and its neighborhood)

$x_{439} + x_{440} + x_{441} + x_{442} + x_{443} \geq 1$ (Compartment 442 and its neighborhood)

$x_{441} + x_{442} + x_{443} + x_{444} + x_{445} \geq 1$ (Compartment 443 and its neighborhood)

$x_{443} + x_{444} + x_{445} \geq 1$ (Compartment 444 and its neighborhood)

$x_{436} + x_{441} + x_{443} + x_{444} + x_{445} \geq 1$ (Compartment 445 and its neighborhood)

	Decision Variable	Solution Value	Unit Cost or Profit c(j)	Total Contribution
1	X277	0	1,0000	0
2	X278	0	1,0000	0
3	X279	0	1,0000	0
4	X280	0	1,0000	0
5	X308	0	1,0000	0
6	X309	0	1,0000	0
7	X310	0	1,0000	0
8	X311	0	1,0000	0
9	X312	0	1,0000	0
10	X319	0	1,0000	0
11	X322	0	1,0000	0
12	X323	0	1,0000	0
13	X324	1,0000	1,0000	1,0000
14	X325	0	1,0000	0
15	X326	0	1,0000	0
16	X327	0	1,0000	0
17	X328	0	1,0000	0
18	X329	0	1,0000	0
19	X330	0	1,0000	0
20	X331	0	1,0000	0
21	X332	0	1,0000	0
22	X333	0	1,0000	0
23	X334	0	1,0000	0
24	X335	0	1,0000	0
25	X336	0	1,0000	0
26	X337	0	1,0000	0
27	X338	1,0000	1,0000	1,0000
28	X339	0	1,0000	0
29	X340	0	1,0000	0
30	X341	0	1,0000	0
31	X342	0	1,0000	0
32	X343	0	1,0000	0
33	X344	0	1,0000	0
34	X346	0	1,0000	0
35	X347	0	1,0000	0
36	X348	0	1,0000	0
37	X349	0	1,0000	0
38	X351	0	1,0000	0
39	X352	0	1,0000	0
40	X353	0	1,0000	0
41	X354	0	1,0000	0
42	X355	0	1,0000	0
43	X356	1,0000	1,0000	1,0000
44	X357	0	1,0000	0
45	X358	0	1,0000	0
46	X359	0	1,0000	0
47	X360	0	1,0000	0
48	X361	0	1,0000	0
49	X362	0	1,0000	0
50	X363	0	1,0000	0
51	X364	0	1,0000	0
52	X365	0	1,0000	0
53	X366	0	1,0000	0
54	X367	0	1,0000	0
55	X368	1,0000	1,0000	1,0000
56	X369	0	1,0000	0
57	X370	0	1,0000	0
58	X371	1,0000	1,0000	1,0000
59	X372	0	1,0000	0
60	X373	0	1,0000	0
61	X374	0	1,0000	0
62	X375	0	1,0000	0
63	X376	1,0000	1,0000	1,0000
64	X377	0	1,0000	0
65	X378	0	1,0000	0
66	X379	1,0000	1,0000	1,0000
67	X380	0	1,0000	0
68	X381	0	1,0000	0
69	X382	0	1,0000	0
70	X383	1,0000	1,0000	1,0000
71	X384	0	1,0000	0
72	X385	0	1,0000	0
73	X386	1,0000	1,0000	1,0000
74	X387	0	1,0000	0
75	X388	0	1,0000	0
76	X389	1,0000	1,0000	1,0000
77	X390	0	1,0000	0
78	X391	0	1,0000	0
79	X392	0	1,0000	0
80	X393	0	1,0000	0
81	X394	0	1,0000	0
82	X395	0	1,0000	0
83	X396	0	1,0000	0
84	X397	0	1,0000	0
85	X398	0	1,0000	0
86	X399	0	1,0000	0
87	X400	1,0000	1,0000	1,0000
88	X401	0	1,0000	0
89	X402	0	1,0000	0
90	X403	0	1,0000	0
91	X404	0	1,0000	0
92	X405	0	1,0000	0
93	X406	0	1,0000	0
94	X407	0	1,0000	0
95	X408	0	1,0000	0
96	X409	0	1,0000	0
97	X410	0	1,0000	0
98	X411	0	1,0000	0
99	X412	1,0000	1,0000	1,0000
100	X413	0	1,0000	0
101	X414	0	1,0000	0
102	X415	0	1,0000	0
103	X416	0	1,0000	0
104	X417	0	1,0000	0
105	X418	0	1,0000	0
106	X419	1,0000	1,0000	1,0000
107	X420	1,0000	1,0000	1,0000
108	X421	0	1,0000	0
109	X422	0	1,0000	0
110	X423	0	1,0000	0
111	X424	0	1,0000	0
112	X425	0	1,0000	0
113	X426	0	1,0000	0
114	X427	1,0000	1,0000	1,0000
115	X428	0	1,0000	0
116	X429	0	1,0000	0
117	X430	0	1,0000	0
118	X431	0	1,0000	0
119	X432	0	1,0000	0
120	X433	0	1,0000	0
121	X434	0	1,0000	0
122	X435	1,0000	1,0000	1,0000
123	X436	0	1,0000	0
124	X437	0	1,0000	0
125	X438	0	1,0000	0
126	X439	0	1,0000	0
127	X440	0	1,0000	0
128	X441	1,0000	1,0000	1,0000
129	X442	0	1,0000	0
130	X443	0	1,0000	0
131	X444	0	1,0000	0
132	X445	0	1,0000	0
	Objective	Function	(Min.) =	17,0000

Figure 4.32 LSCP solution obtained from WINQSB software package.

Figure 4.32 demonstrates LSCP solution obtained from WINQSB software package. According to these results, the minimum numbers of fire crews and the minimum numbers of compartments that these fire crews will be assigned must be 17. Optimum solution is, $x_{324} = x_{338} = x_{356} = x_{368} = x_{371} = x_{376} = x_{379} = x_{383} = x_{386} = x_{389} = x_{400} = x_{412} = x_{419} = x_{420} = x_{427} = x_{435} = x_{441} = 1$ and the rest equals to 0. Figure 4.33 revealed locations of current fire crews and proposed fire crews.

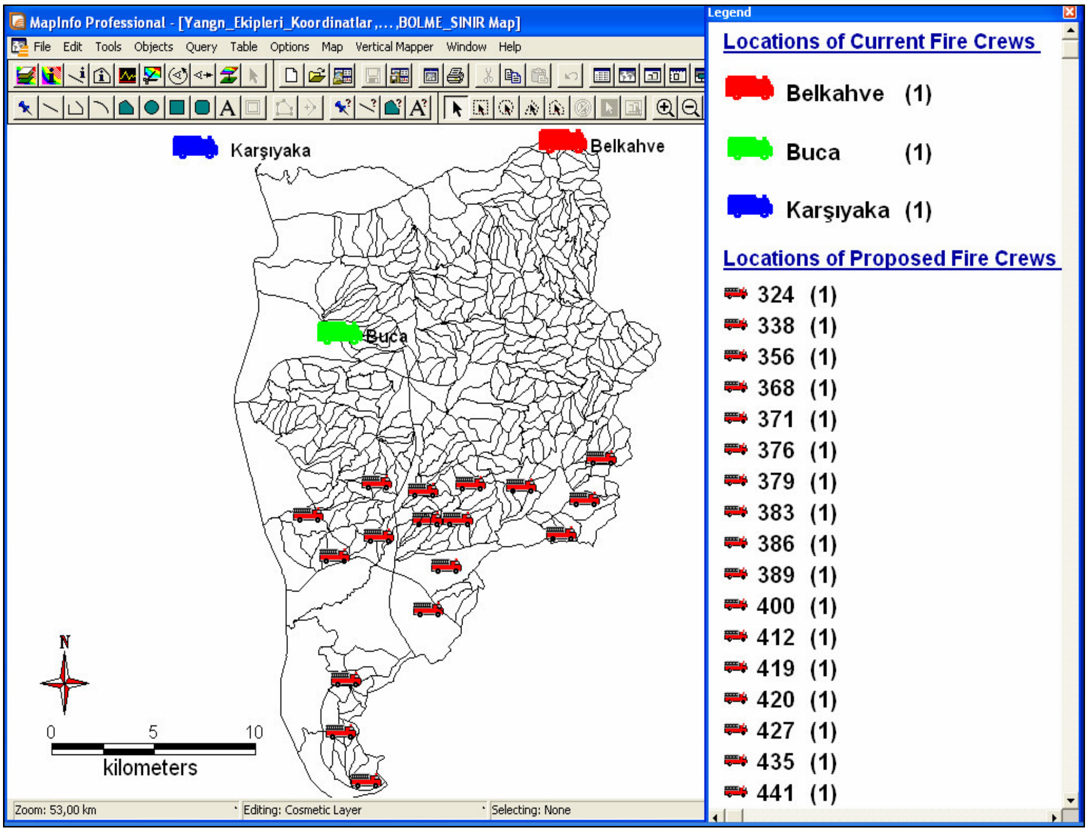

Figure 4.33 Locations of current and proposed fire crews.

Although 17 is the minimum number of fire crews found by LSCP it is difficult to assign 17 fire crews to the south region of the study area because of the budget constraints. In order to minimize numbers of these fire crews, buffering analysis was done. Buffering process involved the creation of a circular polygon about each fire crew of radius equal to buffer distance. In this thesis fixed buffer distance (7 km) was used for all fire crews. Firstly buffering was done on a compartment map to select these fire crews by ensuring coverage of all compartments in the south region of the study area. The aim was to find compartments that fall inside service area of each fire crew and to determine coverage areas of fire crews. Then same buffering was done on the road map to determine the intervention area of each fire crew and total length of roads that was usable by each fire crew in the buffered areas. Same distance, 7 km, was used for each fire crew in buffering. Inside of each buffer indicated total length of usable roads and the intervention area of fire crews.

Different alternatives were possible as to locations of these new fire crews. One of them was assignment of fire crews to the compartments with the number of 356, 368, and 435. According to this assignment, if one fire crew is assigned to the compartment 368, the other two must be assigned to the compartment 356 and 435 (The same interpretation can be done as, if one fire crew is assigned to the compartment 356, the other two must be assigned to the compartment 368 and 435 or if one fire crew is assigned to the compartment 435, the other two must be assigned to the compartment 356 and 368). In this study fire crews were named with the compartment number they were assigned. For instance fire crew 368 means that this fire crew is assigned to the compartment 368 according to LSCP. It is important to note that assignment must be done with this trio set. Total length of usable roads in buffered areas was found as 529 km with this assignment. In figure 4.34 intervention areas and total length of usable roads in buffered areas were shown for the fire crew 356, 368 and 435. Figures 4.35, 4.36 and 4.37 show road types and their total length for buffering of fire crew 368, 356 and 435.

Different trio sets were proposed as shown in figure 4.38. Figures 4.39 and 4.40 show road types and their total length for buffering of fire crew 371 and 383. Figure 4.41 shows 7 km buffers from fire crews 379, 389 and 441. Figures 4.42, 4.43 and 4.44 show road types and their total length for buffering of fire crew 379, 389 and 441. Figure 4.45 display 7 km buffers from fire crew 324, 412 and 427. Figures 4.46, 4.47 and 4.48 show road types and their total length for buffering of fire crew 324, 412 and 427. Figure 4.49 demonstrate the best assignment in terms of total length of usable roads (589 km).

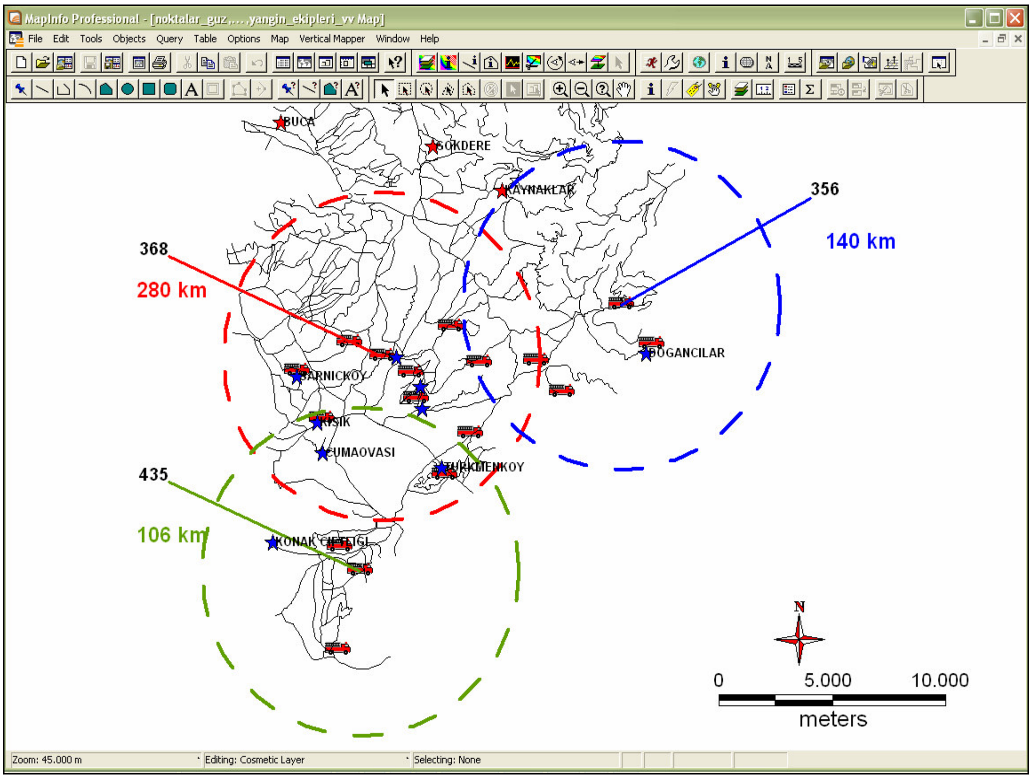

Figure 4.34 7 km buffers from fire crews 356, 368 and 435.

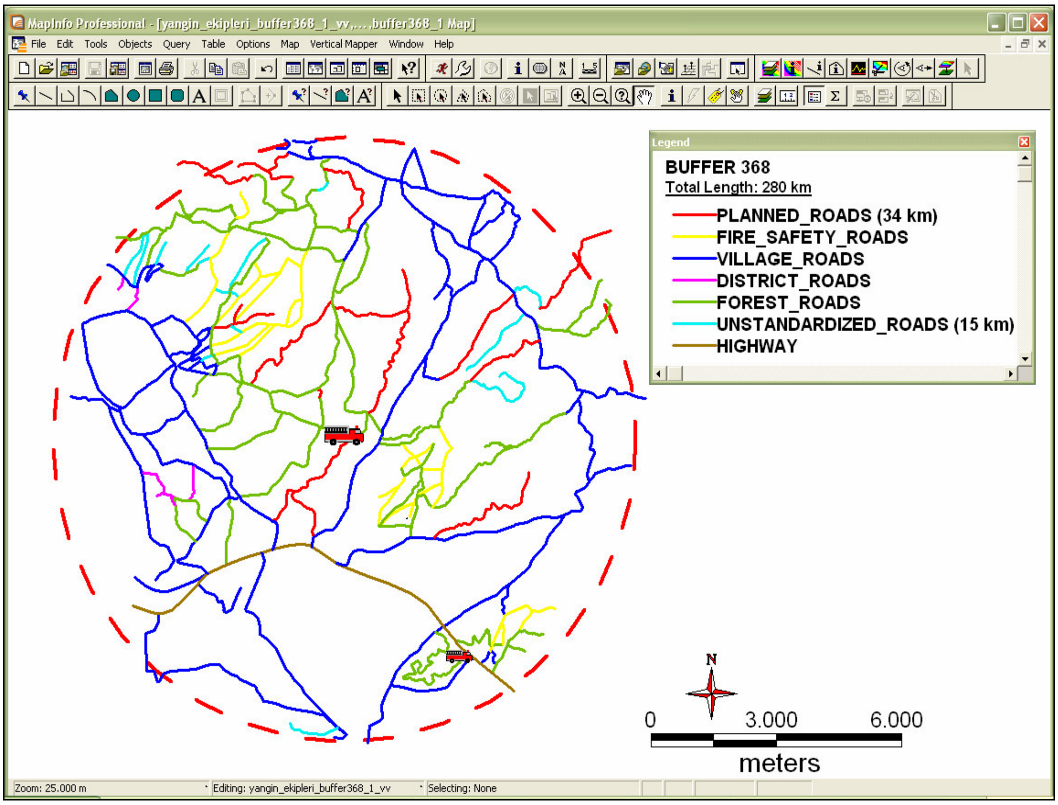

Figure 4.35 Road types and their total length for buffering of fire crew 368.

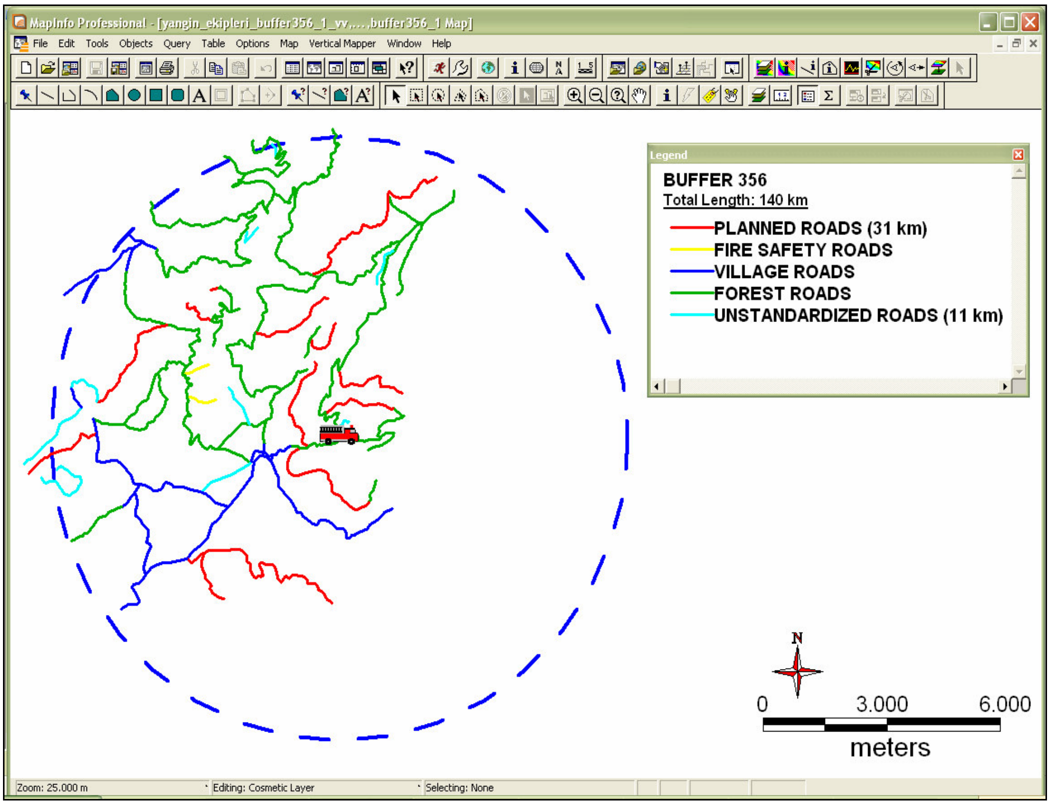

Figure 4.36 Road types and their total length for buffering of fire crew 356.

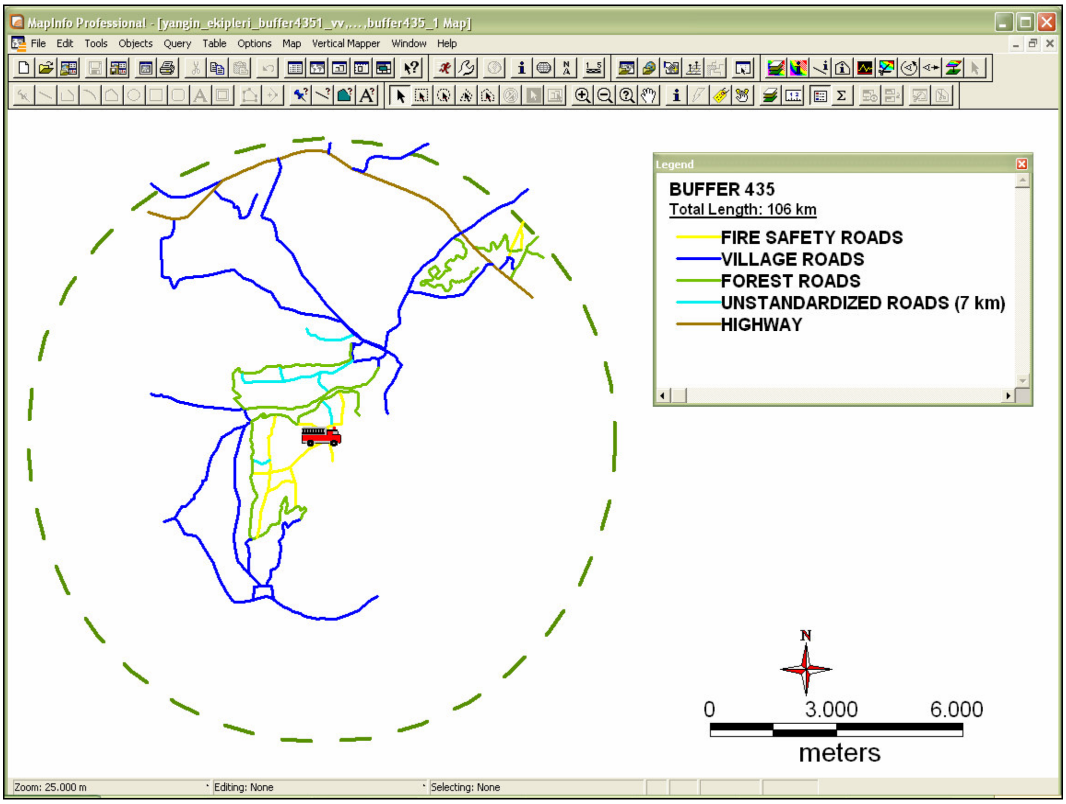

Figure 4.37 Road types and their total length for buffering of fire crew 435.

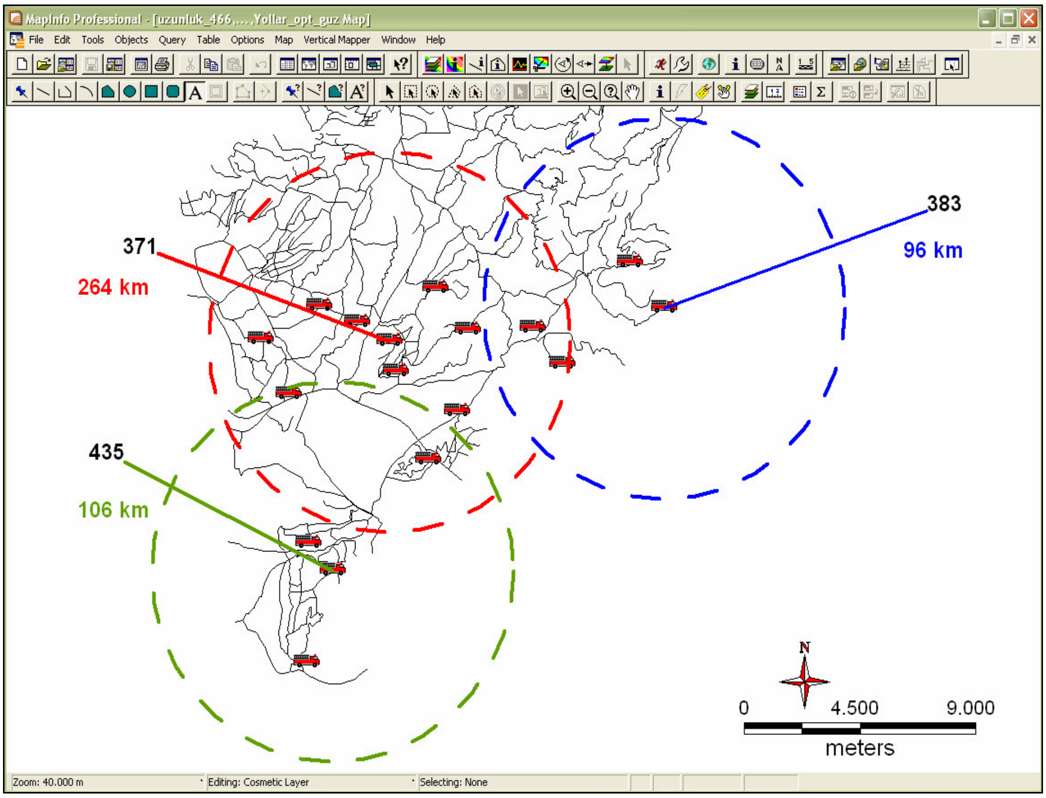

Figure 4.38 7 km buffers from fire crews 371, 383 and 435.

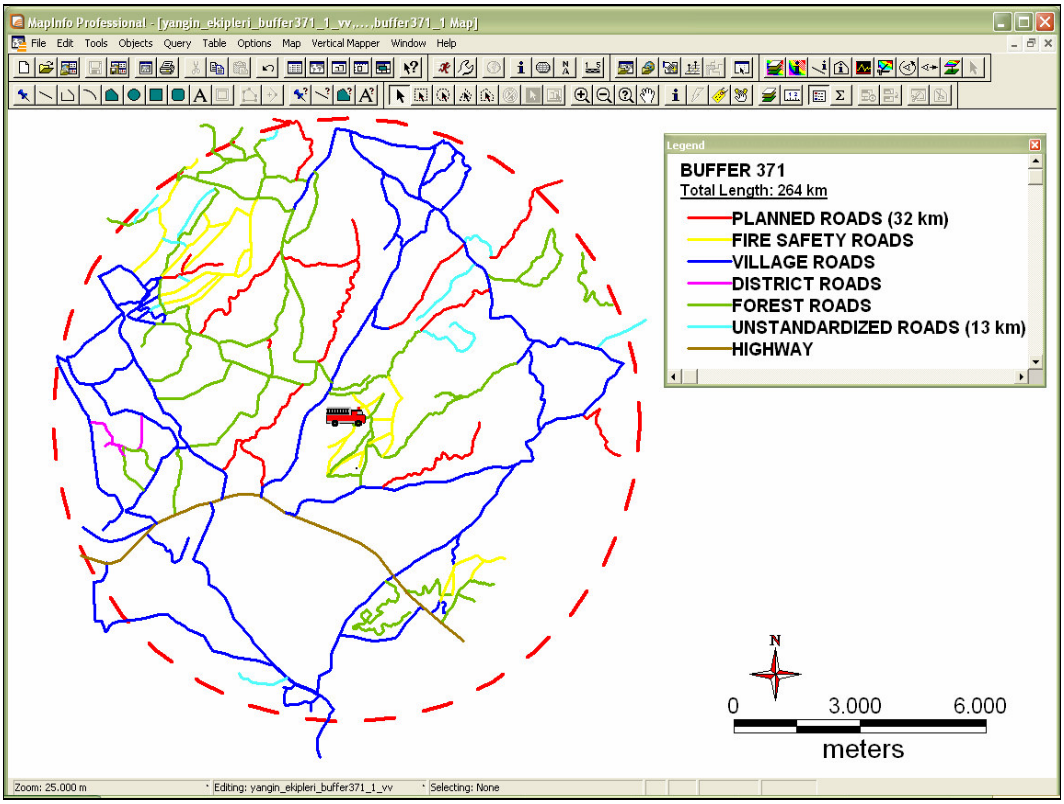

Figure 4.39 Road types and their total length for buffering of fire crew 371.

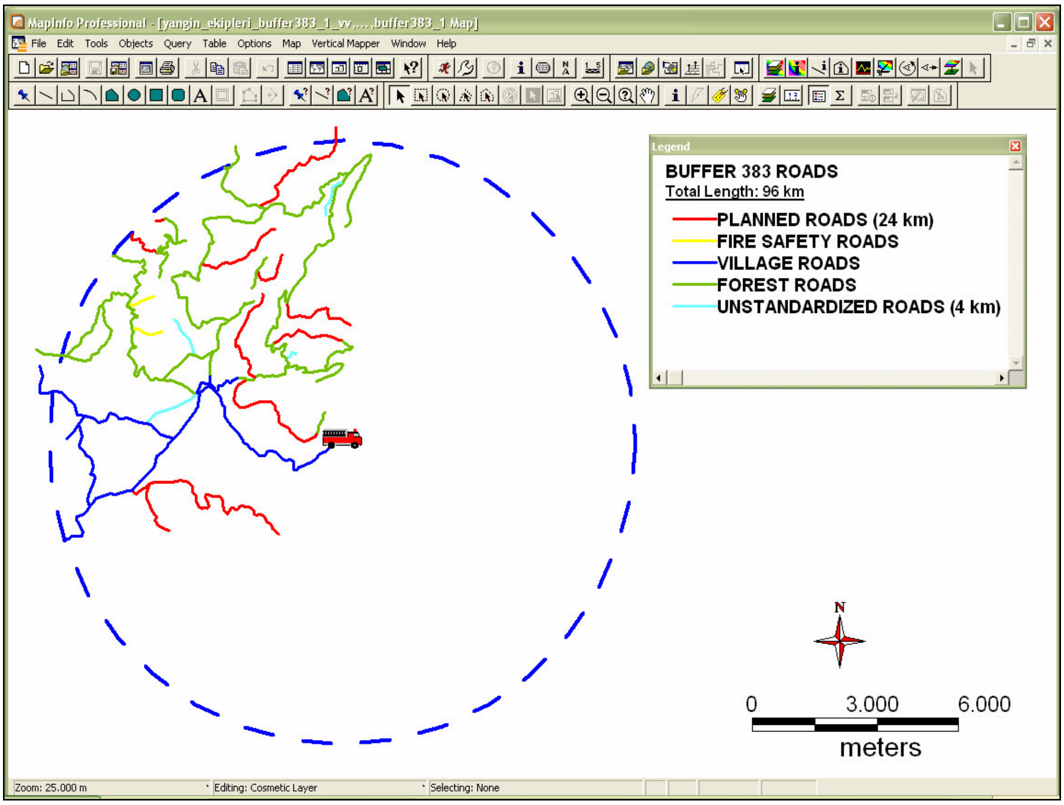

Figure 4.40 Road types and their total length for buffering of fire crew 383.

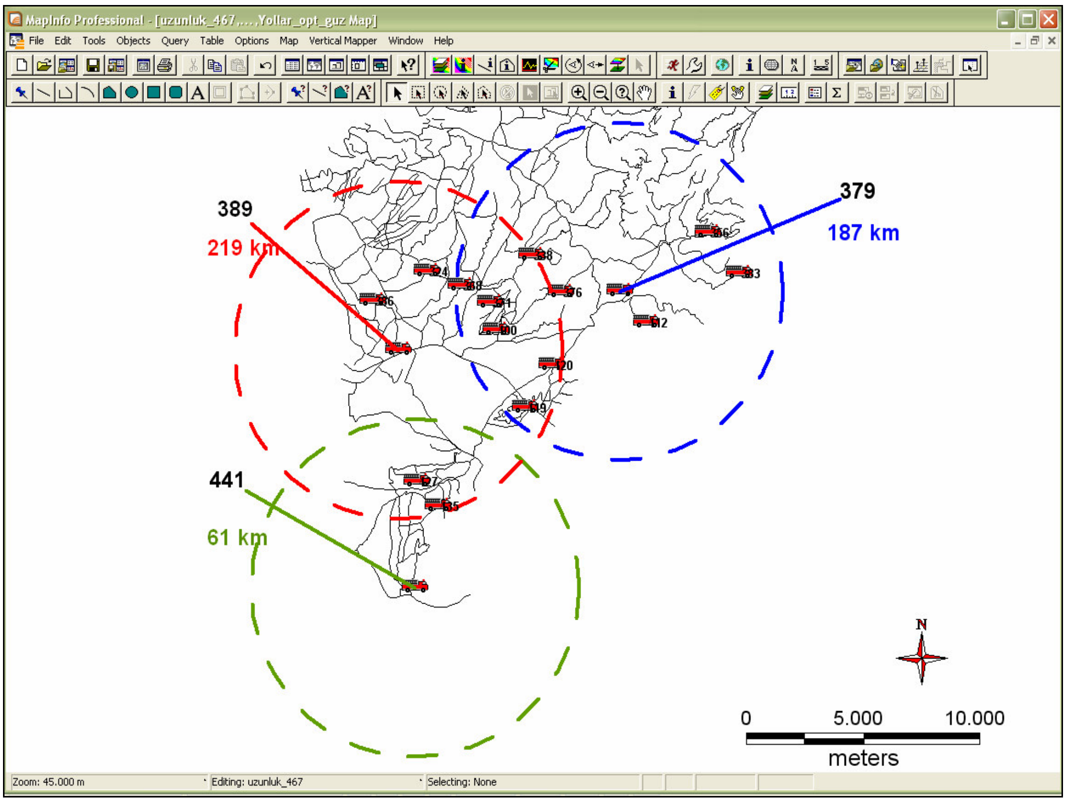

Figure 4.41 7 km buffers from fire crews 379, 389 and 441.

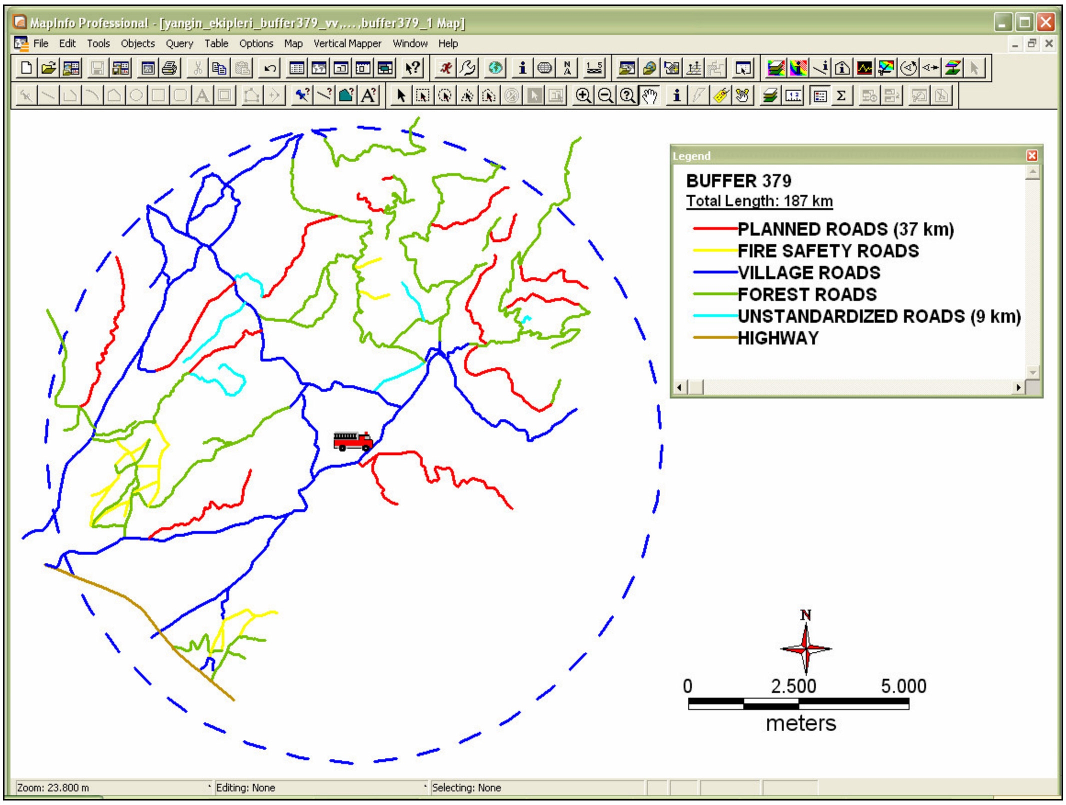

Figure 4.42 Road types and their total length for buffering of fire crew 379.

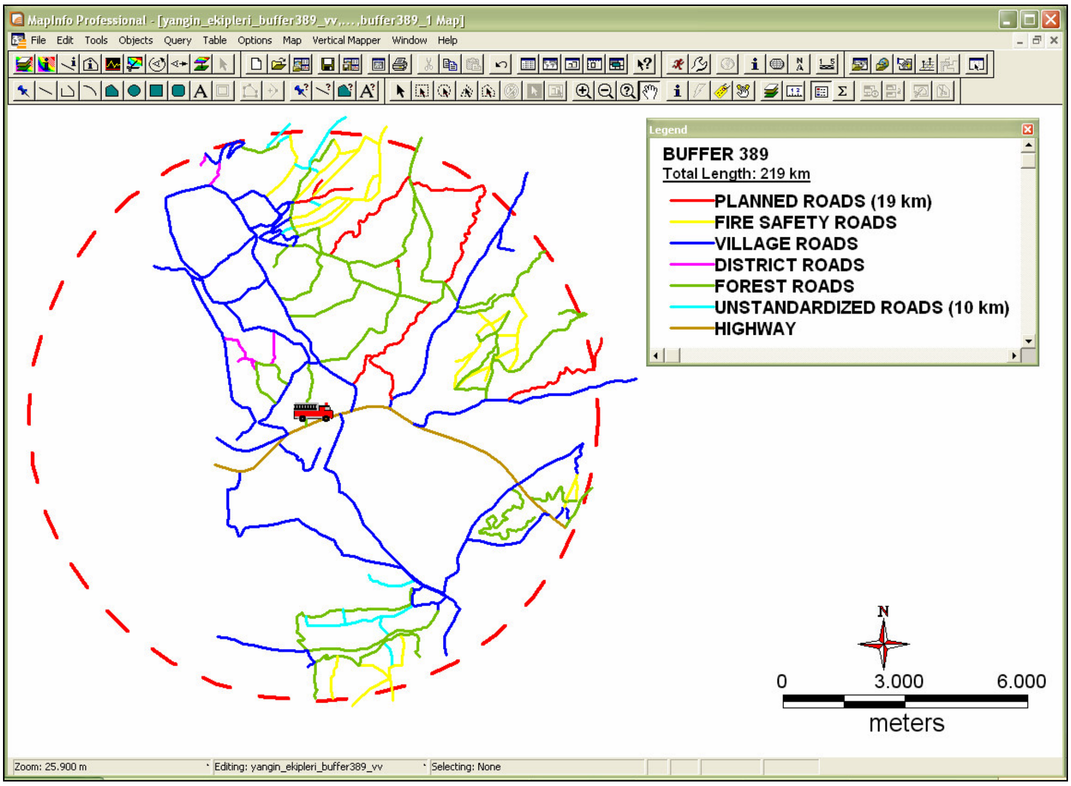

Figure 4.43 Road types and their total length for buffering of fire crew 389.

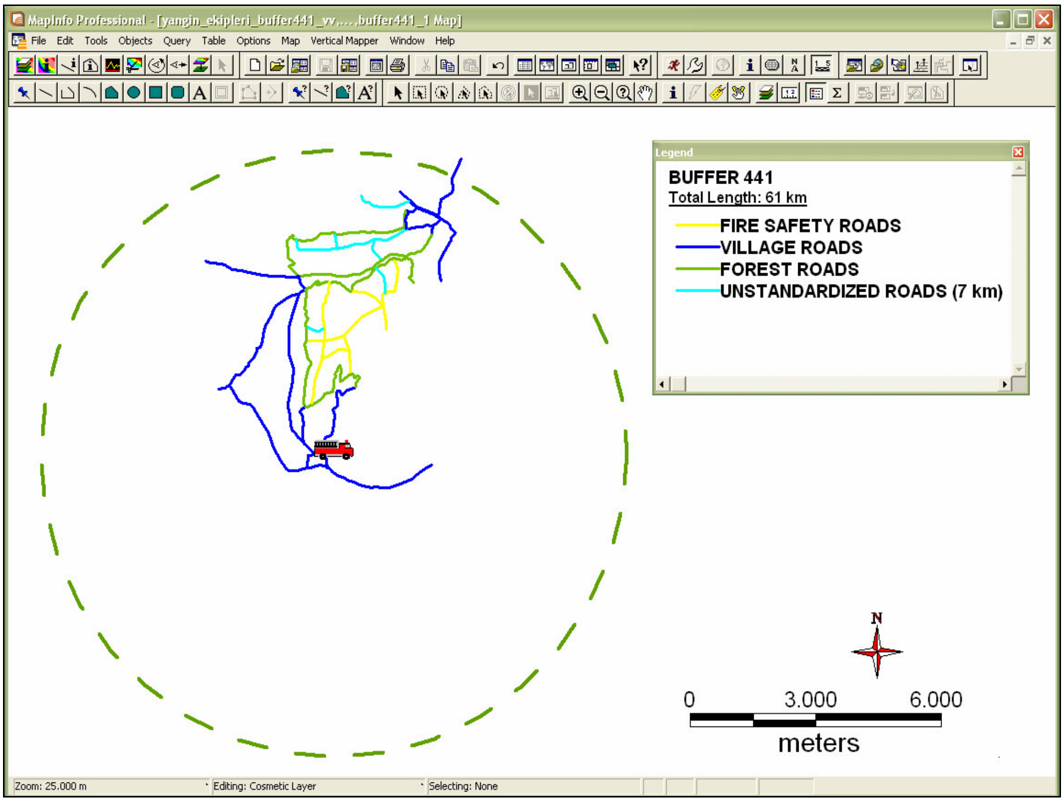

Figure 4.44 Road types and their total length for buffering of fire crew 441.

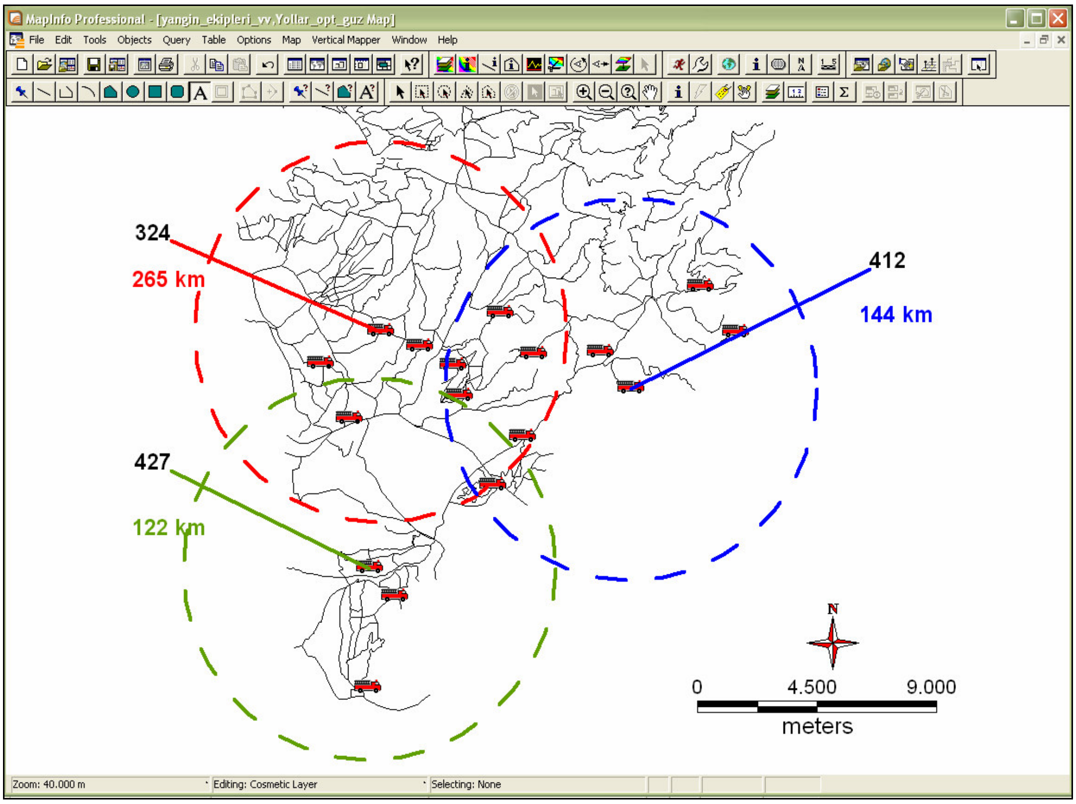

Figure 4.45 7 km buffers from fire crew 324, 412 and 427.

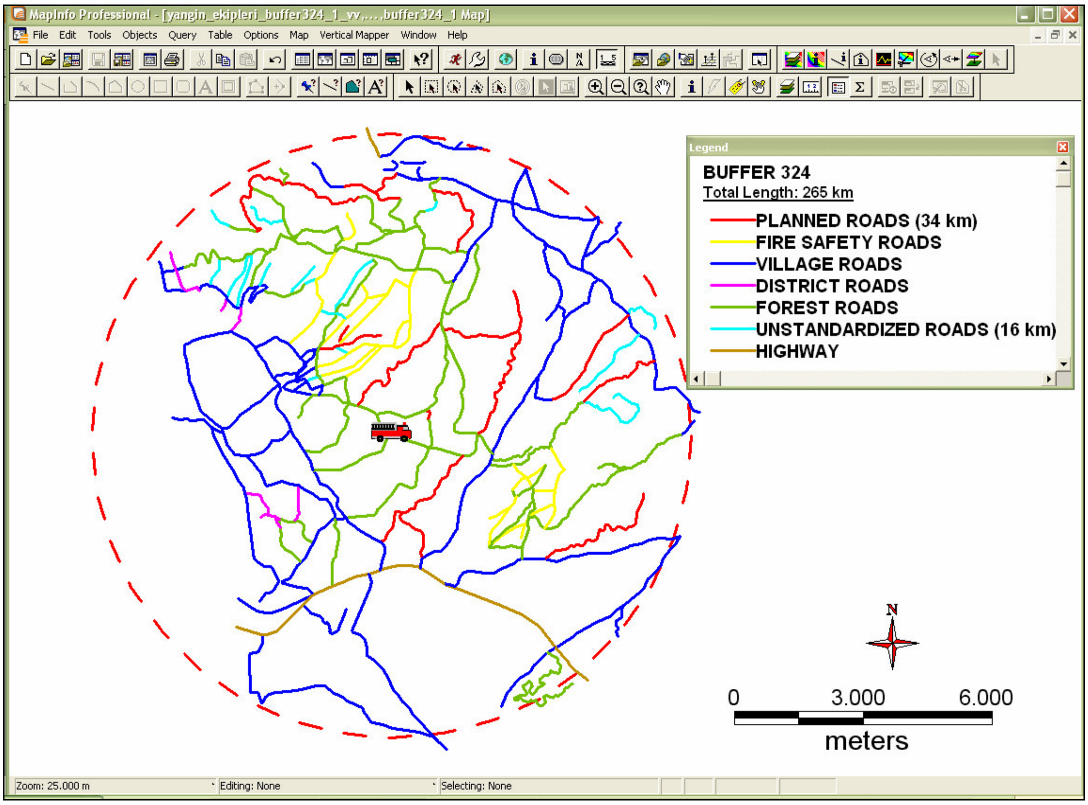

Figure 4.46 Road types and their total length for buffering of fire crew 324.

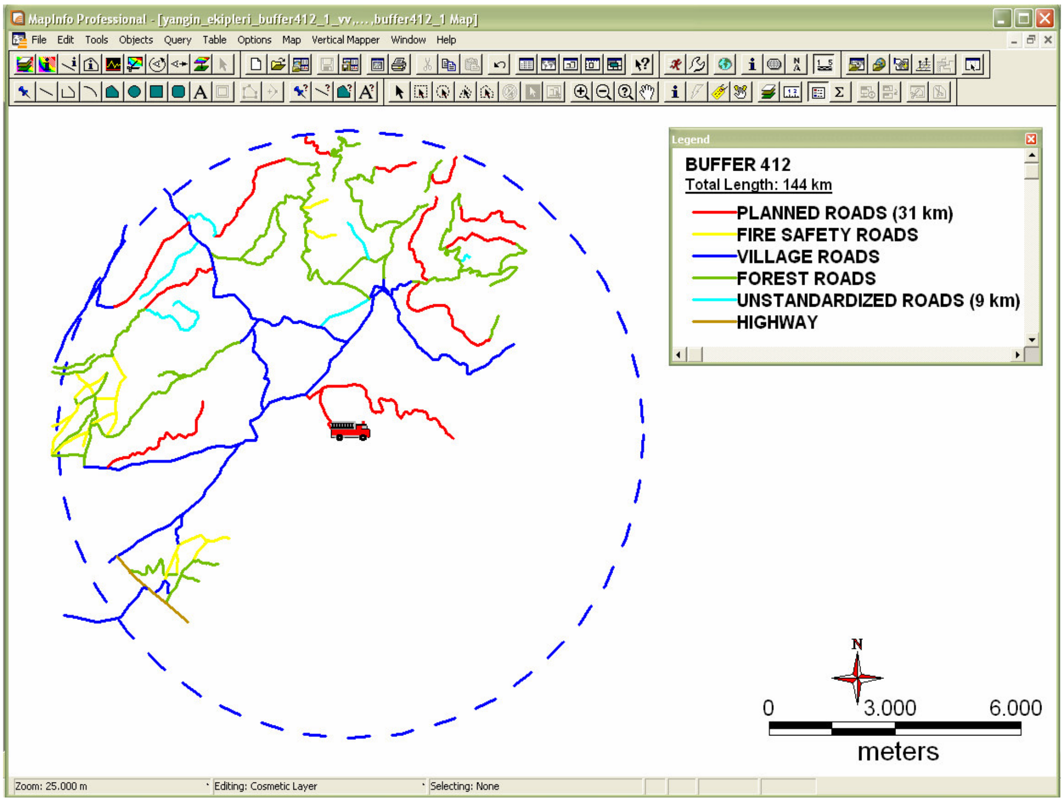

Figure 4.47 Road types and their total length for buffering of fire crew 412.

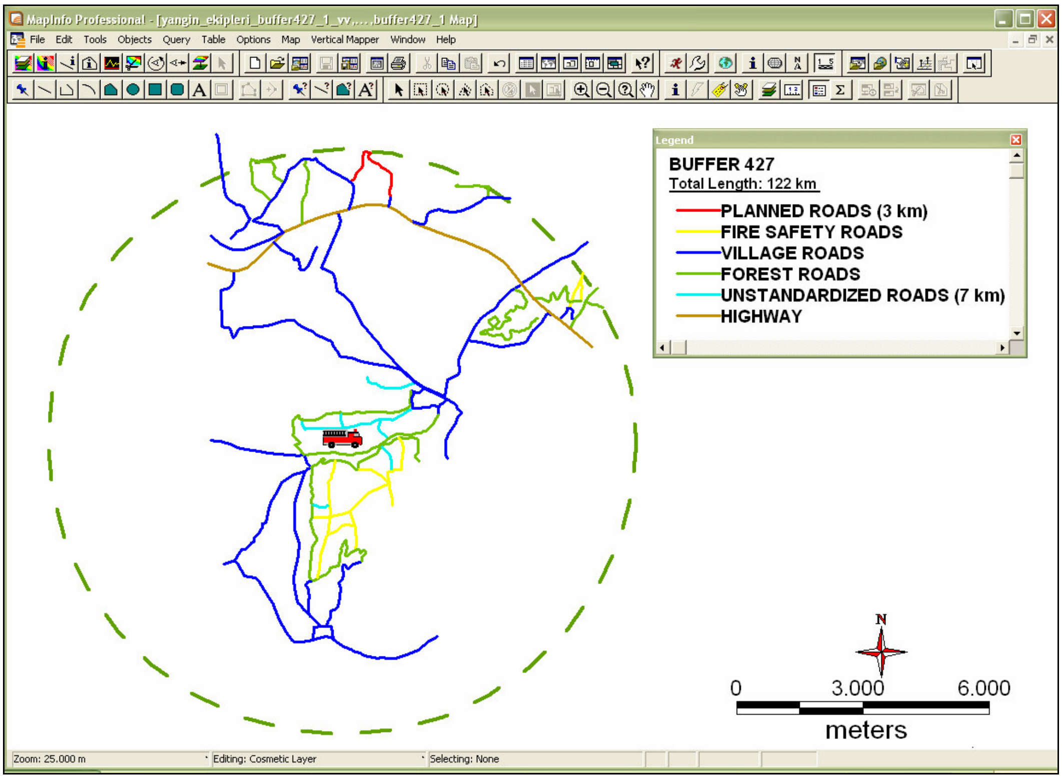

Figure 4.48 Road types and their total length for buffering of fire crew 427.

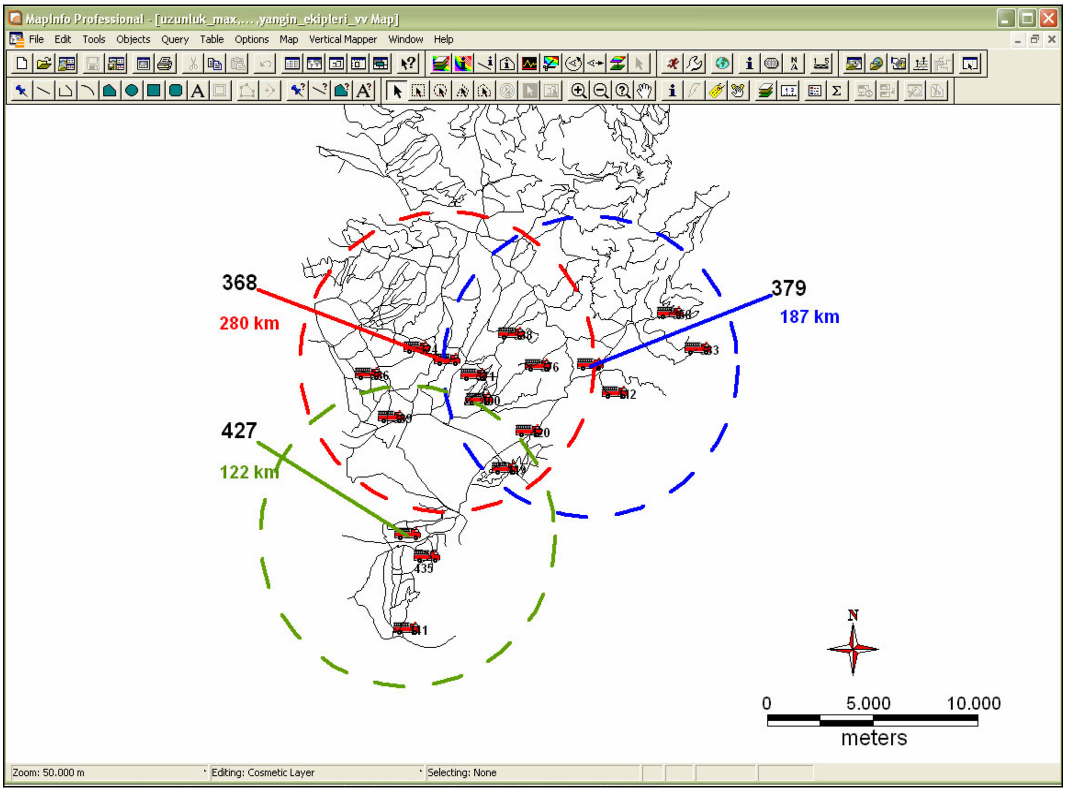

Figure 4.49 7 km buffers from fire crews 368, 379 and 427.

Figure 4.50 summarizes usage of analyses done in this section.

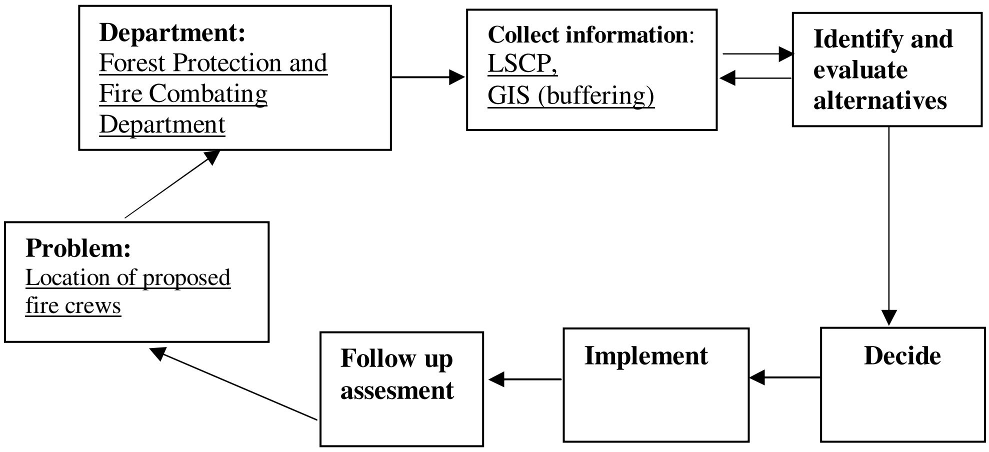

Figure 4.50 Summary of usage of LSCP and GIS.

4.4.4 Road Analyses

Figure 4.51 displays road analyses done in this section.

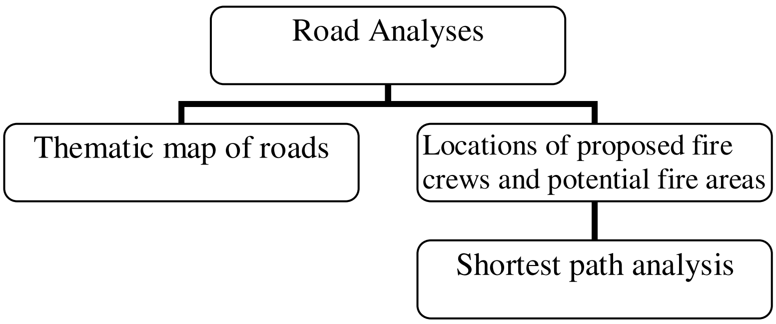

Figure 4.51 Schematic representation of road analyses.

Figure 4.52 shows road map of the study area. Figure 4.53 display thematic mapping of the road map. Figure 4.54 represents locations of current fire crews on the road map of the study area. Figure 4.55 displays thematic maps of the road map and locations of current fire crew simultaneously. Figures 4.56 and 4.57 show some of the residential areas and the locations of the proposed fire crews on the road map, respectively. Potential fire areas and the locations of the proposed fire crews are represented in Figure 4.58.

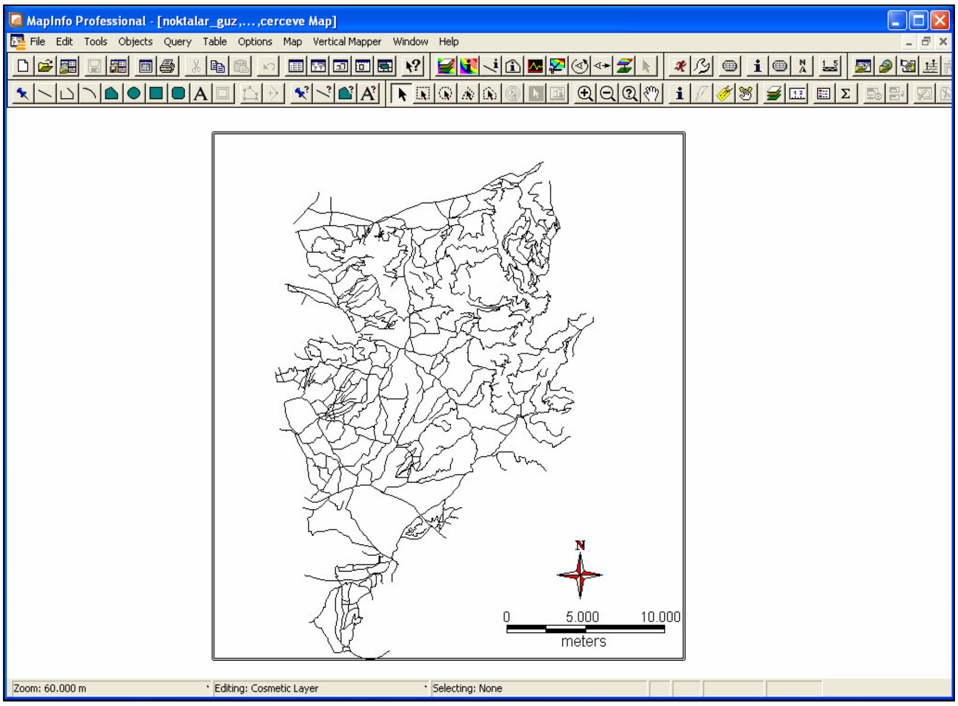

Figure 4.52 Road map of the İzmir Forest Administration Chief Office.

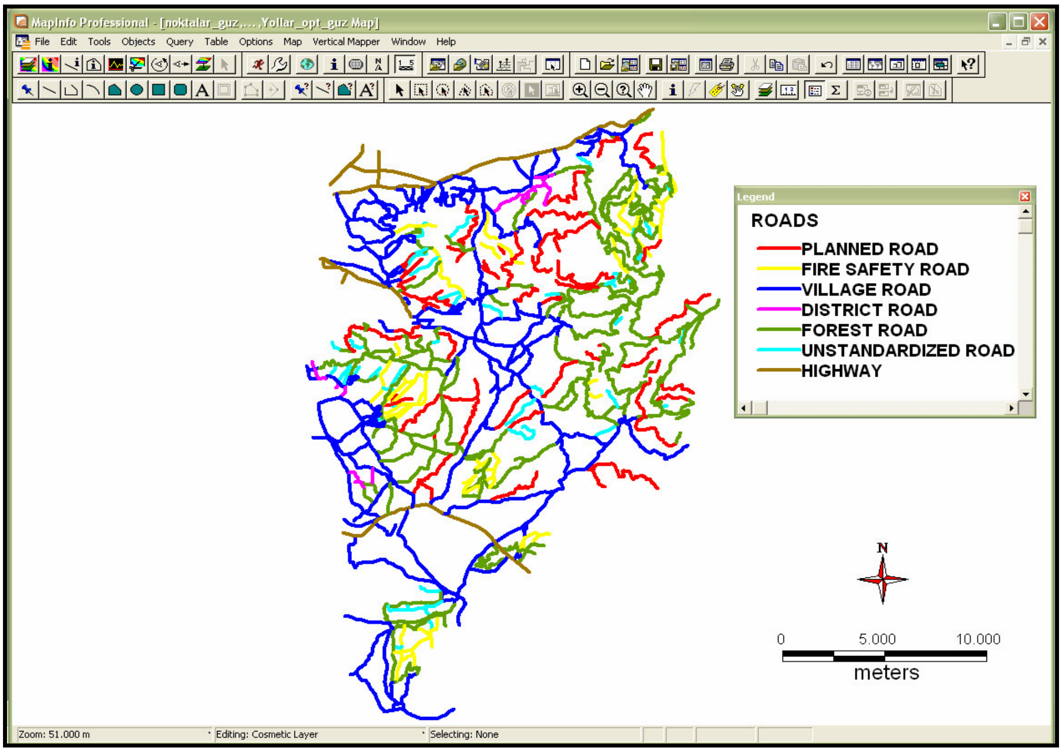

Figure 4.53 Thematic mapping of the road map.

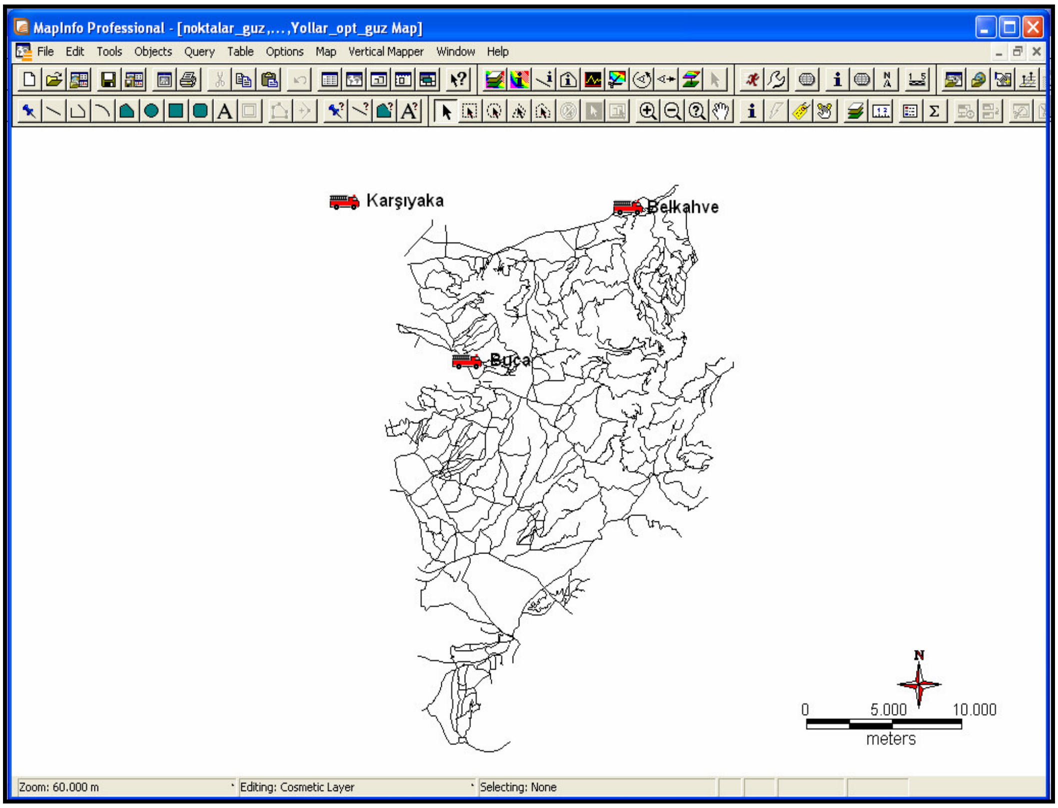

Figure 4.54 Locations of current fire crew on the road map.

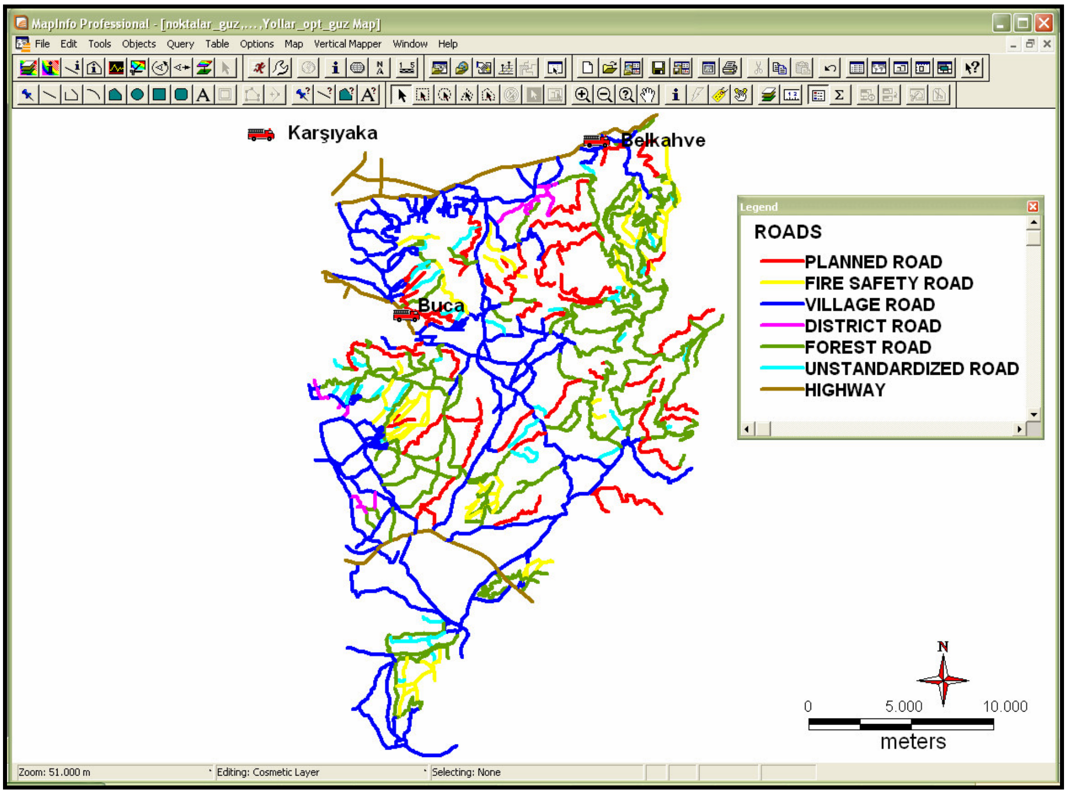

Figure 4.55 Thematic map of the the road map and the locations of current fire crew.

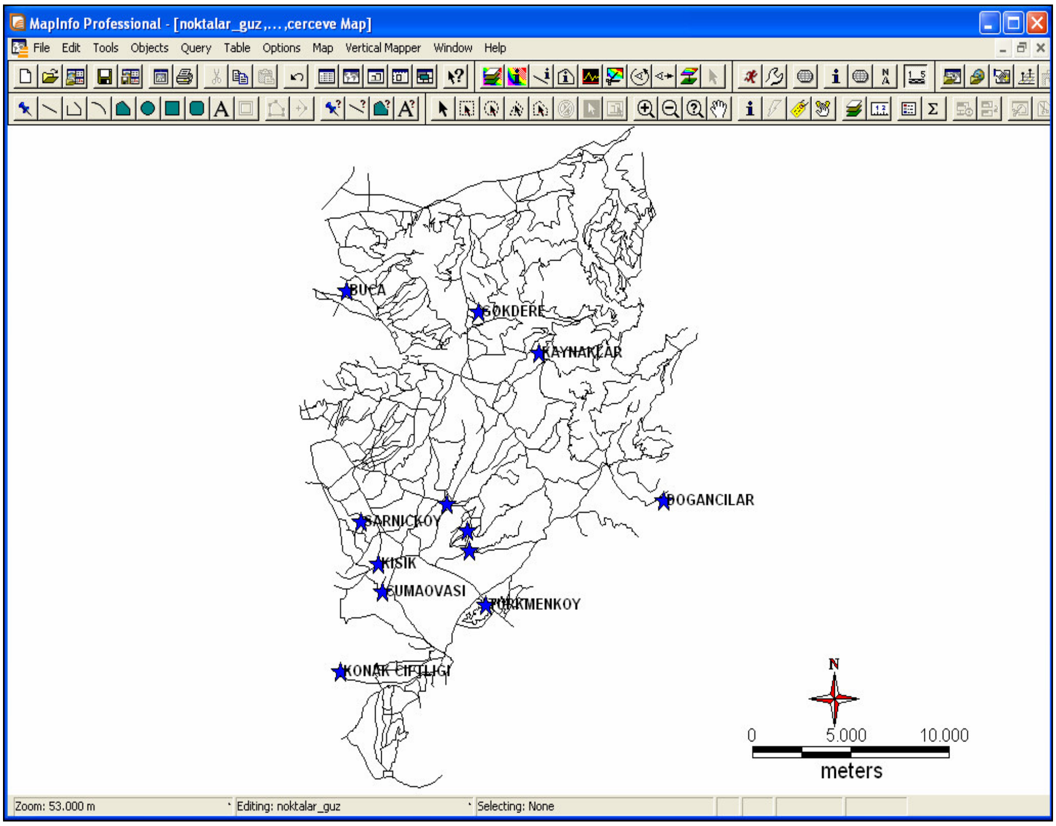

Figure 4.56 Some of the residential areas and the road map.

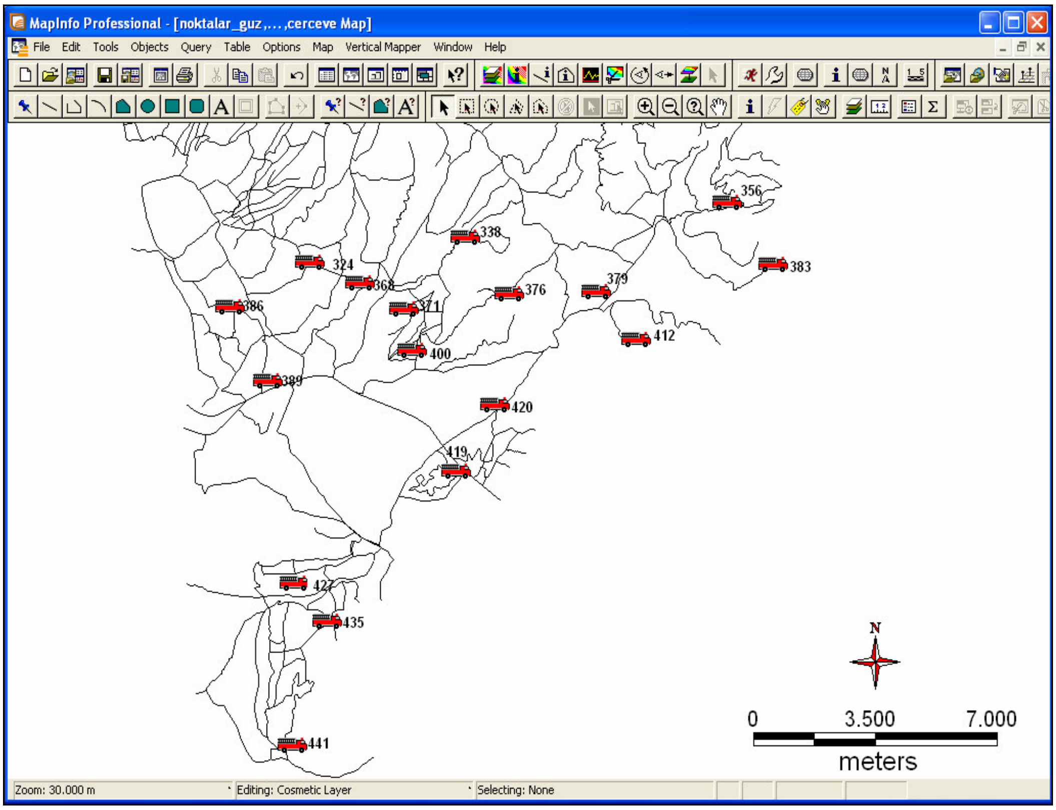

Figure 4.57 Locations of the proposed fire crews on the road map.

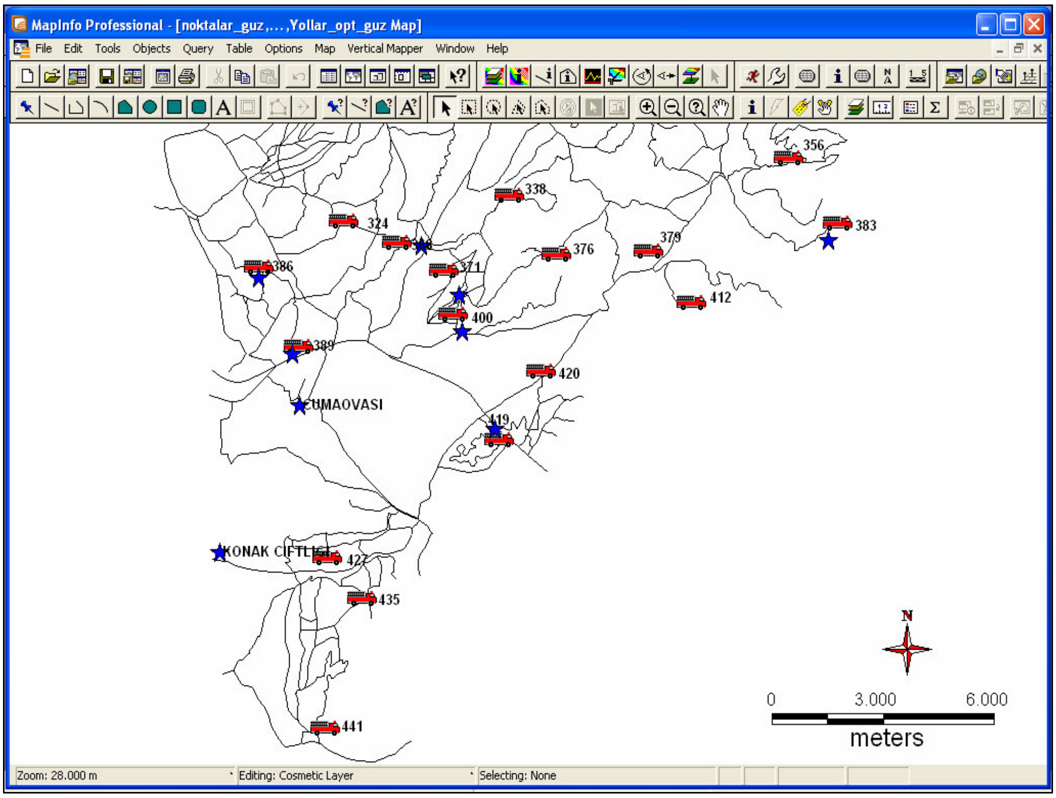

Figure 4.58 Potential fire areas and the locations of the proposed fire crews.

In this part of the application, different areas were determined as potential fire areas by examining fire records since 2000. As shown in Figure 4.58, nine areas were determined as potential fire areas for the south region of the study area. The shortest paths from fire crews, which were found by LSCP, to the potential fire areas were calculated. There may be several alternatives to reach from one fire crew to the one fire area. All of the alternatives were examined and calculated by using functions of GIS. Fire crews and potential fire areas were named with the the number of the compartment they belong to.

Figure 4.59 shows two different paths from fire crew 368 to potential fire area 389. The orange road shows the shortest path whose length is 5.7 km, the purple road shows the second shortest road whose length is 6.7 km. Figures 4.60 and 4.61 show each of these roads and types of the roads in these paths.

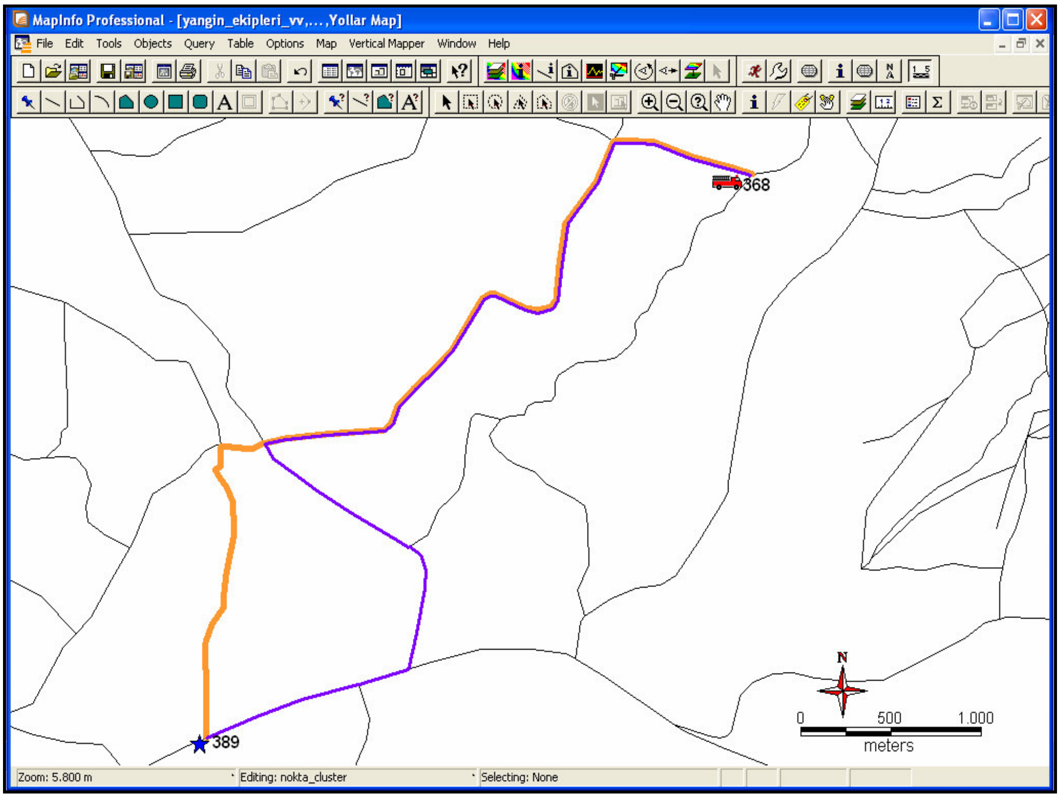

Figure 4.59 Two different paths from fire crew 368 to the potential fire area 389.

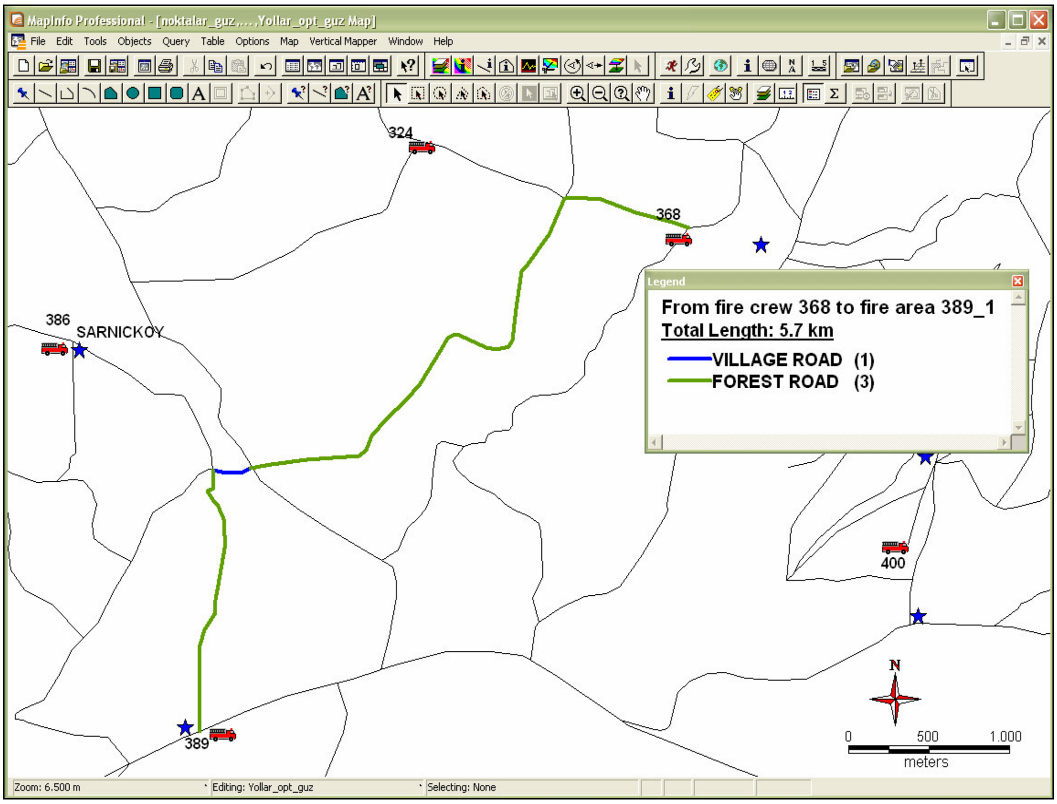

Figure 4.60 The shortest path from fire crew 368 to the potential fire area 389.

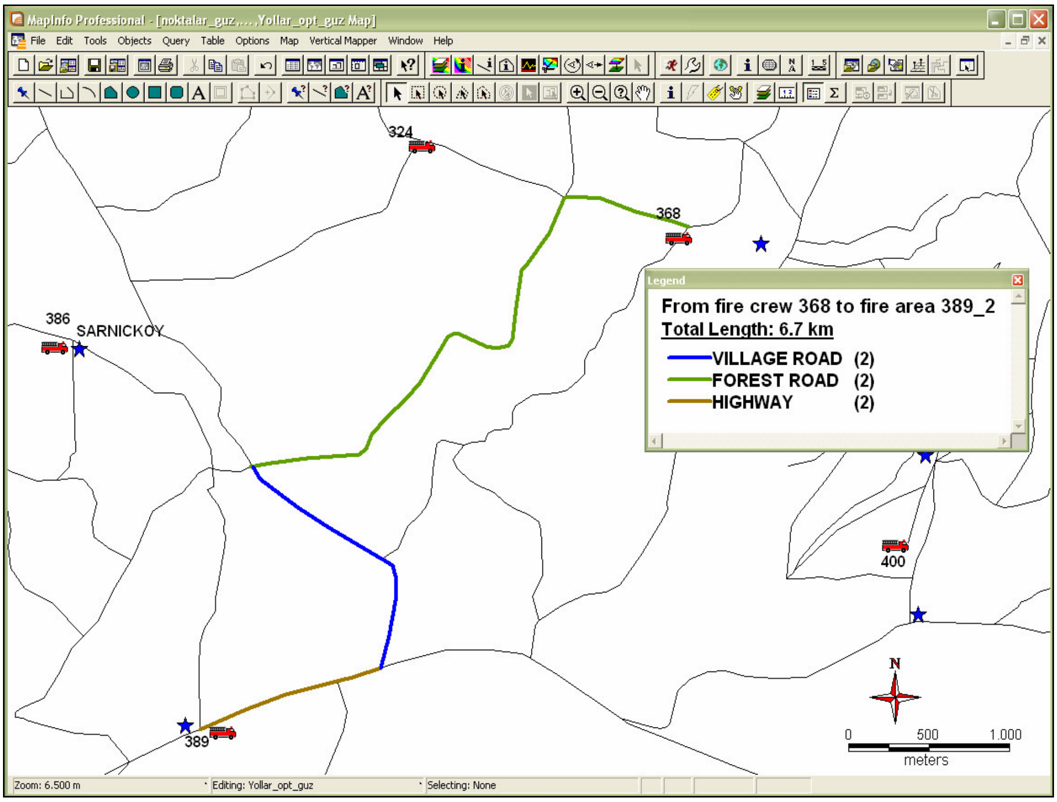

Figure 4.61 The second shortest path from fire crew 368 to the potential fire area 389.

Figure 4.62 shows that the length of the shortest road from fire crew 368 to the fire area 419 is 8 km. This figure also shows type of the roads, such as planned roads, village roads and highways, in this path. But an important point that must be taken into account that, there are planned but have not been completed roads in this path. If planned roads are completed, using this road in the case of fire will give the shortest path (8 km) from 368 to 419, as shown in Figure 4.62. But if these planned roads are not completed other routes must be used as shown in Figures 4.63 and 4.64. Figures 4.63 and 4.64 display each of these roads in a detailed way.

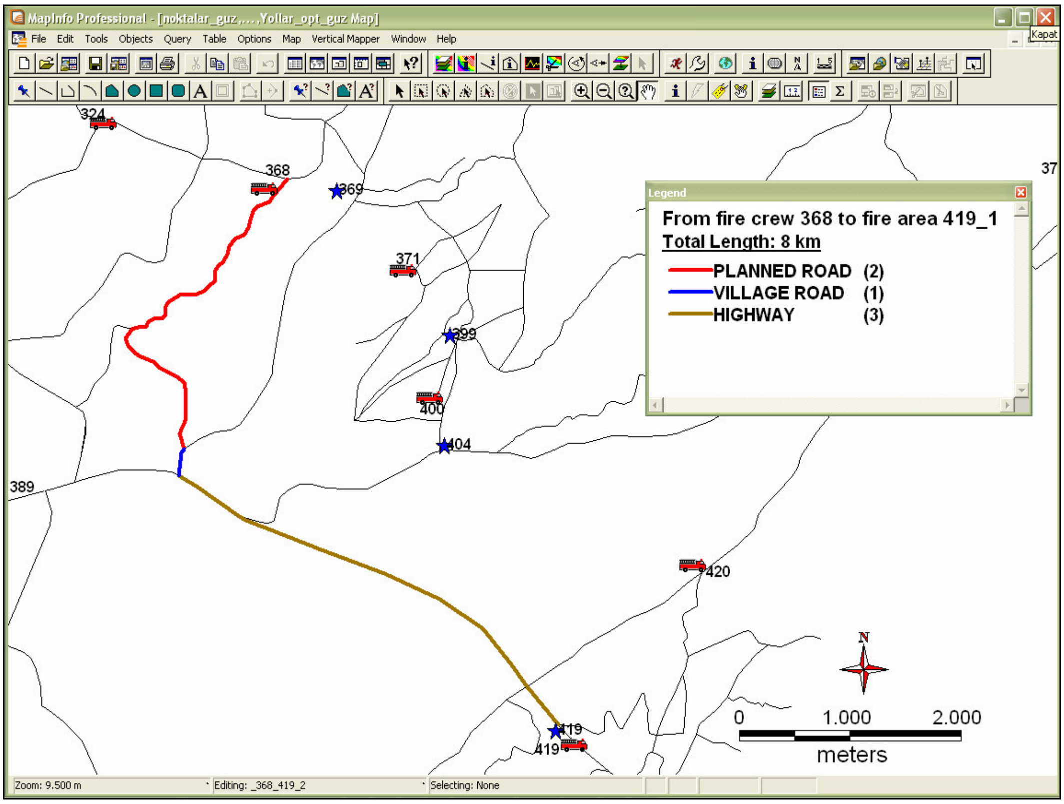

Figure 4.62 The shortest path from fire crew 368 to the potential fire area 419 using planned road.

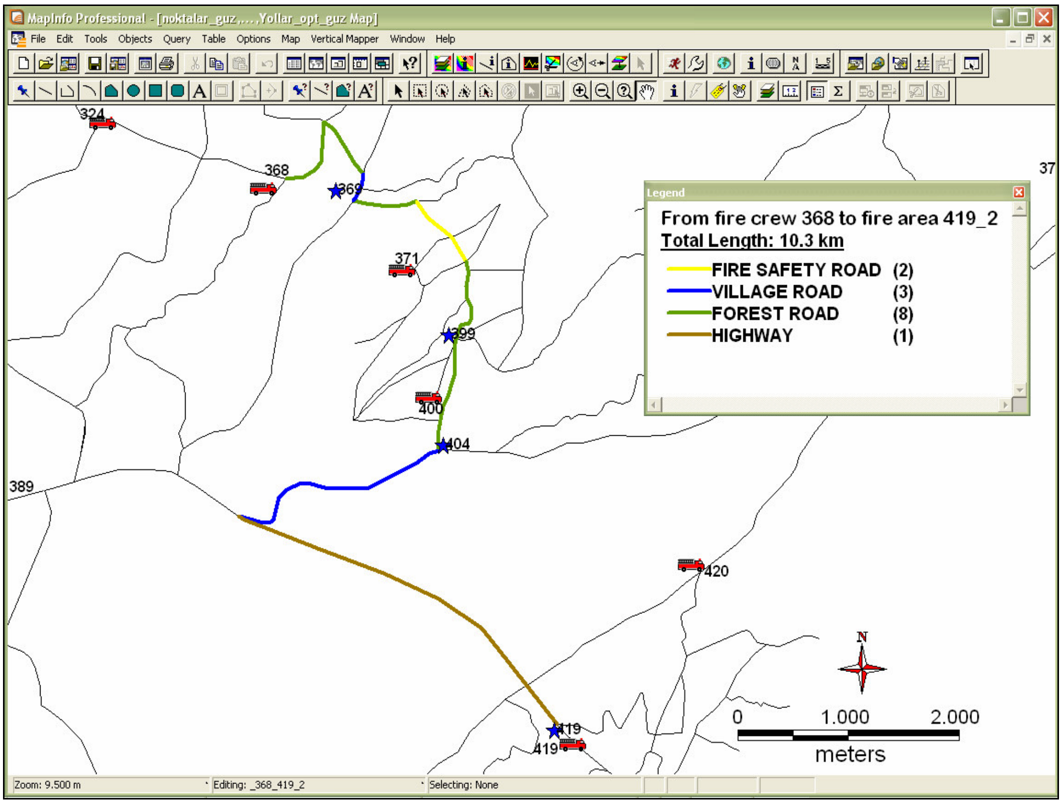

Figure 4.63 One of the alternative roads from fire crew 368 to the potential fire area 419.

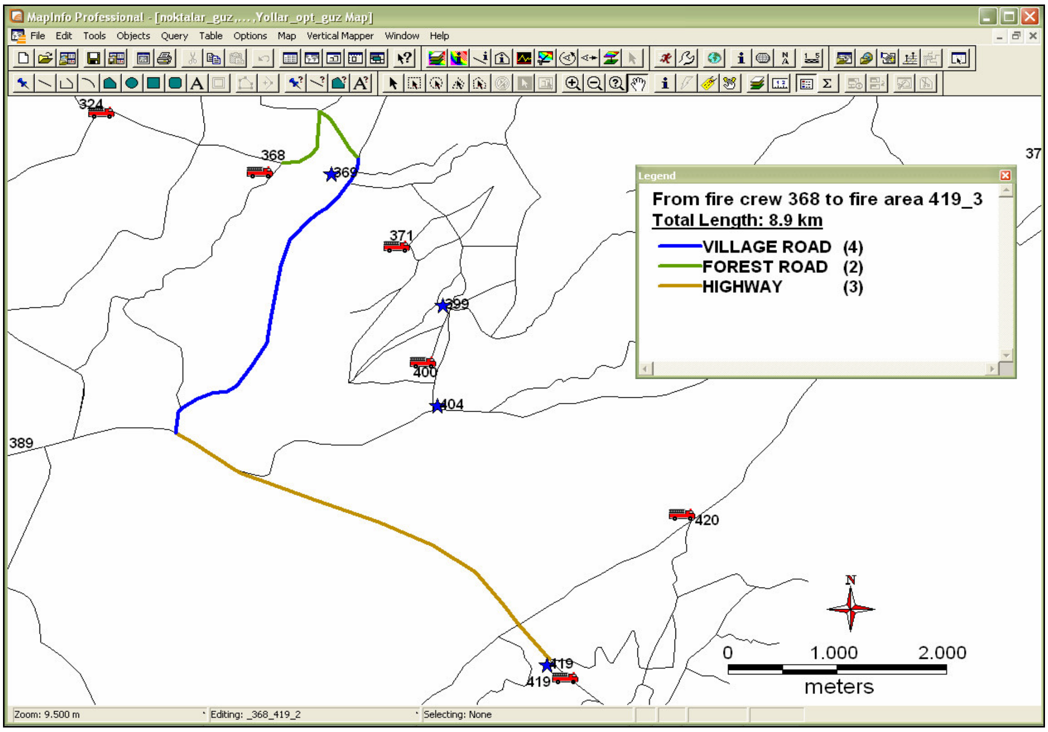

Figure 4.64 The shortest path from fire crew 368 to the potential fire area 419 in the case of disusing of planned roads.

Other scenarios were developed as to calculating distance from fire crew 324 to the potantial fire area 404 as shown in figures 4.65, 4.66, 4.67 and 4.68. Figures 4.66 and 4.68 show types of the roads in these paths.

Figure 4.69 shows four different paths to reach from fire crew 356 to the potential fire area 416. Figures 4.70, 4.71, 4.72 and 4.73 show different scenarios (length of the roads) derived from figure 4.69.

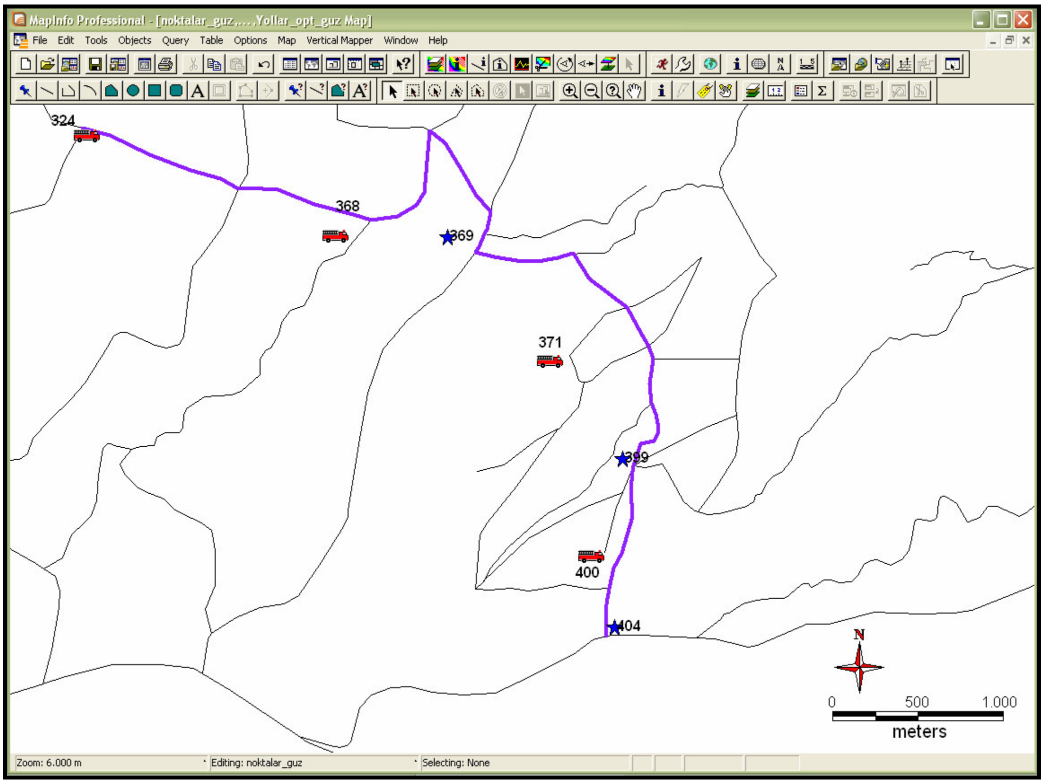

Figure 4.65 The shortest path from fire crew 324 to the fire area 404 (6.5 km).

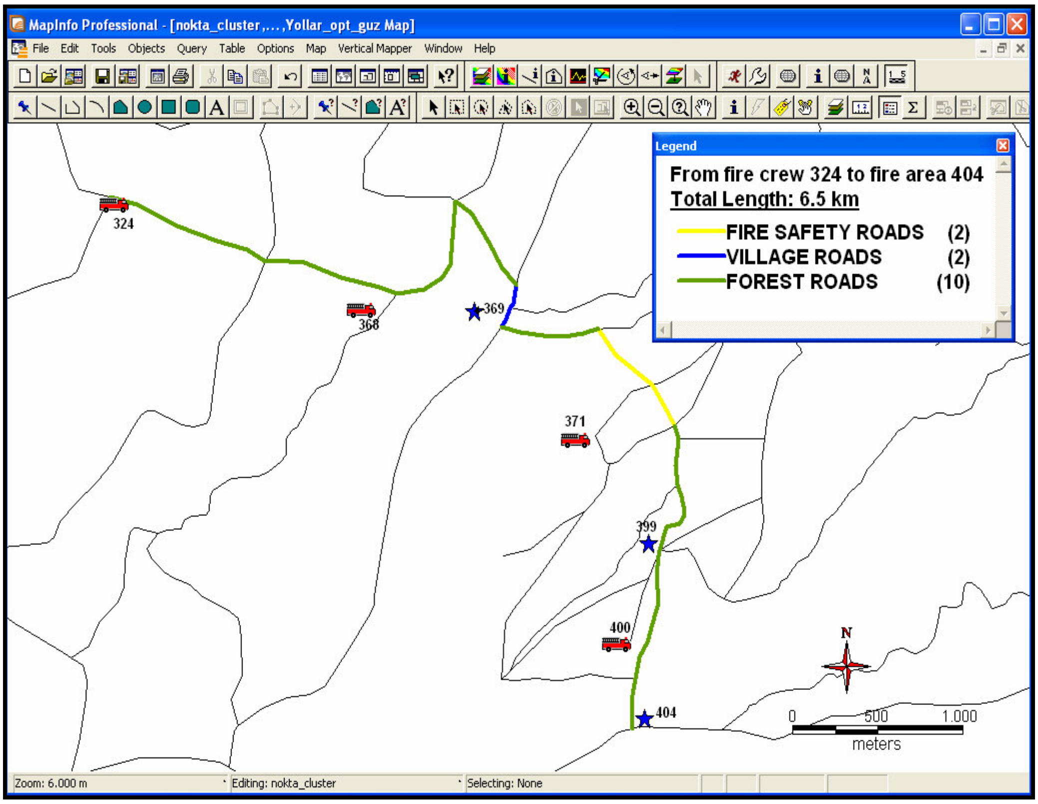

Figure 4.66 Types of the roads in the shortest path from fire crew 324 to the fire area 404.

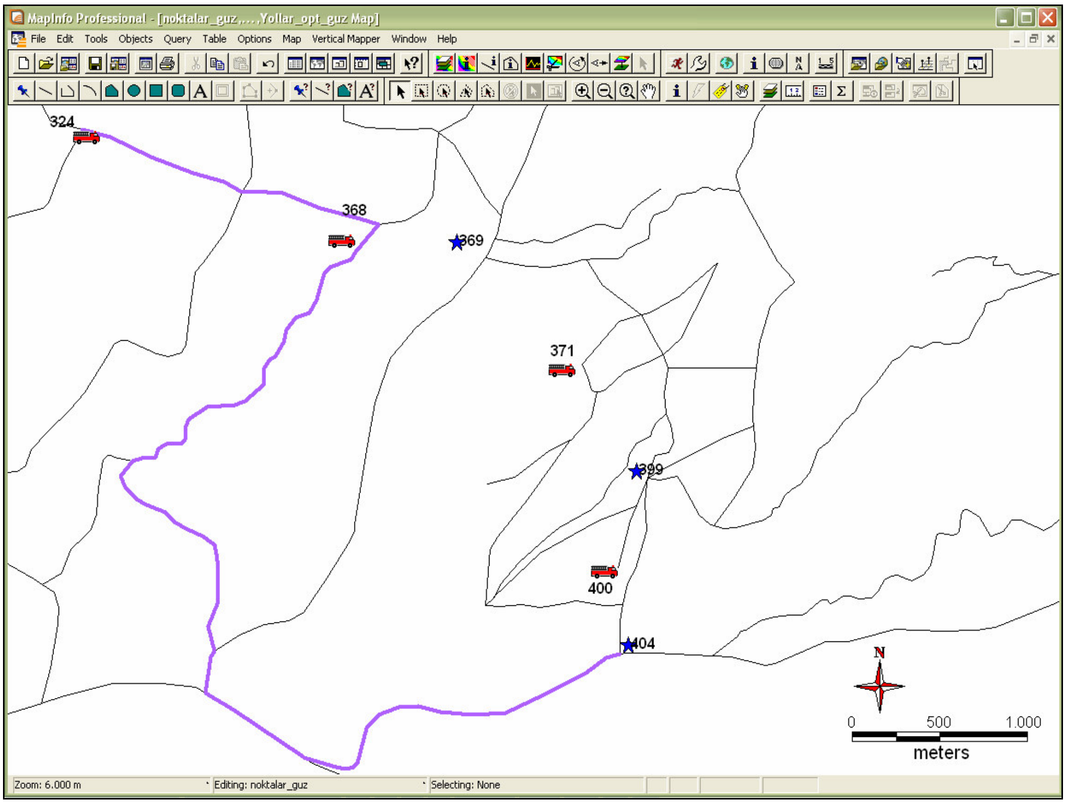

Figure 4.67 The second shortest path from fire crew 324 to the fire area 404 (8.3 km).

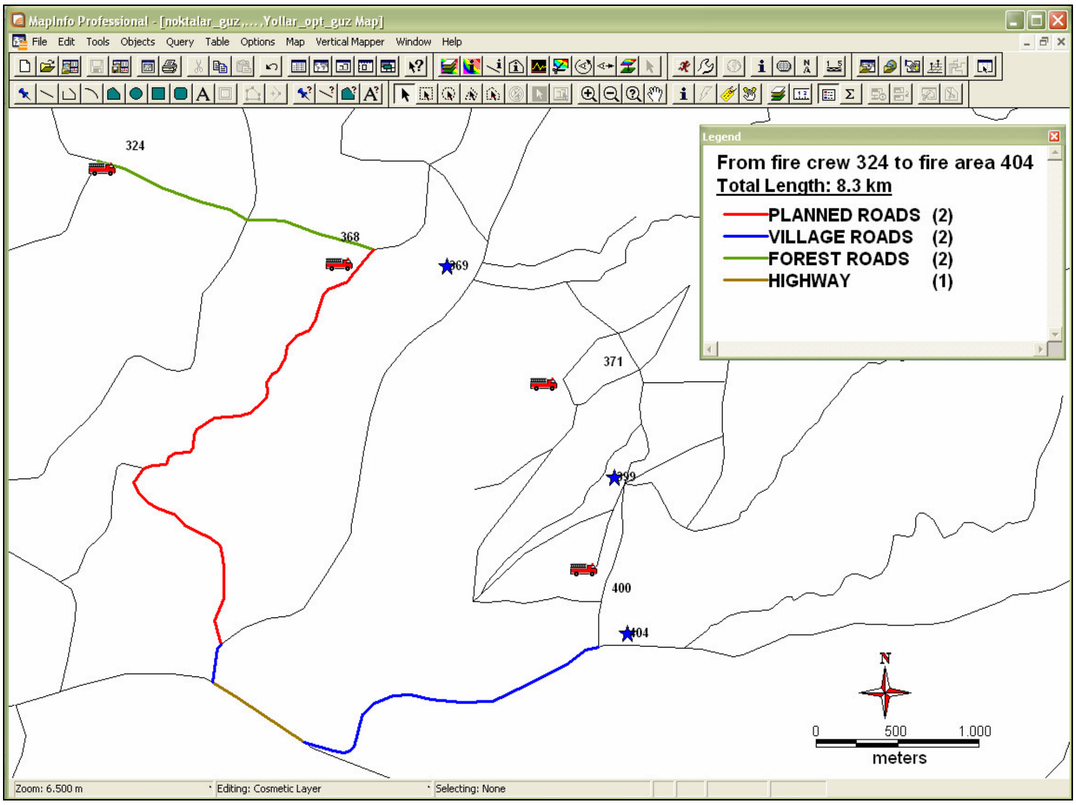

Figure 4.68 Types of the roads in the second shortest path from fire crew 324 to the fire area 404.

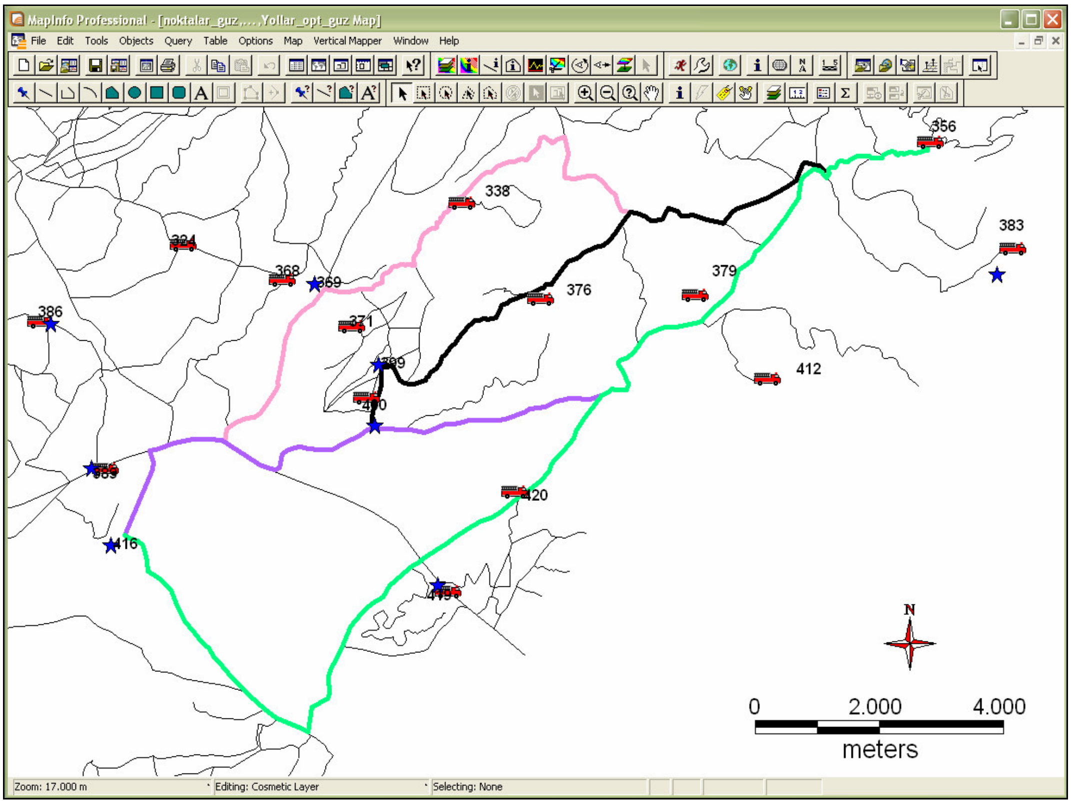

Figure 4.69 Four different paths to reach from fire crew 356 to fire area 416.

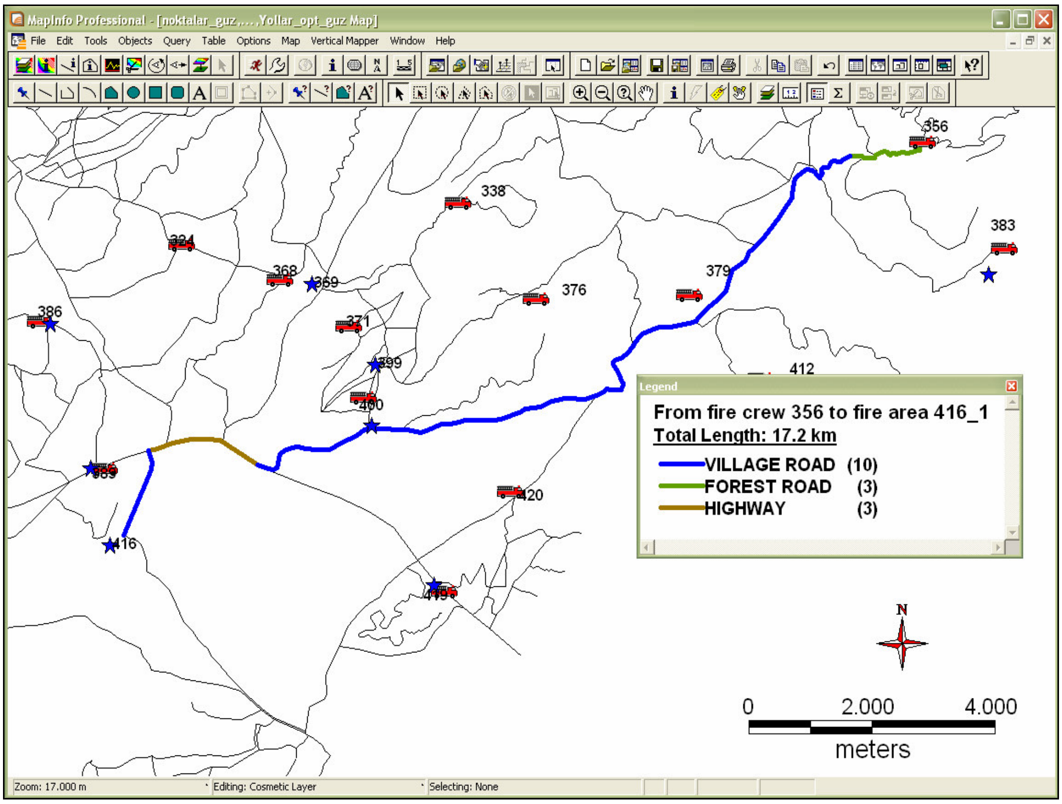

Figure 4.70 Scenario 1 about length of the road from fire crew 356 to the fire area 416.

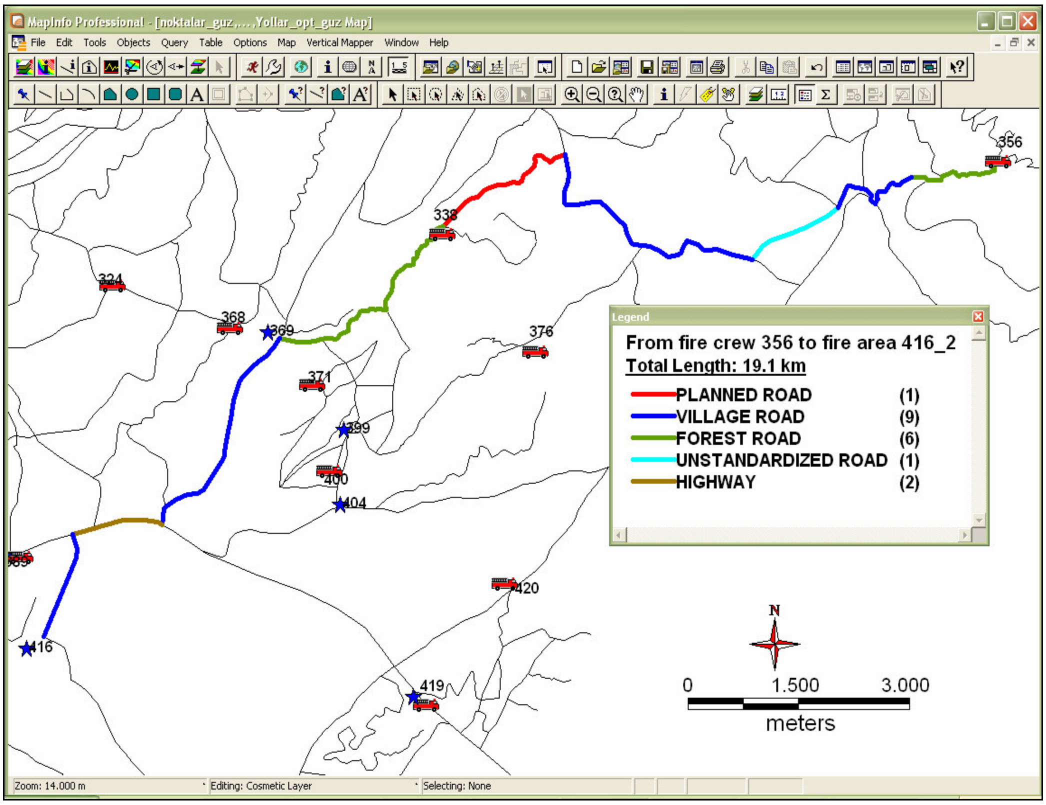

Figure 4.71 Scenario 2 about length of the road from fire crew 356 to the fire area 416.

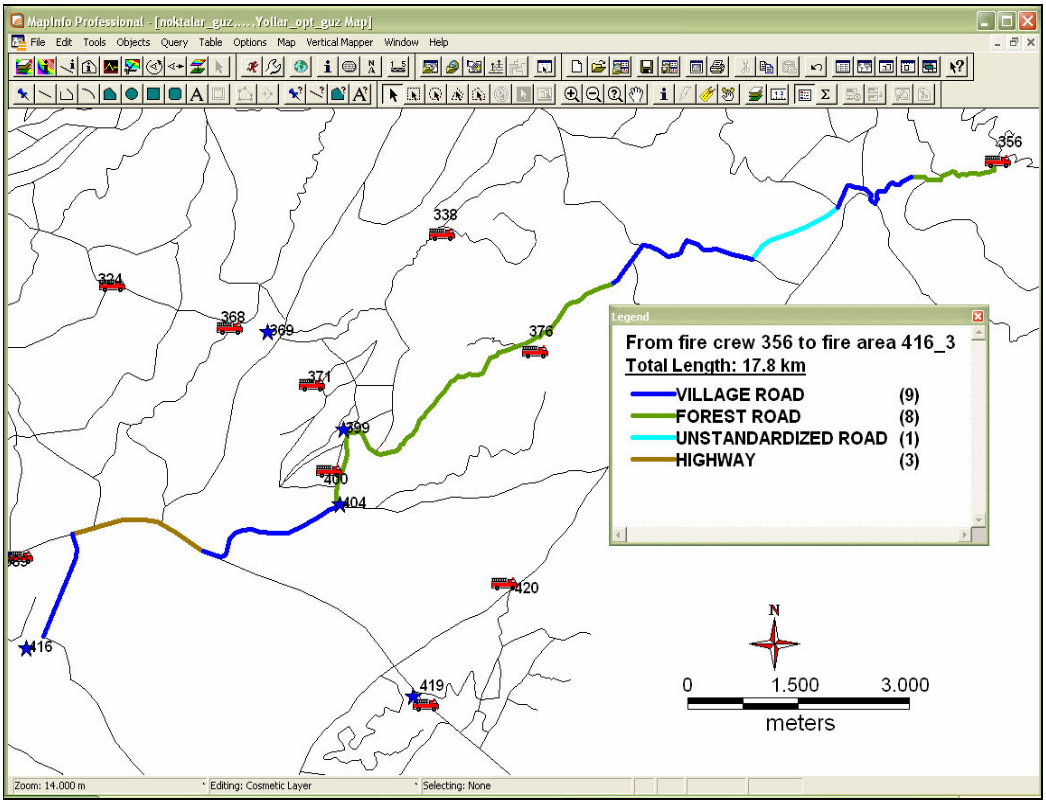

Figure 4.72 Scenario 3 about length of the road from fire crew 356 to the fire area 416.

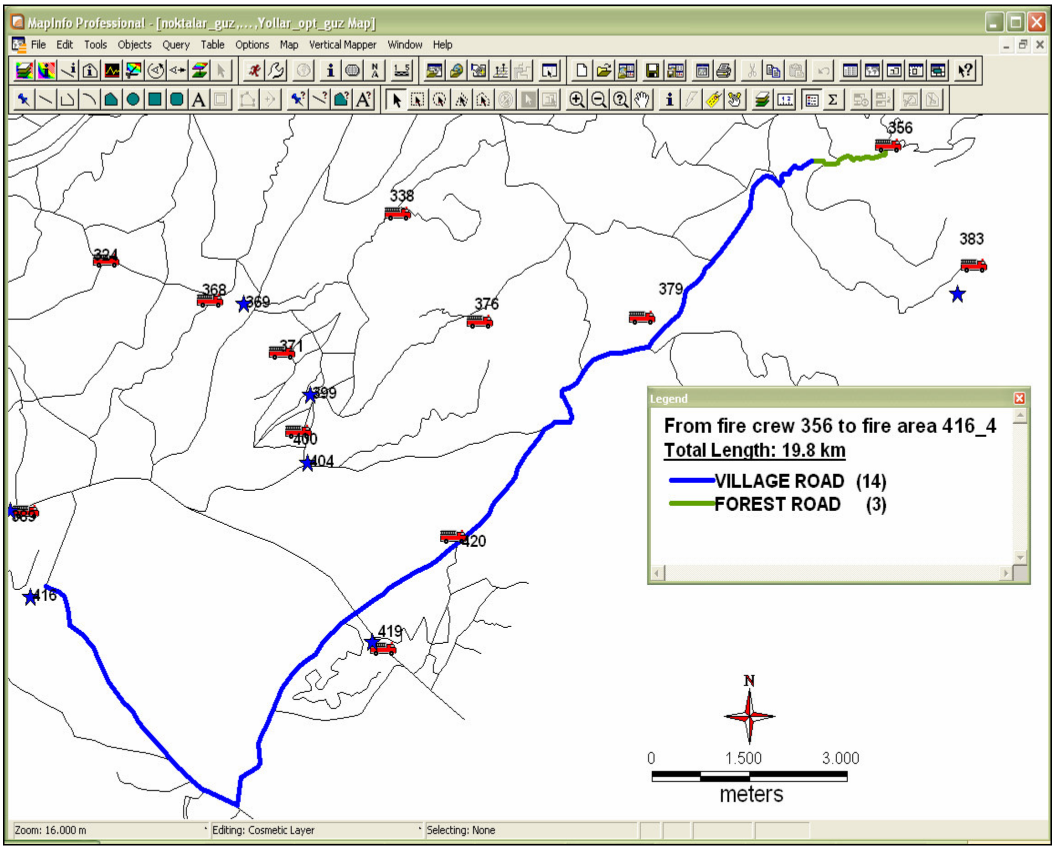

Figure 4.73 Scenario 4 about length of the road from fire crew 356 to the fire area 416.

Figure 4.74 summarizes usage of road analyses done in this part.

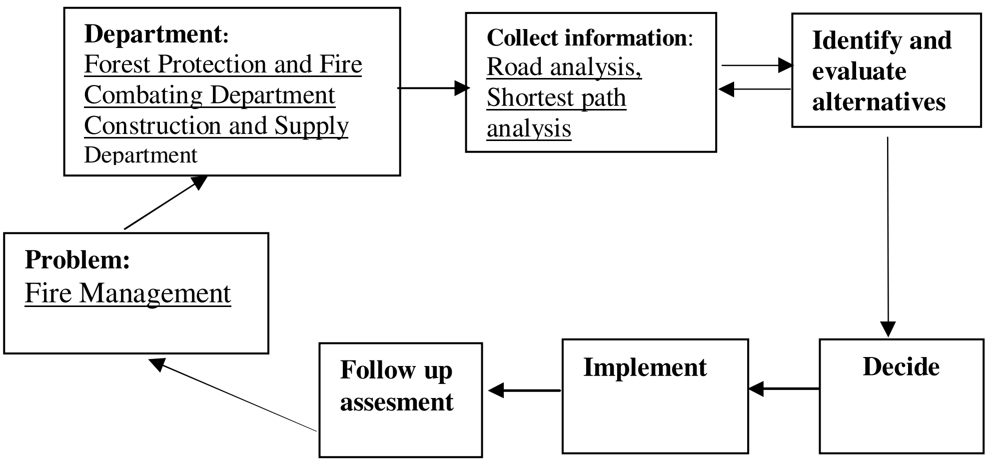

Figure 4.74 Potential usage of road analysis and the shortest path analysis.

In the following part of the thesis it is tried to minimize the numbers of proposed fire crews, which are found by LSCP, by using clustering algorithm.

4.4.5 Clustering Analysis

Clustering deals with grouping of records or cases into classes with similar objects. In a cluster, there are records that are similar to one another. That is clustering collects homogeneous objects in one cluster and dissimilar to objects in other cluster. One of the differences between clustering and classification is that there is no target value for clustering. In clustering it is not tried to classify, estimate or predict the value of a target variable. Clustering algorithms search for segmenting the entire data set into relatively homogenous subgroups or clusters (Larose, 2005; Nasibov, 2008).

One type of clustering that is used for finding clusters in data is called k-means clustering. This type of clustering calculates distance among points in continuos space by using Euclidean distance. Steps of algorithm used in this clustering can be summarized as (Larose, 2005; Nasibov, 2008):

Step 1: Deciding how many clusters k the data set should be partitioned into.

Step 2: Assignment of k records to be the initial cluster center locations randomly.

Step 3: Finding the nearest cluster center for each record. The nearest criterion in this step is usually Euclidean distance. Each cluster center owns a subset of the records, thereby representing a partition of the data set. Therefore, k clusters, C_1, C_2, ….C_k exist.

Step 4: Finding the cluster centroid for each of the k clusters and updating the locations of each cluster center to the new value of the centroid.

Step 5: Repeating steps 3 to 5 until convergence or termination.

The algorithm terminates when for all clusters C_1, C_2, ….C_k, all the records owned by each cluster center remain in that cluster. The algorithm may terminate when some convergence criterion, such as no significant shrinkage in the sum of squared errors (SSE), is met. SSE is shown in formula 4.2.

$$SSE = \sum_{i=1}^{k} \sum_{p \in C_i} d(p, m_i)^2 \qquad (4.2)$$

where $p \in C_i$ represents each data point in cluster i and m_i represents the centroid of cluster i.

Locations of the fire crews found by LSCP were positioned on the road map of İzmir Forest Administration Chief Office, as shown in Figure 4.75. In order to develop fire scenarios, different areas were determined as potential fire areas on the road map. 22 points (combination of both the numbers of fire crews and the numbers of fire areas) were pointed out on the road map, as shown in Figure 4.76.

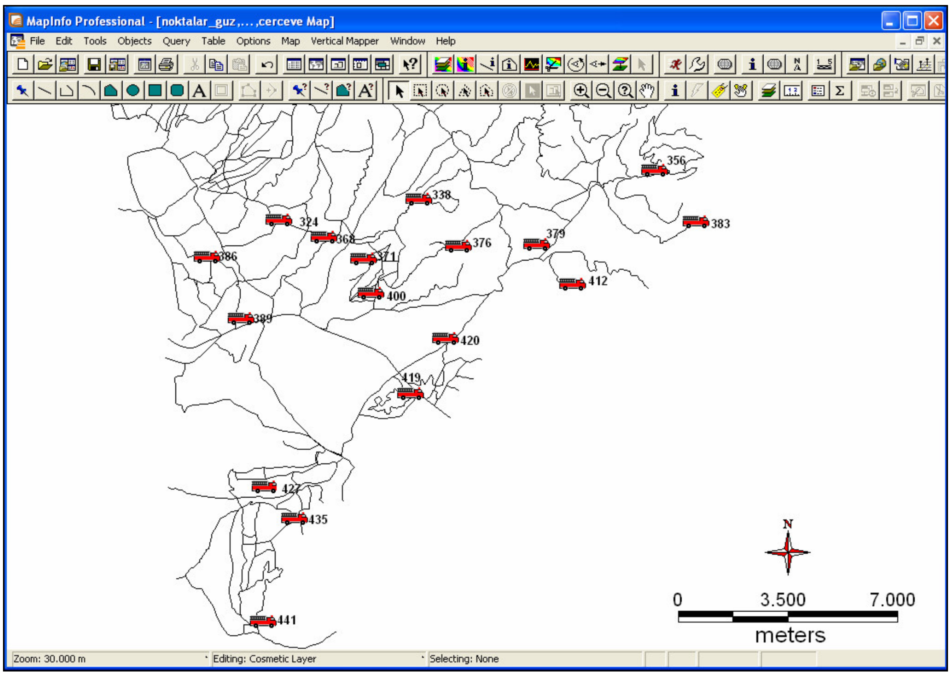

Figure 4.75 Locations of the proposed fire crews on the road map.

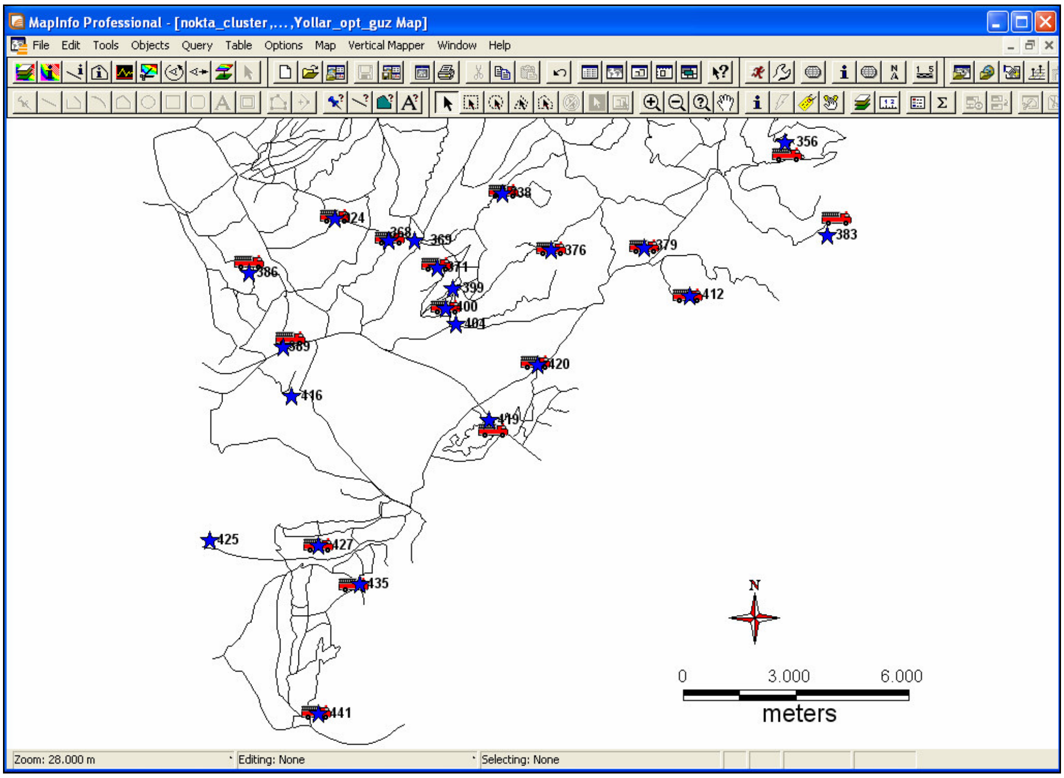

Figure 4.76 Fire crews, potential fire areas and the road map.

The shortest paths from fire crews found by LSCP, to the potential fire areas were found by using functions of GIS and 22x22 the shortest roads matrix was constituted. This matrix consisted of lengths of the shortest roads (km) from fire crews to the potential fire areas. The objective was to minimize the numbers of fire crews found by LSCP for the fire scenario developed on this road map. Mathematical model of this problem was expressed as shown in formulas (4.3)-(4.7).

The objective of this new clustering algorithm is to minimize SSE as shown in formula 4.3, 4.4, 4.5, 4.6 and 4.7.

$$SSE = \sum_{i=1}^{n}\sum_{j=1}^{n} y_i u_{ij} d_{ij} \rightarrow \min \qquad (4.3)$$

$$\sum_{i=1}^{n} y_i = C \qquad (4.4)$$

$$u_{ij} = \begin{cases} 1, & \text{if } d_{ij} = \min\limits_{k=1,n} d_{kj} \\ 0, & \text{otherwise} \end{cases}, \qquad j = \overline{1,n} \qquad (4.5)$$

$$\sum_{i=1}^{n} u_{ij} = 1, \qquad j = \overline{1,n} \qquad (4.6)$$

$$y_i \in \{0,1\}, \qquad i = \overline{1,n} \qquad (4.7)$$

where

C= number of clusters;

d_{ij}= road distance between points i and j;

$$y_i = \begin{cases} 1, & \text{if point i is selected as fire crew} \\ 0, & \text{otherwise} \end{cases}$$

$$u_{ij} = \begin{cases} 1, & \text{if point j belongs to the cluster with center point i} \\ 0, & \text{otherwise} \end{cases}$$

Problem (4.3)-(4.7) is a type of clustering problem and in this problem y_i are the determining decision variables. This is non-linear discrete 0-1 integer programming problem. This problem can not be solved by classical clustering algorithms and current software packages because of the constraint (4.5). Since road distances on the road map are not Euclidean distance and they are discrete in nature classical clustering is not suitable for this study. Thus a new clustering algorithm, which is based on combinatorial search, has been developed for this thesis and used to find an optimum solution for the fire scenario we have developed. The new clustering algorithm used 22x22 the shortest roads matrix as shown in Table 4.5. Rows and coloumns of Table 4.5 constitutes of 22 points, combination of both the numbers of fire crews and the numbers of potential fire areas.

Table 4.5 The shortest roads matrix.

	324	**338**	**356**	**368**	**369**	**371**	**376**	**379**	**383**	**386**	**389**	**399**	**400**	**404**	**412**	**416**	**419**	**420**	**425**	**427**	**435**	**441**
324	0	6.6	17.1	1.8	3.3	4.9	8.6	13.9	19.3	5.1	5.5	5.5	6	6.5	15.7	7.4	9.8	12.3	19.7	14.5	18.2	20.3
338	6.6	0	14.8	4.8	3.4	3.6	6.3	11.6	19.3	10.1	8.5	3.7	4.7	4.7	13.4	9	9.9	10.6	21	16.7	20.1	22.2
356	17.1	14.8	0	15.3	13.4	12.8	8.2	5.5	6.5	19.6	16.7	11.4	11.9	12.4	7.4	17.2	12.4	10.1	21.8	18.1	22.1	24.2
368	1.8	4.8	15.3	0	1.6	3.1	6.8	12.1	17.6	5.3	5.7	3.7	4.2	4.7	12.8	6.5	8.9	10.6	17.4	16.7	20	22.1
369	3.3	3.4	13.4	1.6	0	1.6	5.4	10.6	15.8	6.9	5.4	2.2	2.7	3.2	12.5	5.9	8.8	10.3	16.8	13.1	17.1	19.2
371	4.9	3.6	12.8	3.1	1.6	0	4.6	9.9	15	8.4	6.8	1.4	2	2.5	11.7	7.3	8.1	9.5	17.5	14.5	17.8	19.9
376	8.6	6.3	8.2	6.8	5.4	4.6	0	5.3	10.8	12	9.1	3.2	3.7	4.2	7.2	9.6	9.8	7.6	19.2	16.2	19.5	21.6
379	13.9	11.6	5.5	12.1	10.6	9.9	5.3	0	7.8	13.2	11.2	7.3	7.8	6.3	1.9	11.7	6.9	4.6	16.3	12.7	16.7	18.8
383	19.3	19.3	6.5	17.6	15.8	15	10.8	7.8	0	20.9	18.9	13.6	14.5	14	9.6	19.5	14.6	12.3	24	20.1	24.4	26.5
386	5.1	10.1	19.6	5.3	6.9	8.4	12	13.2	20.9	0	3	8.9	8.5	7	15.1	5.3	8.4	9.8	15.8	12.2	16.1	18.3
389	5.5	8.5	16.7	5.7	5.4	6.8	9.1	11.2	18.9	3	0	5.9	6.5	4.9	13.1	2.4	6.4	7.8	13.2	9.6	13.5	15.7
399	5.5	3.7	11.4	3.7	2.2	1.4	3.2	7.3	13.6	8.9	5.9	0	0.6	1.1	9.2	6.5	6.7	7	16.1	13.1	17.7	18.5
400	6	4.7	11.9	4.2	2.7	2	3.7	7.8	14.5	8.5	6.5	0.6	0	1.6	9.7	7	7.2	7.5	16.6	12.9	16.9	19
404	6.5	4.7	12.4	4.7	3.2	2.5	4.2	6.3	14	7	4.9	1.1	1.6	0	8.2	5.5	5.7	7.1	15.1	11.4	15.4	17.5
412	15.7	13.4	7.4	12.8	12.5	11.7	7.2	1.9	9.6	15.1	13.1	9.2	9.7	8.2	0	13.6	8.8	6.5	18.2	14.6	18.5	20.7
416	7.4	9	17.2	6.5	5.9	7.3	9.6	11.7	19.5	5.3	2.4	6.5	7	5.5	13.6	0	6.9	8.3	10.9	7.2	11.2	13.3
419	9.8	9.9	12.4	8.9	8.8	8.1	9.8	6.9	14.6	8.4	6.4	6.7	7.2	5.7	8.8	6.9	0	2.4	10.3	6.7	10.7	12.8
420	12.3	10,6	10.1	10.6	10.3	9.5	7.6	4.6	12.3	9.8	7.8	7	7.5	7.1	6.5	8.3	2.4	0	11.8	8.1	12.1	14.2
425	19.7	21	21.8	17.4	16.8	17.5	19.2	16.3	24	15.8	13.2	16.1	16.6	15.1	18.2	10.9	10.3	11.8	0	4.9	5	7.1
427	14.5	16.7	18.1	16.7	13.1	14.5	16.2	12.7	20.1	12.2	9.6	13.1	12.9	11.4	14.6	7.2	6.7	8.1	4.9	0	6.3	7.4
435	18.2	20.1	22.1	20	17.1	17.8	19.5	16.7	24.4	16.1	13.5	17.7	16.9	15.4	18.5	11.2	10.7	12.1	5	6.3	0	4.9
441	20.3	22.2	24.2	22.1	19.2	19.9	21.6	18.8	26.5	18.3	15.7	18.5	19	17.5	20.7	13.3	12.8	14.2	7.1	7.4	4.9	0

GIS was used for positioning fire crews, fire areas on a digital map and finding the shortest roads from fire crews to fire areas. C++ was used for the development of new algorithm. In this study fire crews were named with the compartment number they were assigned. For instance fire crew 435 means that this fire crew must be assigned to the compartment 435 according to LSCP.

The result of the new clustering algorithm was shown in Figure 4.77.

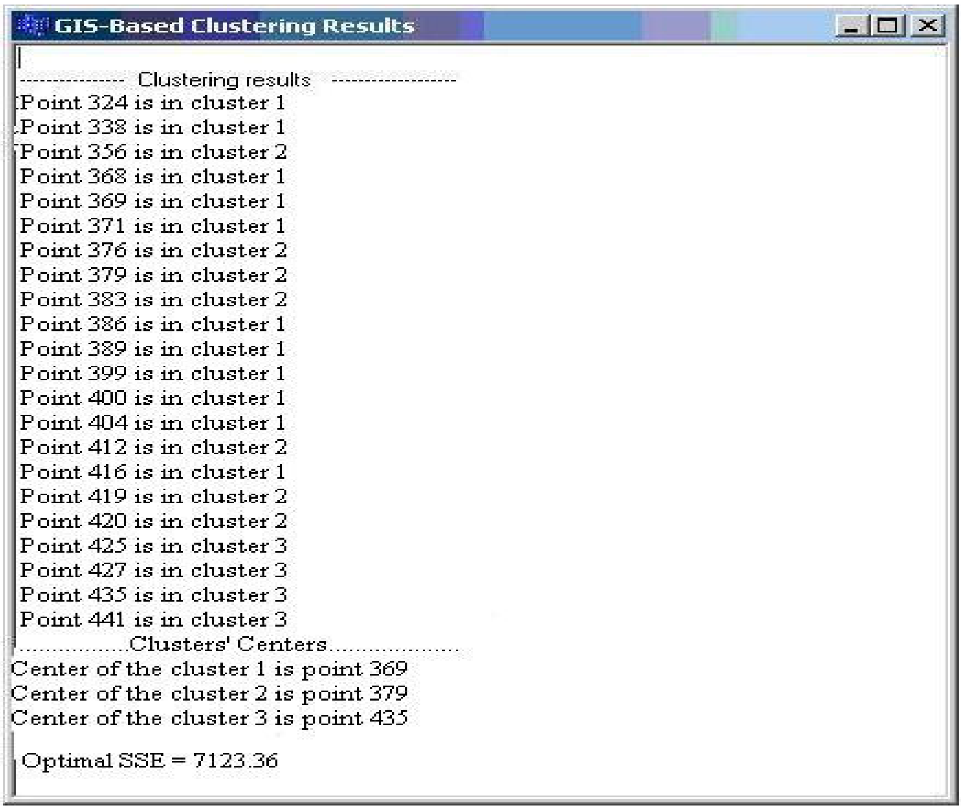

Figure 4.77 Results of the new algorithm.

The numbers of clusters were determined as three and they were numbered as, 1, 2 and 3. According to this new algorithm, points, 324, 338, 368, 369, 371, 386, 389, 399, 400, 404 and 416 were assigned to the cluster 1; points, 356, 376, 379, 383, 412, 419 and 420 were assigned to the cluster 2; and the points, 425, 427, 435 and 441 were assigned to the cluster 3, as shown in figure 4.76. For this fire scenario, centers of the clusters were found as 369 for cluster 1, 379 for cluster 2, and 435 for cluster 3. The numbers of fire crews, which were found as 17 by LSCP, were minimized to the three by the new clustering algorithm. It was proposed that fire crews must be assigned to the compartments 369, 379 and 435 for this fire scenario.

Figure 4.78 shows results of the new algoritm on the map.

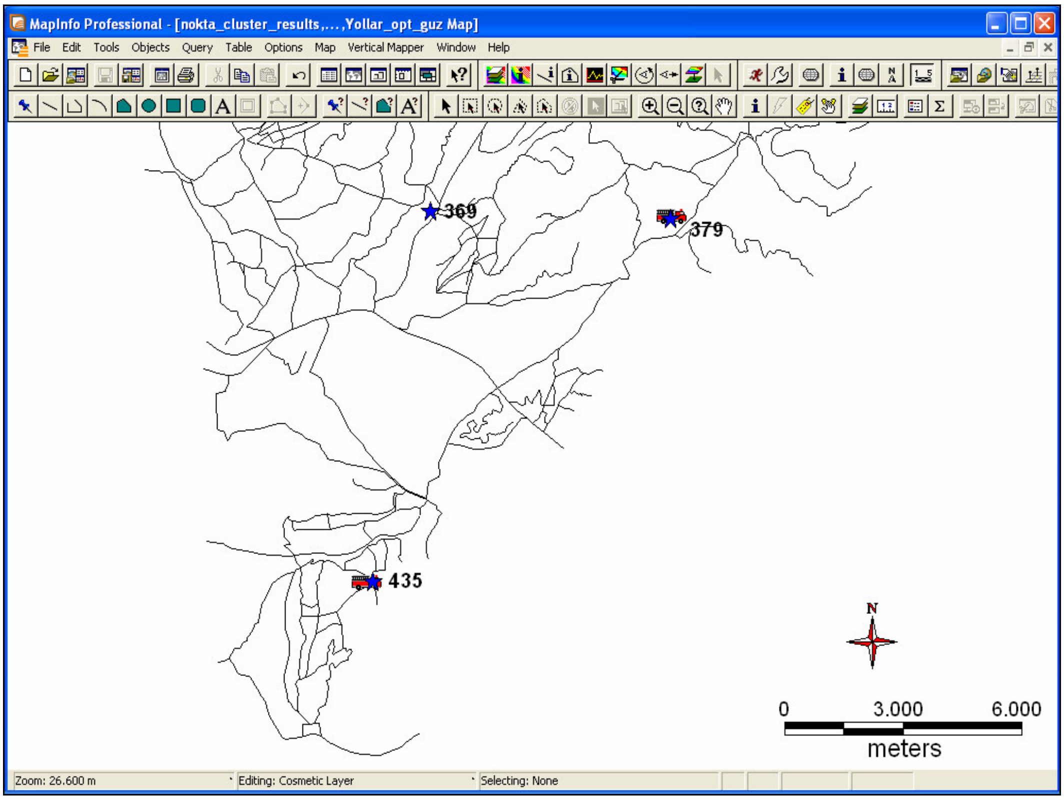

Figure 4.78 Representation of the results of the new clustering algorithm on the road map.

4.4.6 Boolean Approach

Boolean approach is used to combine series of input map layers into a single output layer through use of and, or and not operators. In GIS, this methodology is used in a multiplication overlay between layers containinig only zeros (represents areas where conditions false or criterion is not satisfied. In many real-world problems, decision making proces can be more complicated. There are situations where a boolean analysis does not produce satisfactory solution and with Boolean approach all of the criteria carry equal importance in solution (Dane, 2007).

IDRISI GIS Software package was used for Boolean Analysis.

4.4.6.1 Boolean Standardization of Factors

In our study, Boolean Approach is used to determine the most suitable areas that cope with fires effectively. First of all all criteria were standardized to Boolean values (0 and 1). Factors of our study are, distance from water resources, distance from streams and distance from settlement areas.

4.4.6.1.1 Distance From Water Resources Factor. As mentioned before water resources are very important in fire management. Areas closer to water resources are considered more suitable to cope with fire than areas that are distant from water resources. Water resources map is derived by rasterizing and using the module DISTANCE as a distance operator under the GIS analysis in IDRISI software package as shown in Figure 4.79. Then, distance image is obtained. Figure 4.80 shows a simple linear distance from all water resources in our study area.

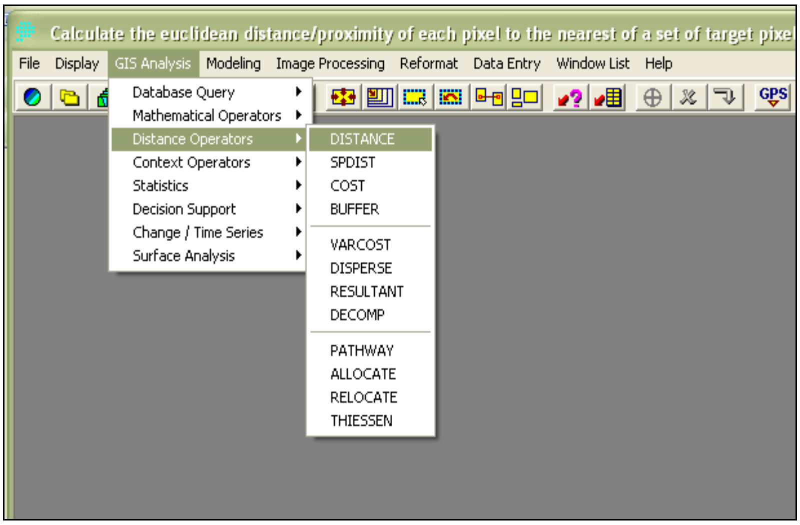

Figure 4.79 IDRISI GIS software distance analysis.

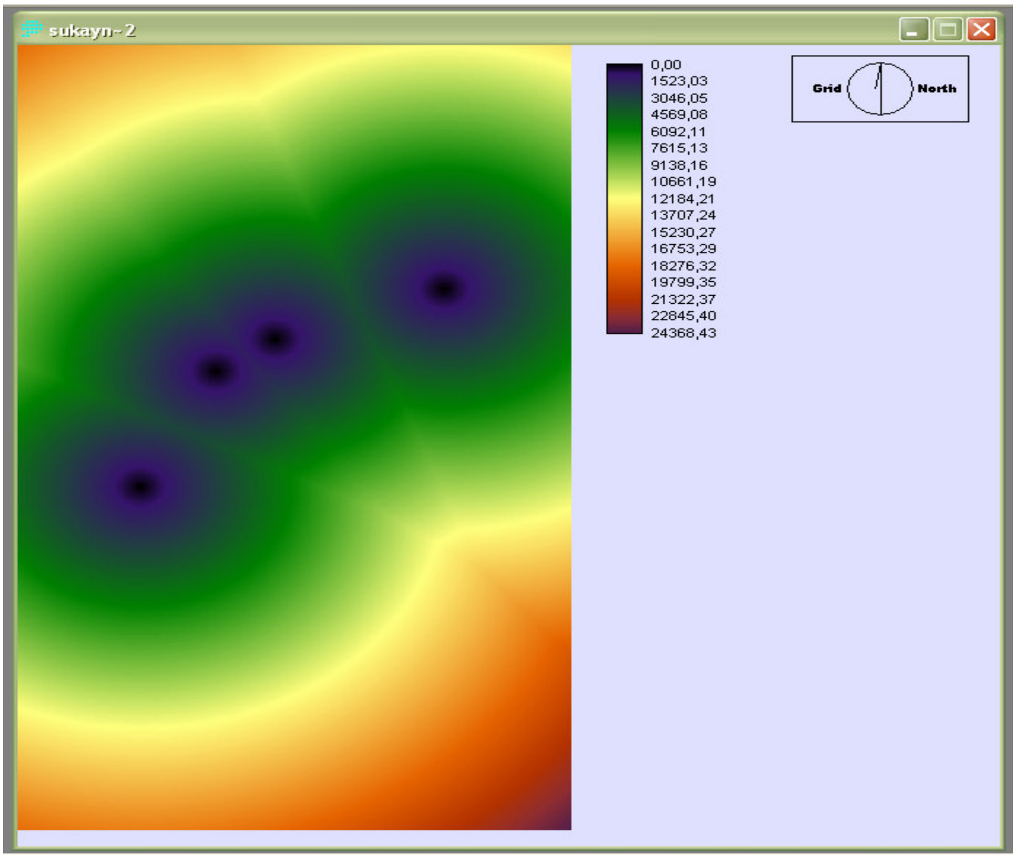

Figure 4.80 Distance map of water resources.

In this stage it is needed to RECLASSIFY continuos image of distance from water resources to a Boolean expression of distances that are suitable and distances that are not suitable. We reclassified our image of distance from water resources such that areas less than 5000 meters from any water resources are suitable (1) and those equal to or beyond 5000 meters are not suitable (0). Reclassification process and reclassified distance map of water resources are shown in Figure 4.81 and Figure 4.81, respectively. Figure 4.83 shows compartment map and reclassed distance map of water resources.

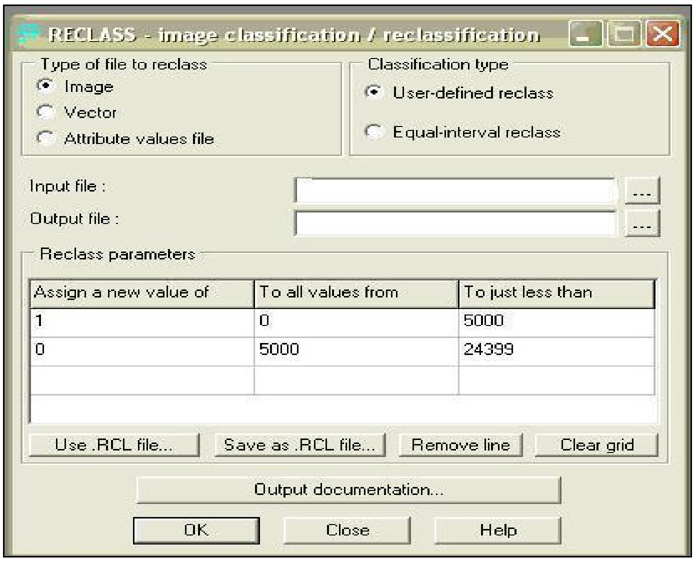

Figure 4.81 Reclassification of water resources distance map.

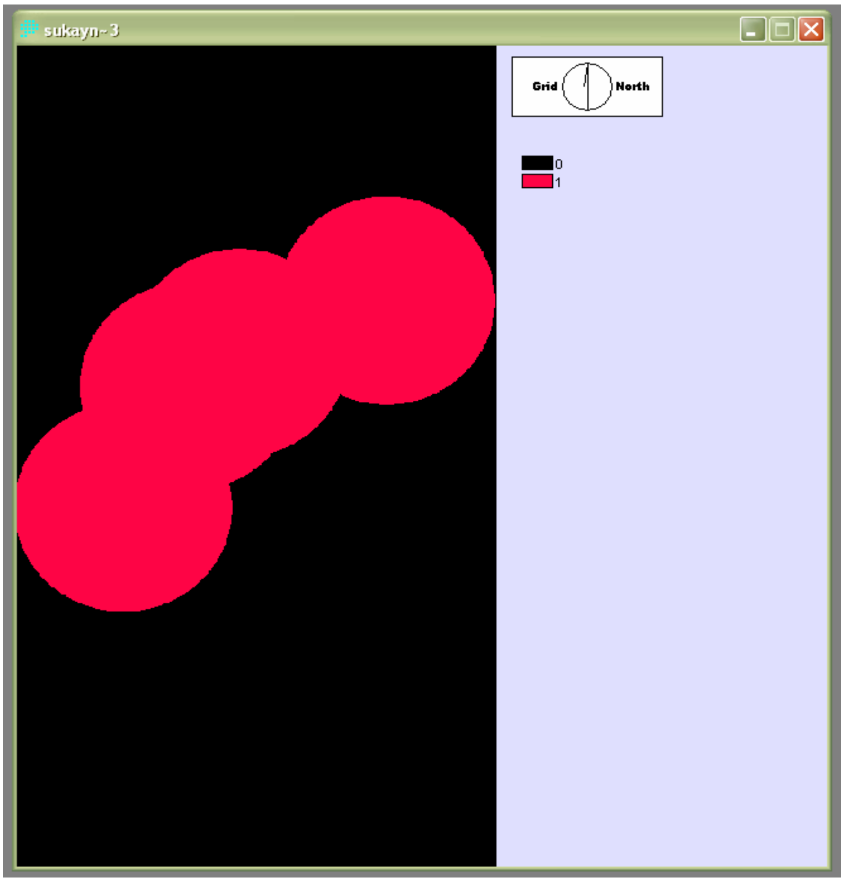

Figure 4.82 Reclassed distance map of water resoures.

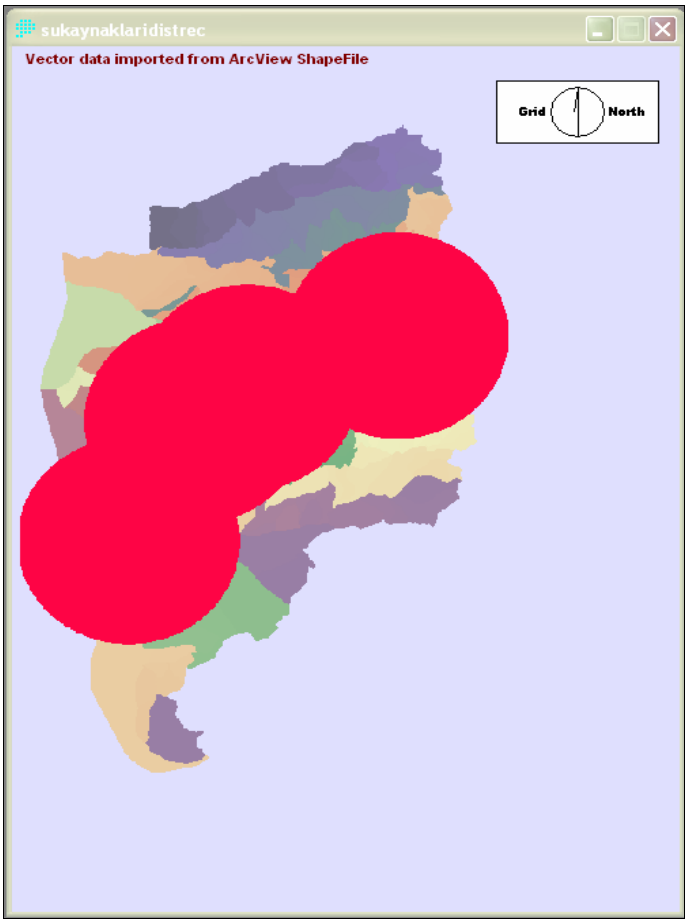

Figure 4.83 Compartment map and reclassed distance map of water resources.

4.4.6.1.2 Distance From Streams Factor. Streams also play very important role in fire management policy. To get distance map of streams and reclassed distance map of streams, all procedure is the same as procedure of distance from water resources factor. Figure 4.84 shows raster image of stream maps. Distance map of streams, reclassification of the distance map of streams, reclassed distance map of streams are shown in Figures 4.85, 4.86, and 4.87. Figure 4.88 displays reclassed distance map of streams and stream map together.

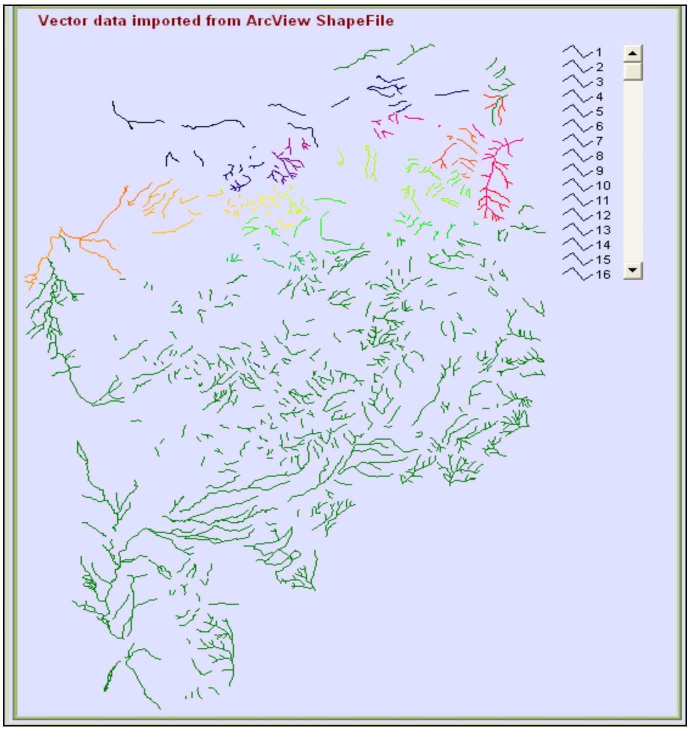

Figure 4.84 Raster image of stream map.

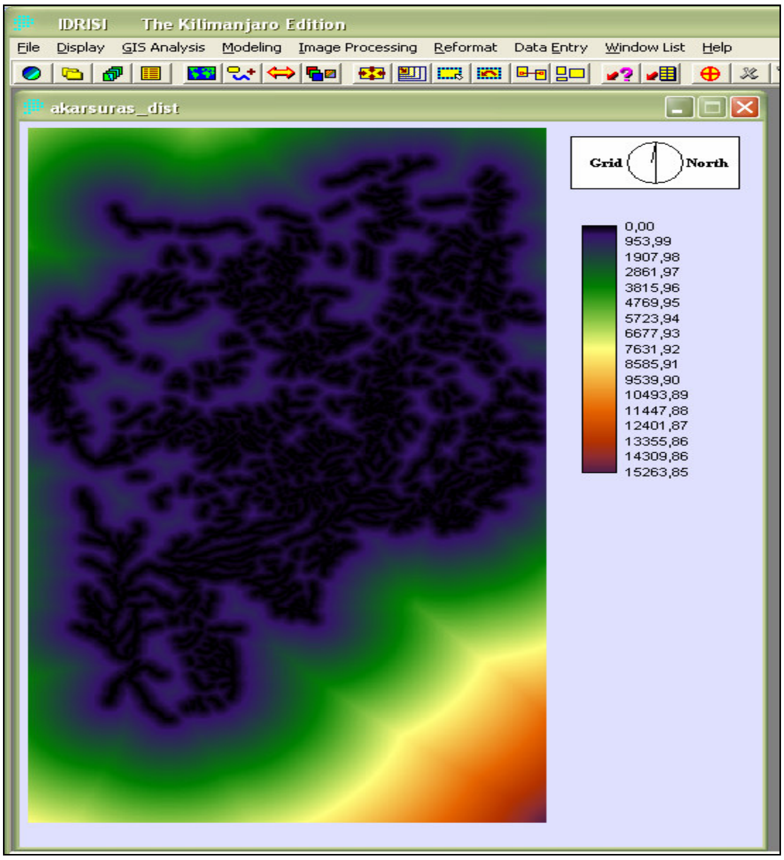

Figure 4.85 Distance map of streams.

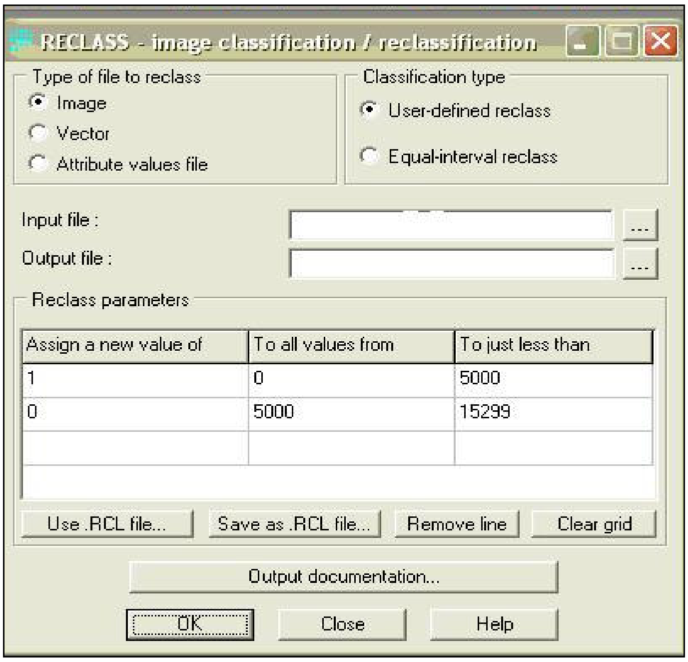

Figure 4.86 Reclassification of distance map of streams.

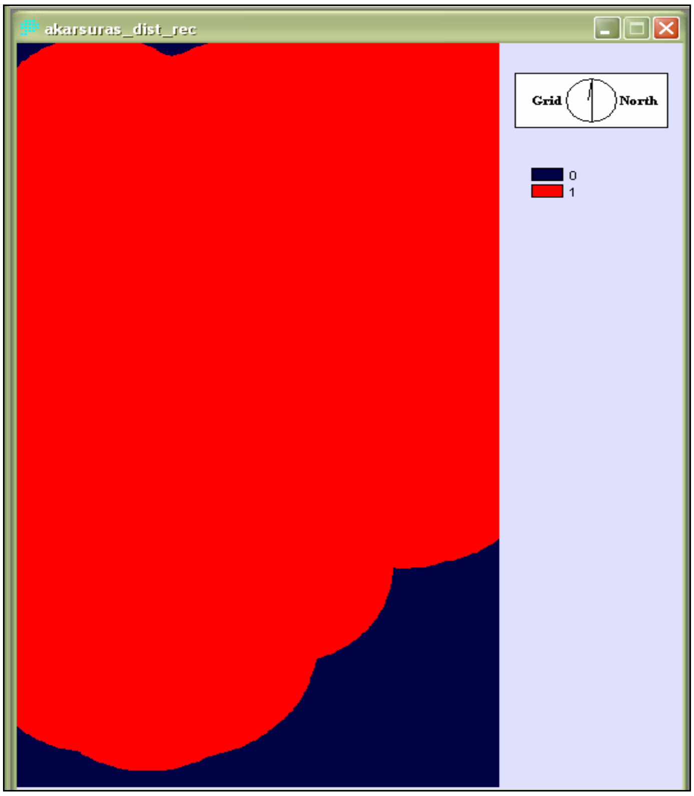

Figure 4.87 Reclassed distance map of streams.

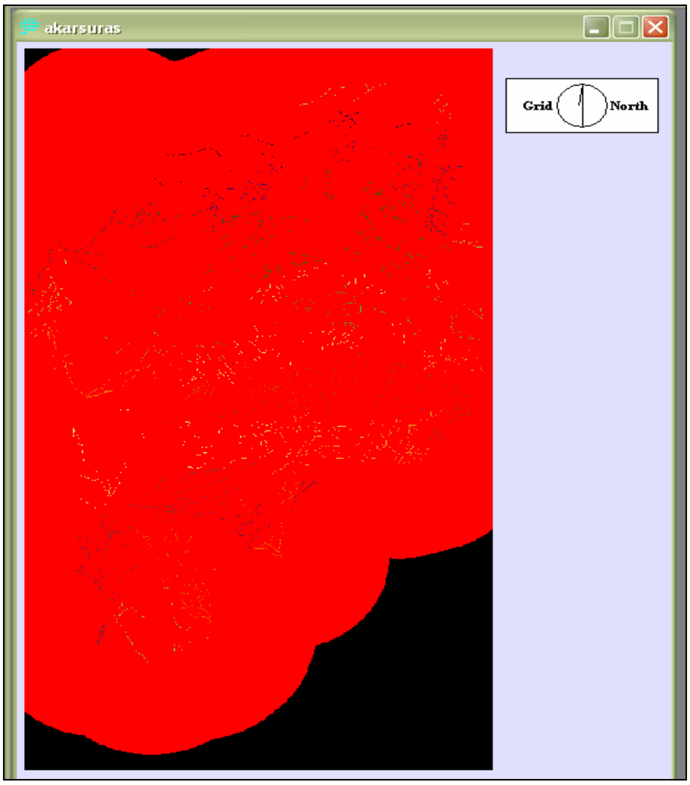

Figure 4.88 Reclassed distance map of streams and streams.

4.4.6.1.3 Distance From Settlement Areas Factor. 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 risky factor. In some cases, the areas closer to the settlement areas are more fire prone because of the human factor. In this thesis settlement areas are thought as an important factor in controlling fire. Areas less than 2000 meters from any settlement are suitable areas for effectively struggling with fire and areas equal to or beyond 2000 meters are not suitable areas. Other procedures followed are the same as the procedure of distance from water resources factor and distance from streams factor.

Figure 4.89 shows raster image of settlement areas. Figure 4.90 shows distance map of settlement areas. Figure 4.91 displays reclassification procedure of distance map of settlement areas.Figure 4.92 represents result of reclassification and Figure 4.93 represents reclassed distance map of settlement area and settlement area together.

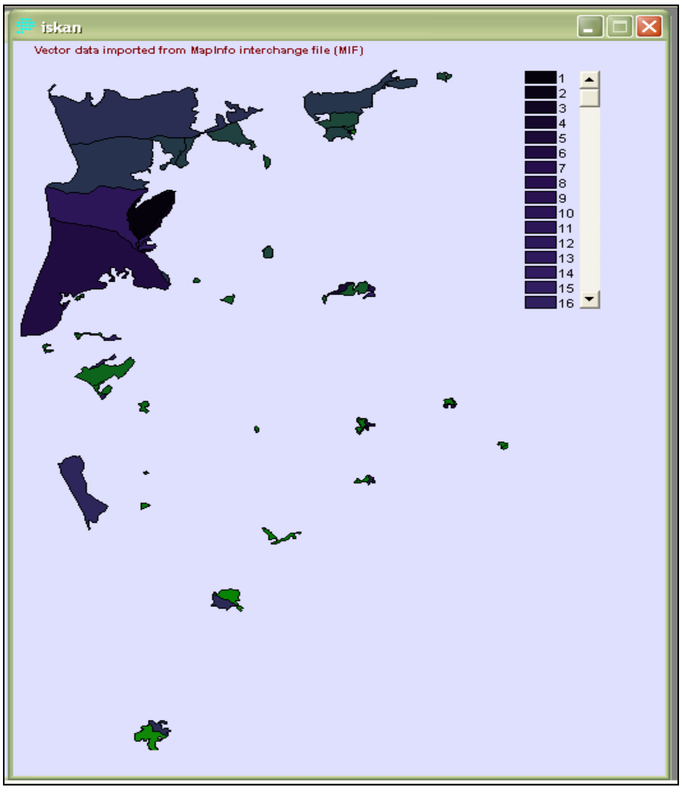

Figure 4.88 Raster image of settlement areas.

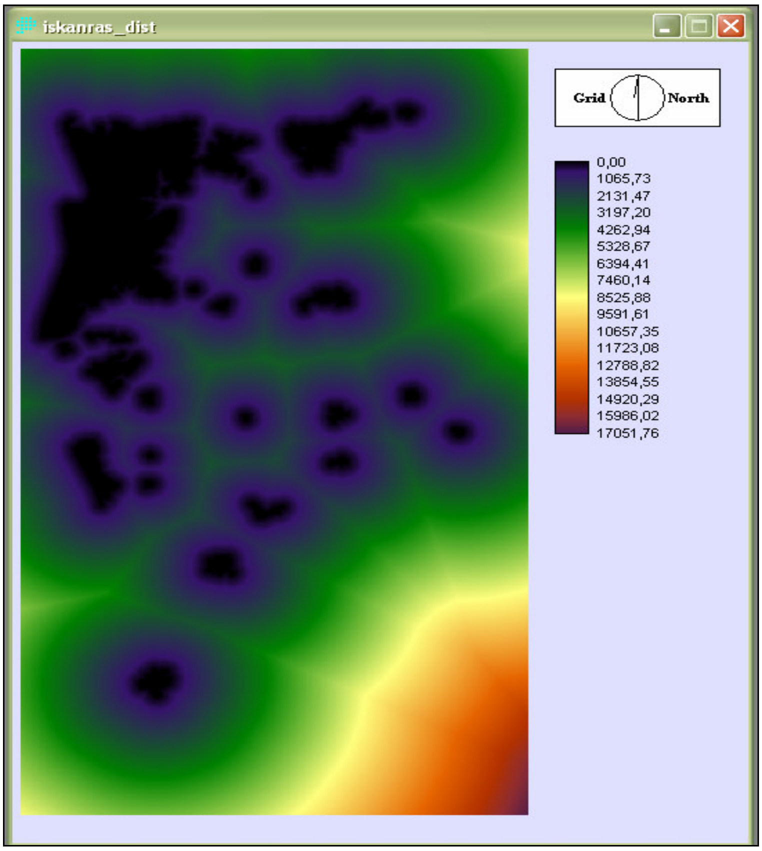

Figure 4.89 Distance map of settlement areas.

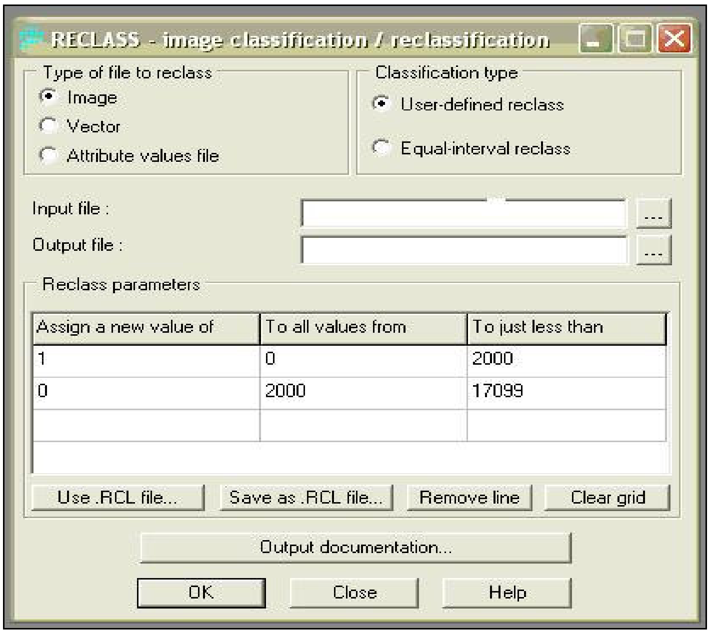

Figure 4.90 Reclassification of distance map of settlement areas.

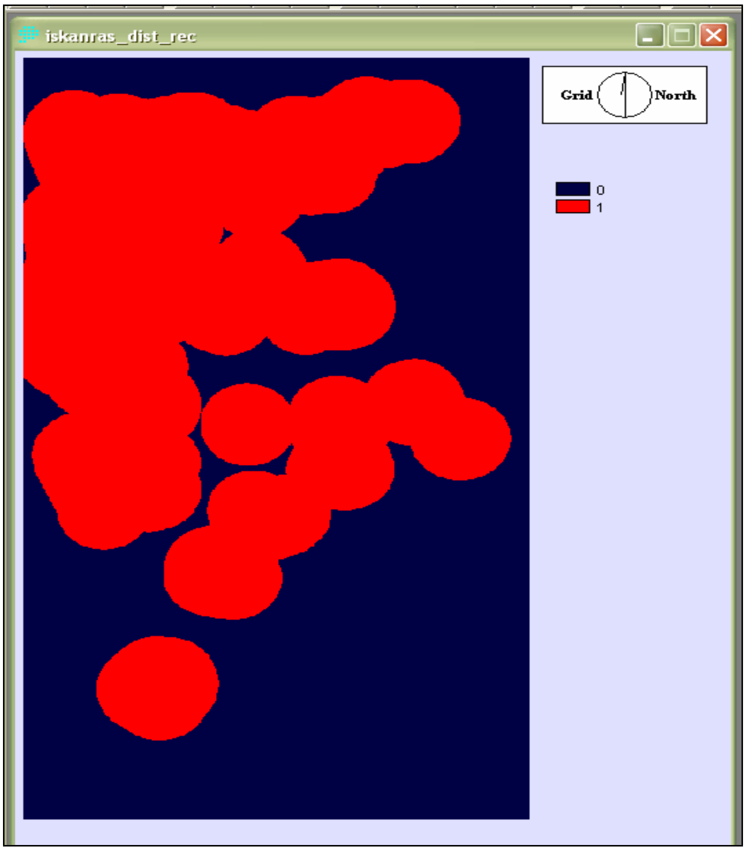

Figure 4.91 Reclassed distance map of settlement areas.

Figure 4.92 Reclassed distance map of settlement area and settlement areas.

4.4.6.2 Boolean Aggregation of Factors

All factors have been transformed into Boolean images and they are ready to be aggregated. All of these three factors are multiplied together to produce a single image of suitable areas for effectively coping with fire. This aggregation process can be done by using Image Calculator with AND operation in IDRISI software package (Dane, 2007). Figure 4.93 shows multiplication process and Figure 4.94 shows result of multiplication.

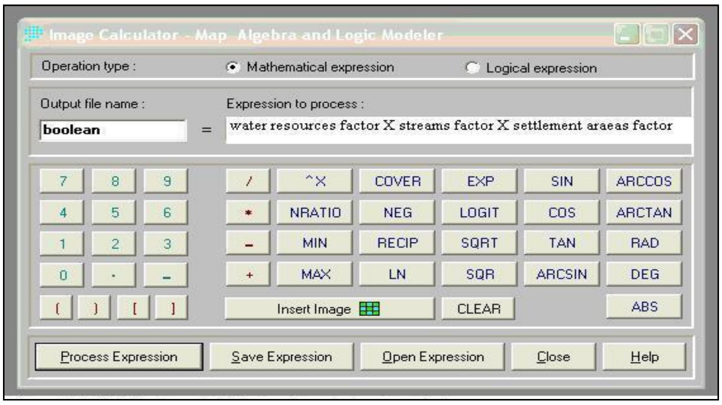

Figure 4.93 Multiplying all factors at image calculator.

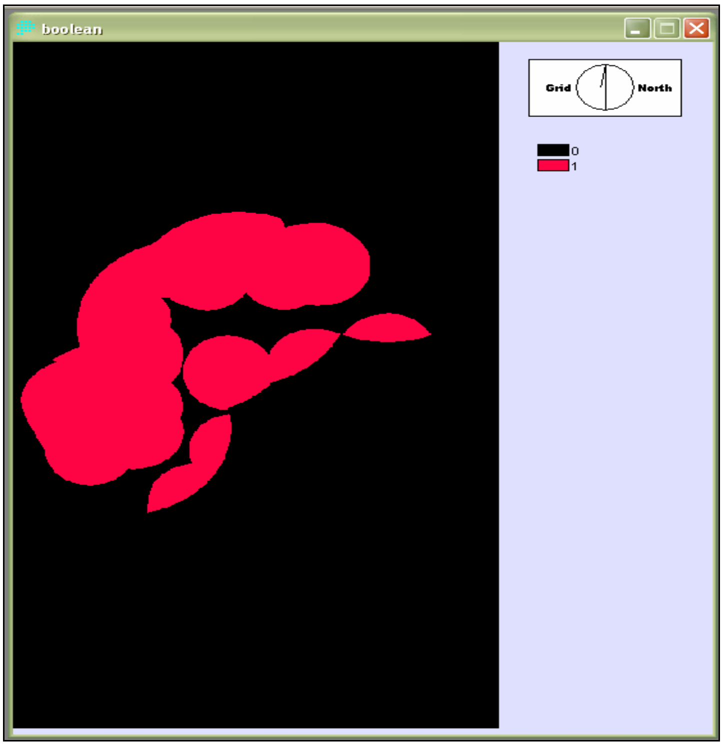

Figure 4.94 The most suitable areas that can cope with fire effectively according to Boolean approach.

4.4.7 Analytic Hierarchy Process (AHP)

As mentioned in the theoretical part of thesis, AHP is a decision making technique developed by mathematician Thomas L Saaty. It is a mathematical decision making based on, building hierarchy of criteria and at each node of hierarchy weighting is performed (Saaty, 1980; Saaty; 1986; Yaralıoğlu, 2004).

AHP starting process is shown in Figure 4.95.

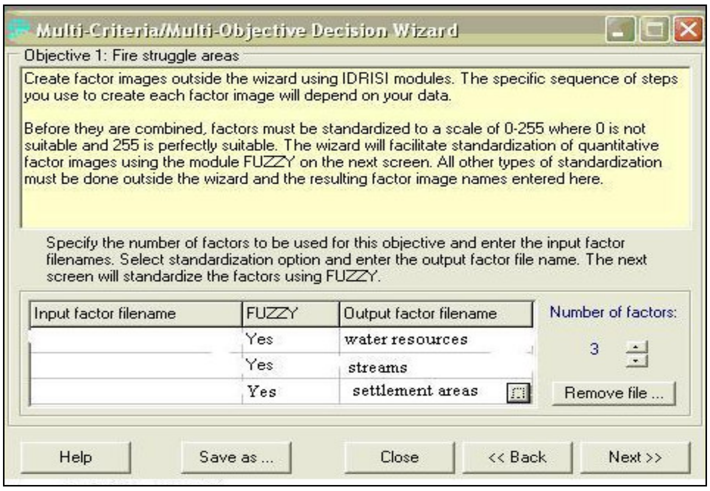

Figure 4.95 AHP module of IDRISI.

4.4.7.1 Fuzzy Standardization of Factors

In order to perform AHP in IDRISI first of all fuzzy standardization of factors must be done. In fuzzy standardization factors are not just reclassified into 0 and 1, but are rescaled to a particular common range according to some function. In order to use fuzzy factors with the multi criteria evaluation these factors will be standardized to a byte level range of 0-255.

4.4.7.1.1 Distance From Water Resources Factor. Distance from water resources must be rescaled to the byte range 0-255. In boolean approach areas less than 5000 meters from any water resources are suitable (1) and those equal to or beyond 5000 meters are not suitable (0). The suitability decrease with the distance and we choose monotonically decreasing. Figures 4.96, 4.97, 4.98, 4.99, 4.100, 4.101, 4.102, 4.103, 4.104 and 4.105 show AHP procedure followed in IDRISI software package.

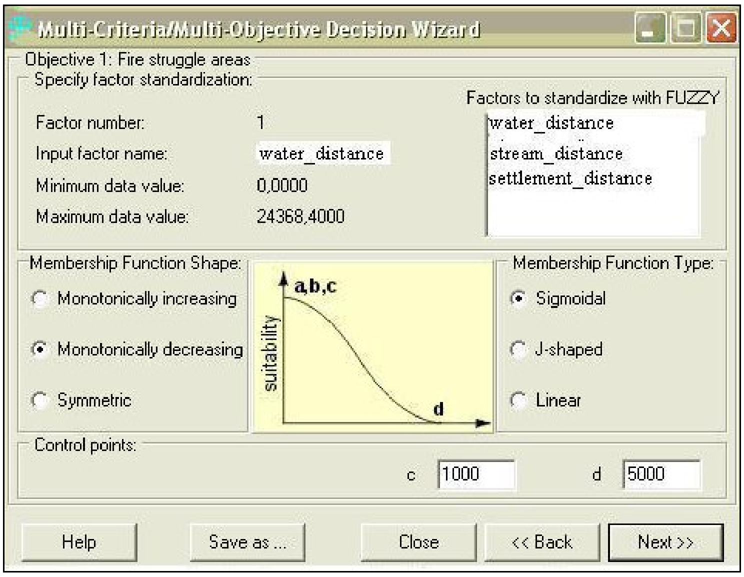

Figure 4.96 Fuzzy standardization of water resources distance map.

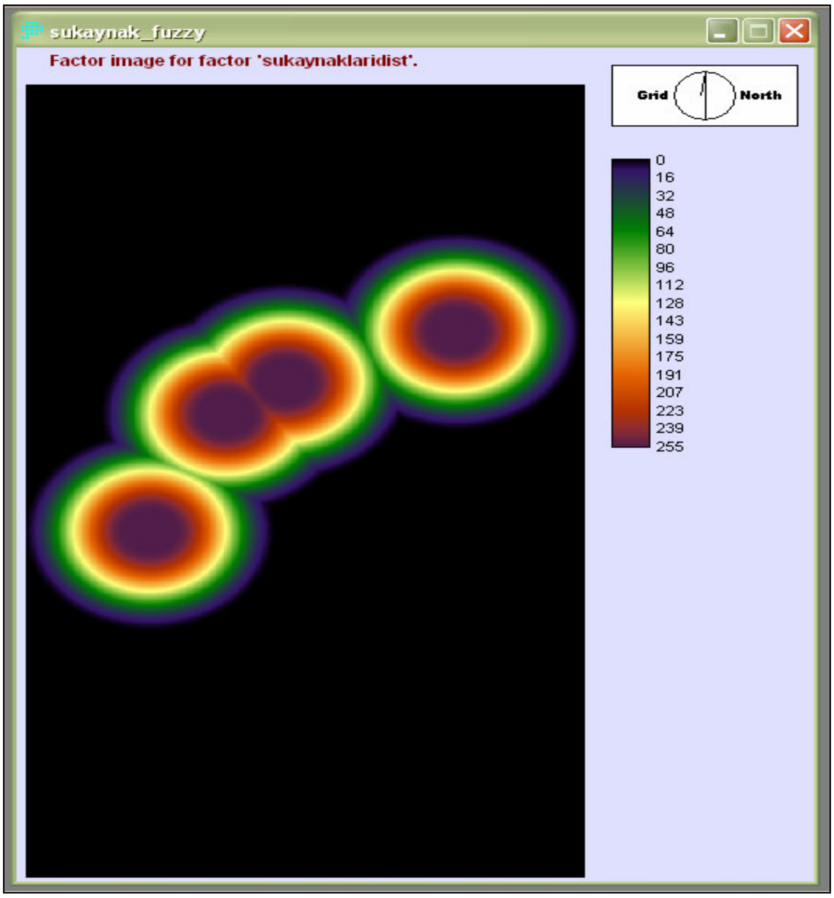

Figure 4.97 Fuzzy standardized distance map of water resources.

4.4.7.1.2 Distance From Streams Factor

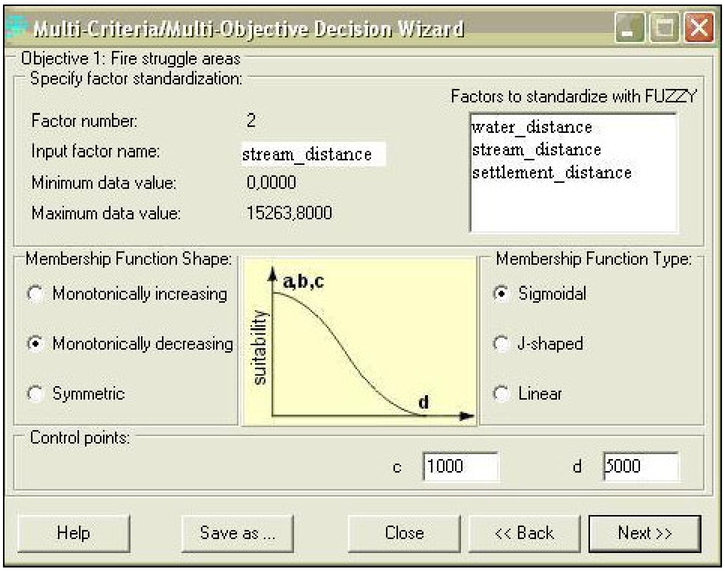

Figure 4.98 Fuzzy standardization of distance map of streams.

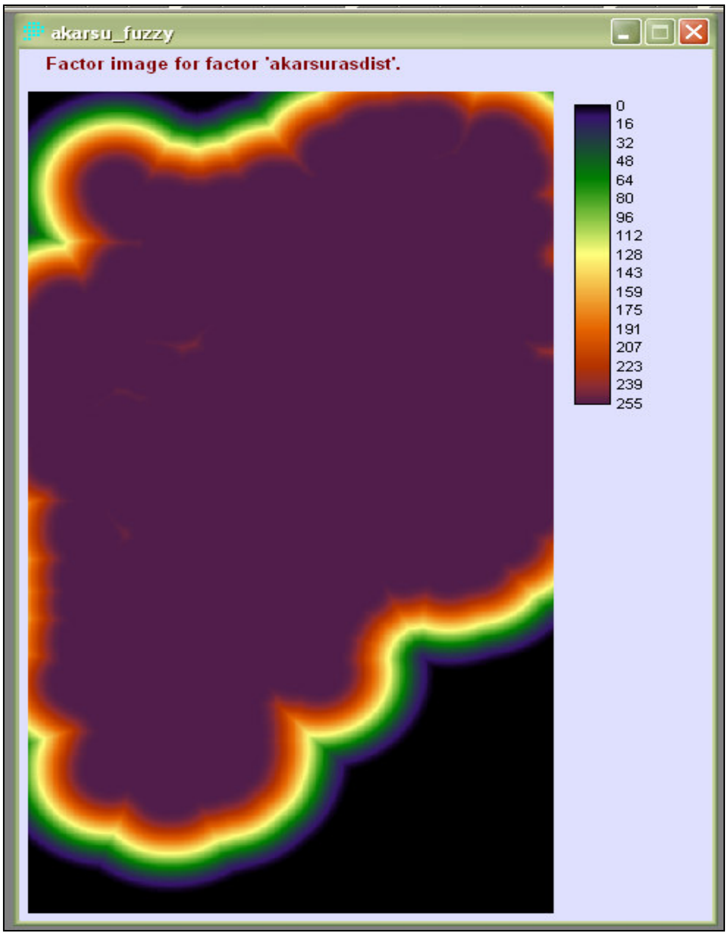

Figure 4.99 Fuzzy standardized distance map of streams.

4.4.7.1.3 Distance From Settlement Areas Factor

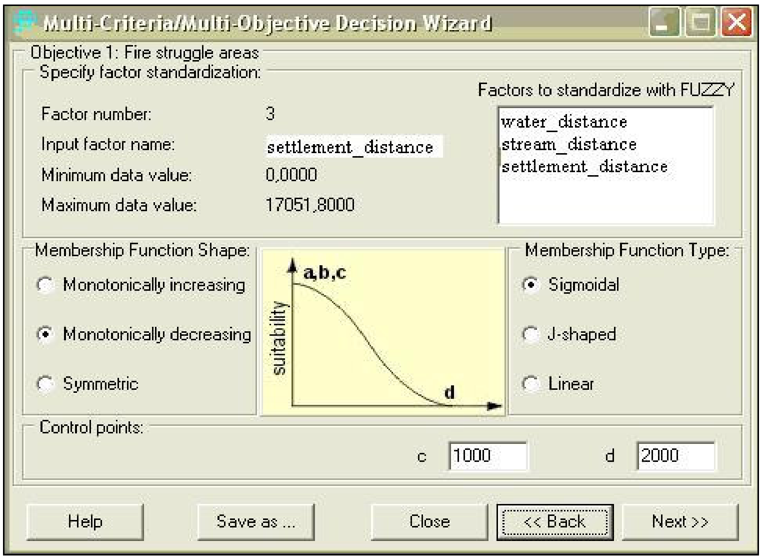

Figure 4.100 Fuzzy standardization of distance map of settlement areas.

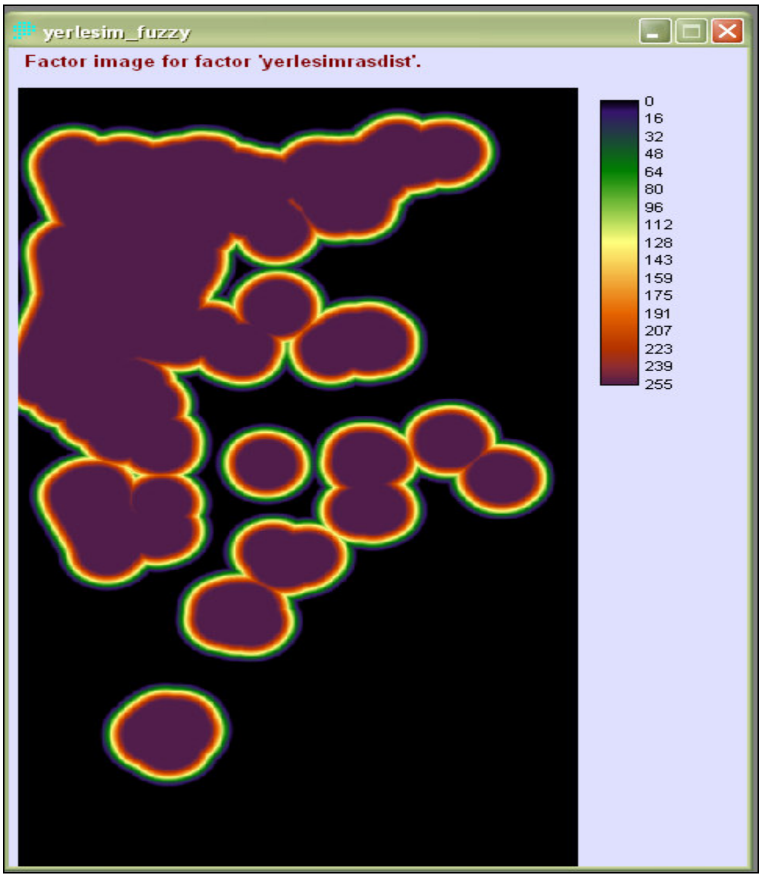

Figure 4.101 Fuzzy standardized distance map of settlement areas.

4.4.7.2 AHP Procedure

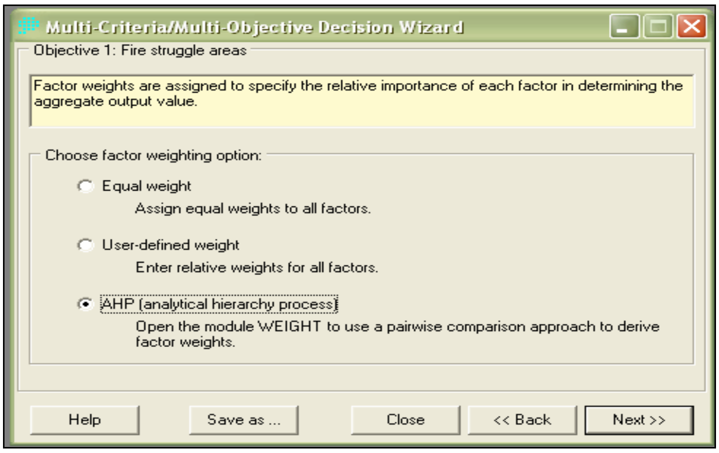

Figure 4.102 Selecting AHP choice from the menu.

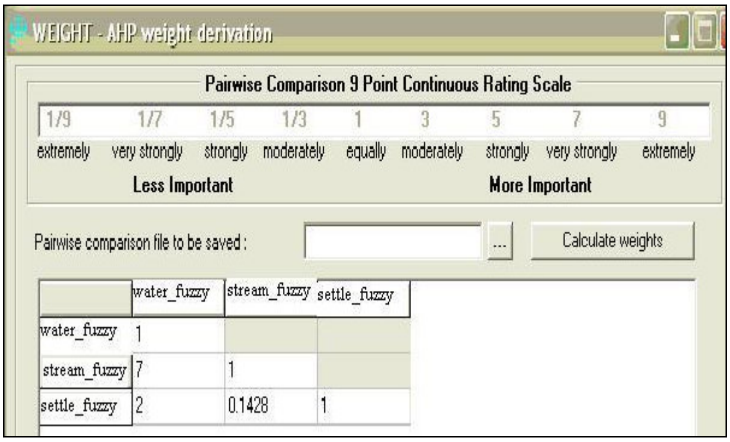

Figure 4.103 Pairwise comparisions.

Eigenvectors of weights were found as 0.0877 for water resources, 0.7732 for streams and 0.1391 for settlement areas. Consistency ratio was found as 0.05 and was acceptable for this study.

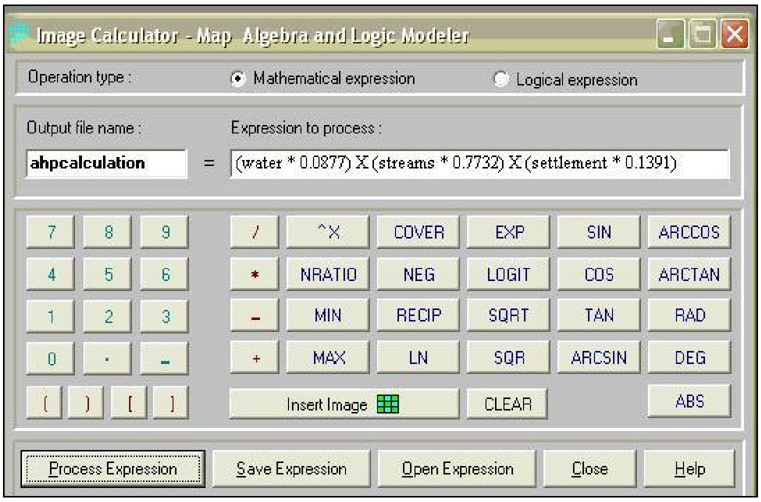

Figure 4.104 Multiplying all factors at image calculator.

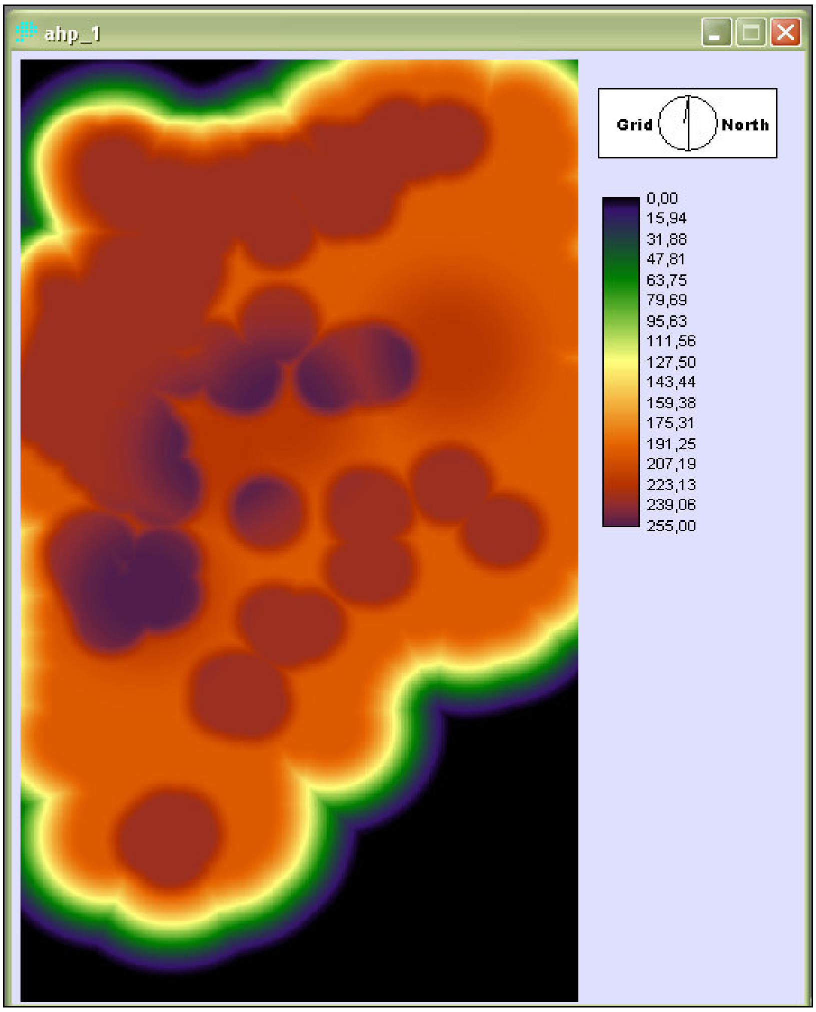

Figure 4.105 The most suitable areas that can cope with fire according to AHP.

Figure 4.106 shows water resources, streams and settlement areas.

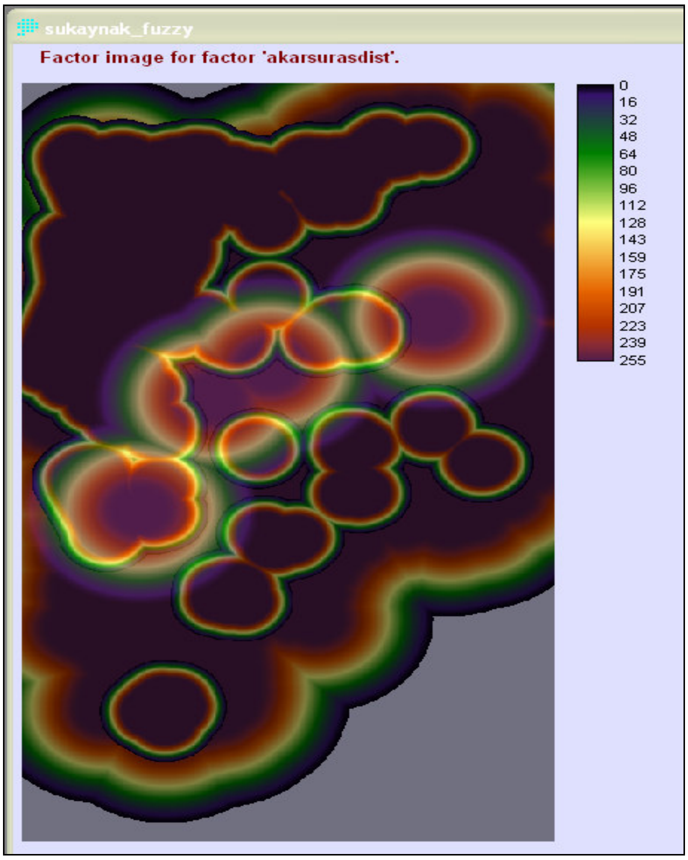

Figure 4.106 Water resources, streams and settlement areas.

Figure 4.107 shows decision process of SMCDM for determining suitable/unsuitable areas that can cope with forest fire effectively.

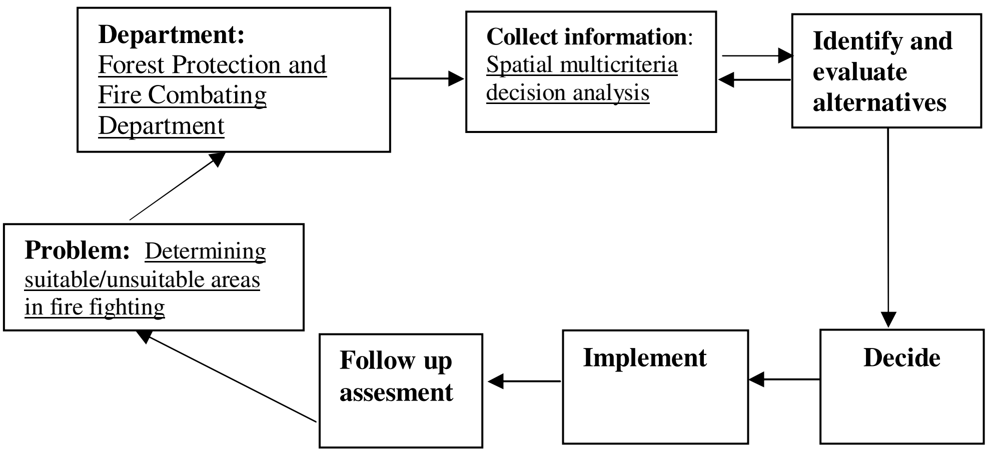

Figure 4.107 Summary of spatial multi criteria decision process.

4.4.8 3D, Slope and Aspect Maps

In this part topographic information of İzmir Forest Administration Chief Office was evaluated. 3D view, slope and aspect maps were done using Vertical Mapper module of MapInfo Professional Software package. Figure 4.108 shows 3D view of İzmir Forest Administration Chief Office. Figures 4.109, 4.110, 4.111, 4.112 and 4.113 show, altitude map, altitude contour map, altitude contour map and compartment map, slope map and aspect map. Altitude contour map shows altitude intervals in our study area.

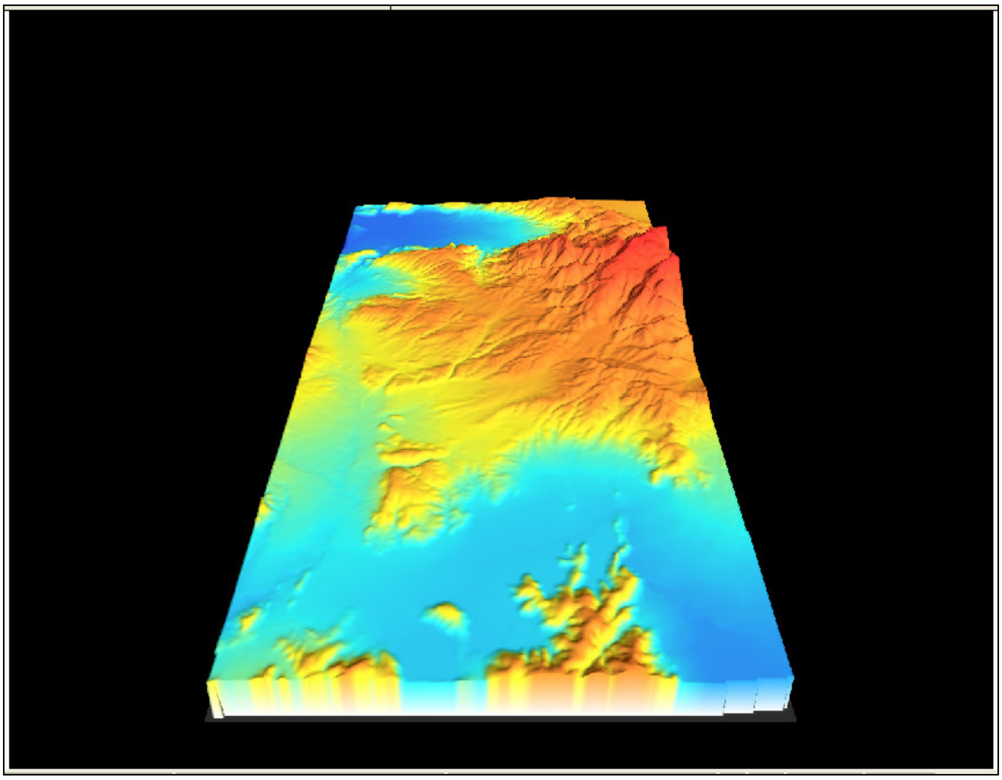

Figure 4.108 3D map of İzmir Forest Administration Chief Office.

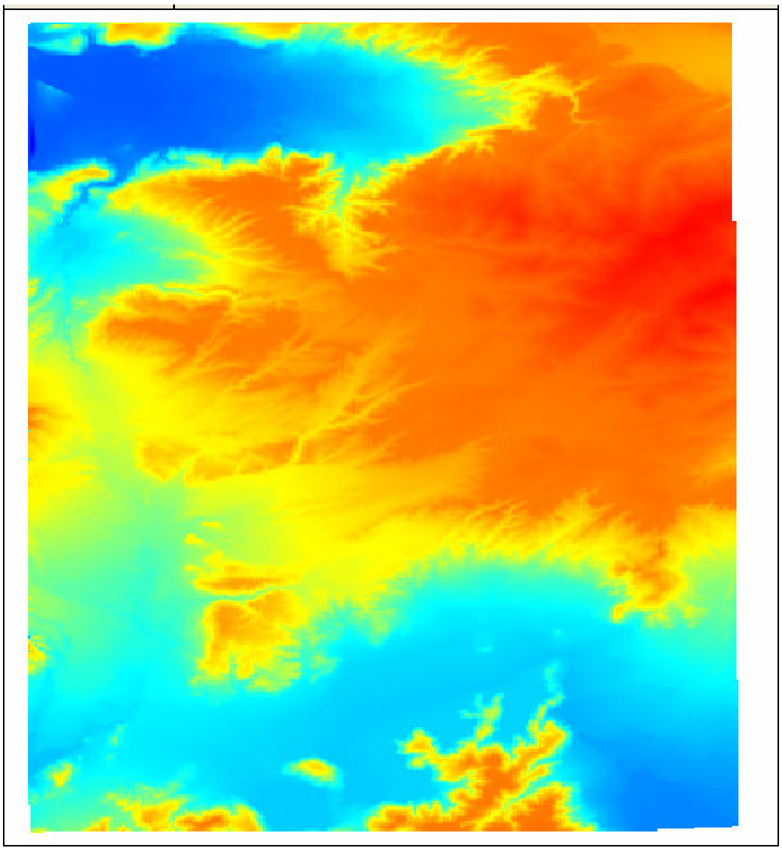

Figure 4.109 Altitude map of İzmir Forest Administration Chief Office.

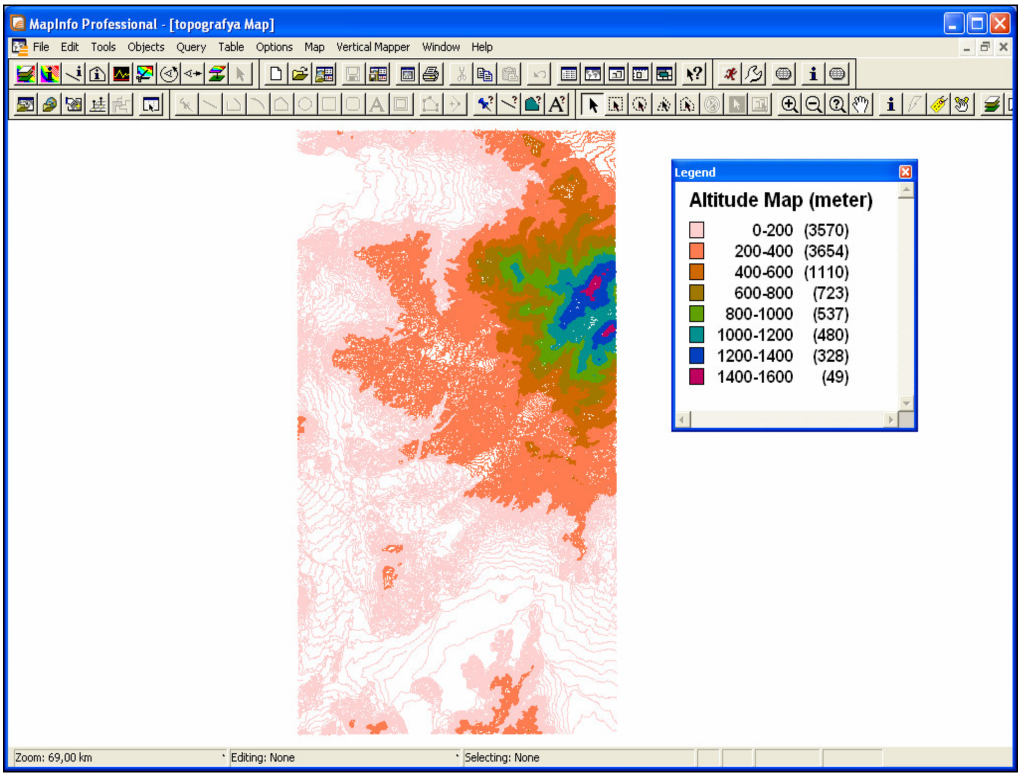

Figure 4.110 Altitude contour map of the study area.

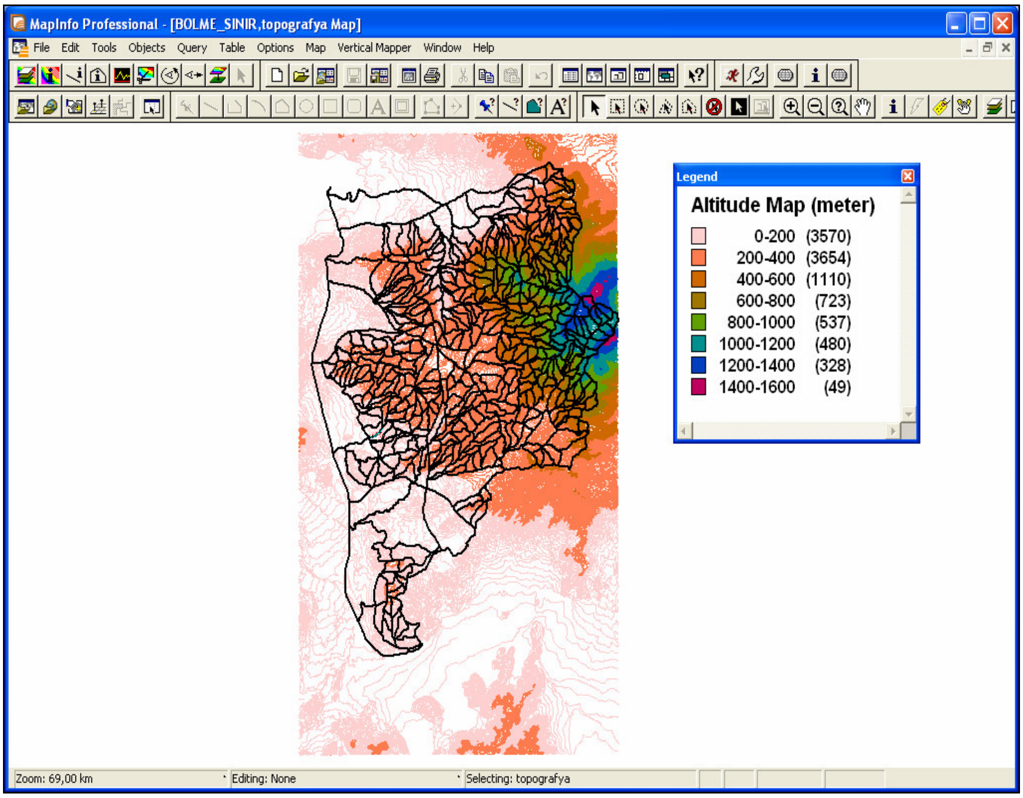

Figure 4.111 Altitude contour map and compartment map together.

Figure 4.112 shows slope of study area in degree units. As the degree raises slope also increases and land will be steep. Slope is very important factor in aforestation studies, in fire fighting activities. In steep land fire fighting activities will be more difficult. As it is seen from Figure 4.112, our study area is not very step and has a slope commonly between 10 degrees and 30 degrees.

Aspect shows visible area by taking north aspect as a base. In figure 4.113 all values are in degree units. This map shows direction that hillside looks.

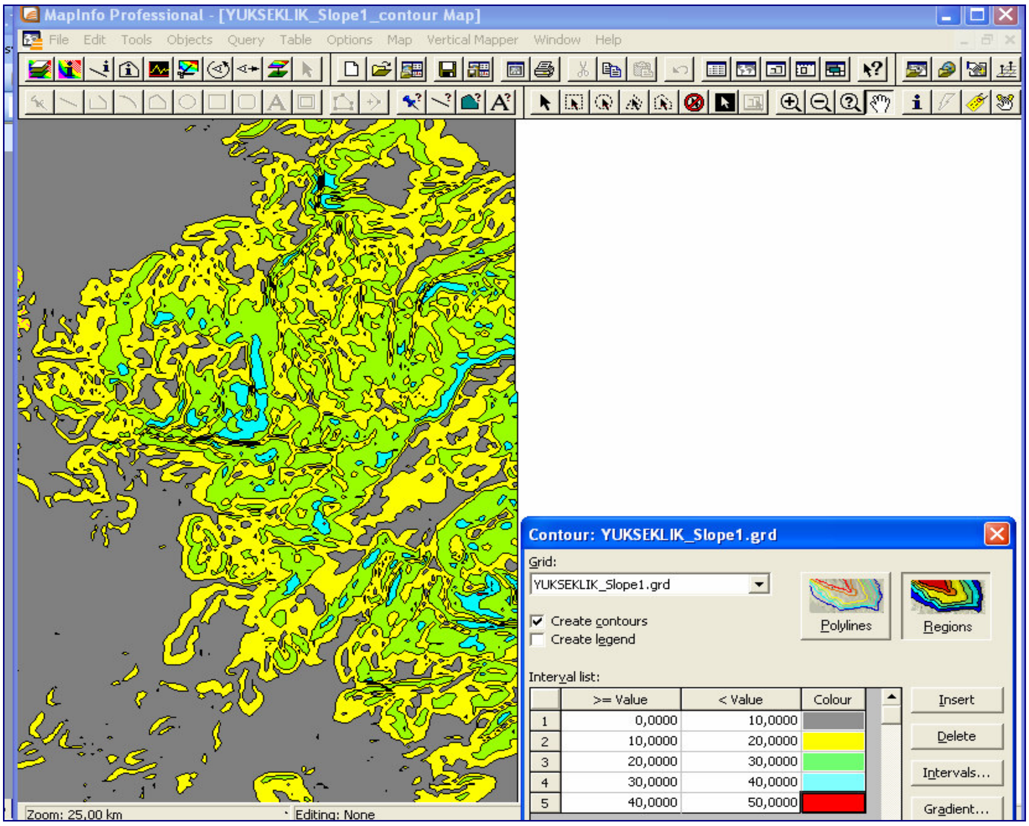

Figure 4.112 Slope map of the study area.

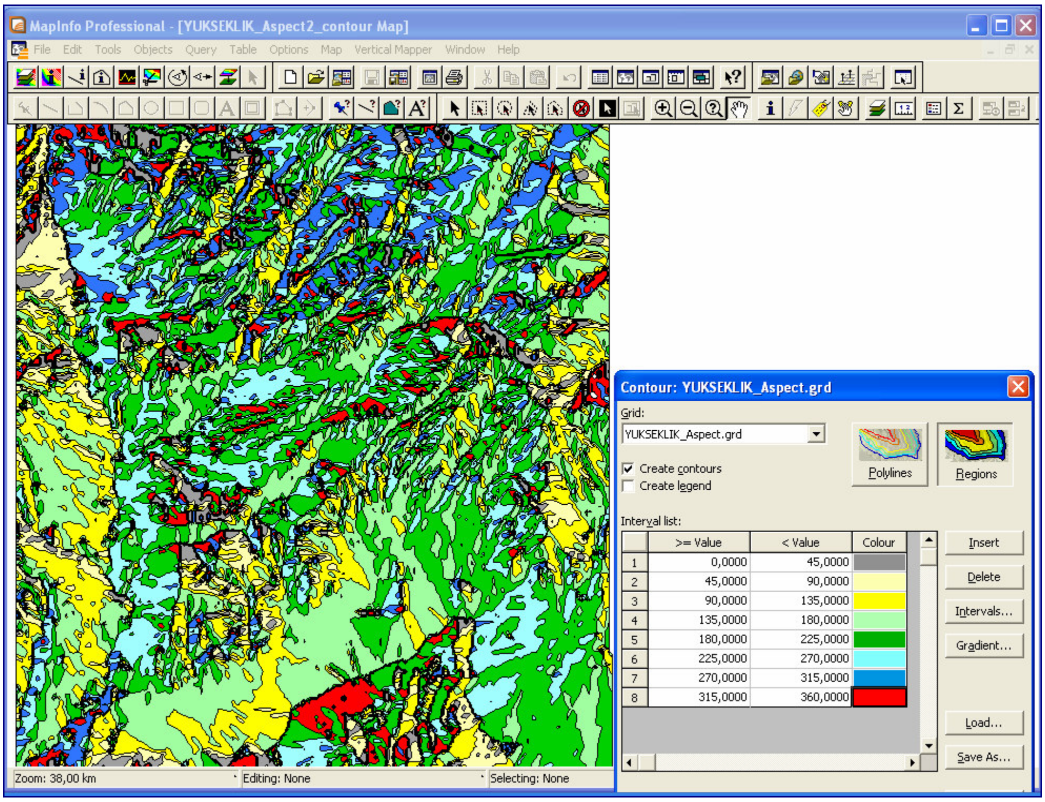

Figure 4.113 Aspect map of study area.

Figures 4.114 and 4.115 show potential usage of analyses done in this part, for different problem situations.

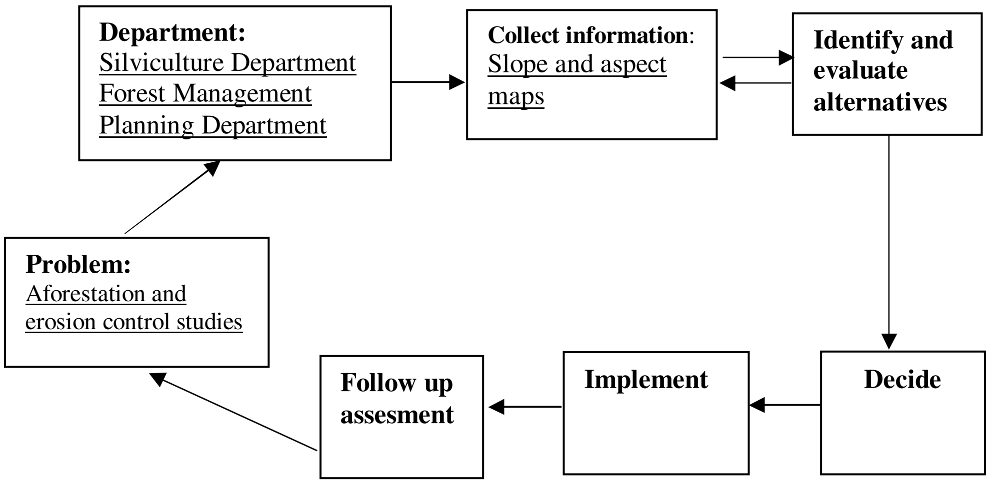

Figure 4.114 Potential usage of slope and aspect analysis for study area.

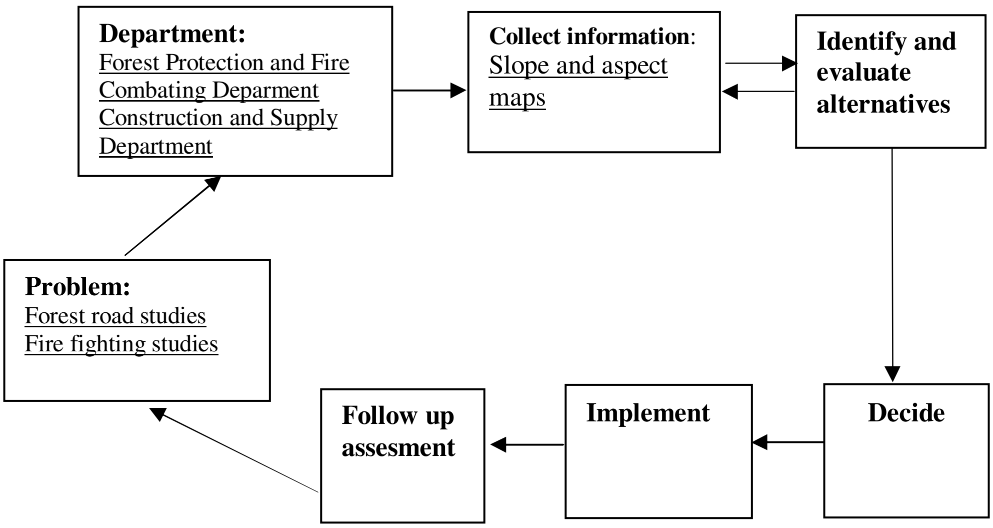

Figure 4.115 Potential usage of slope and aspect map for study area.

4.4.9 Visibility Analysis

In this part 4 points selected from the north, south, west and east to analyze their visibility and to decide where fire tower can be positioned if necessary. Visibility analysis was done using vertical mapper as shown in Figure 4.116.

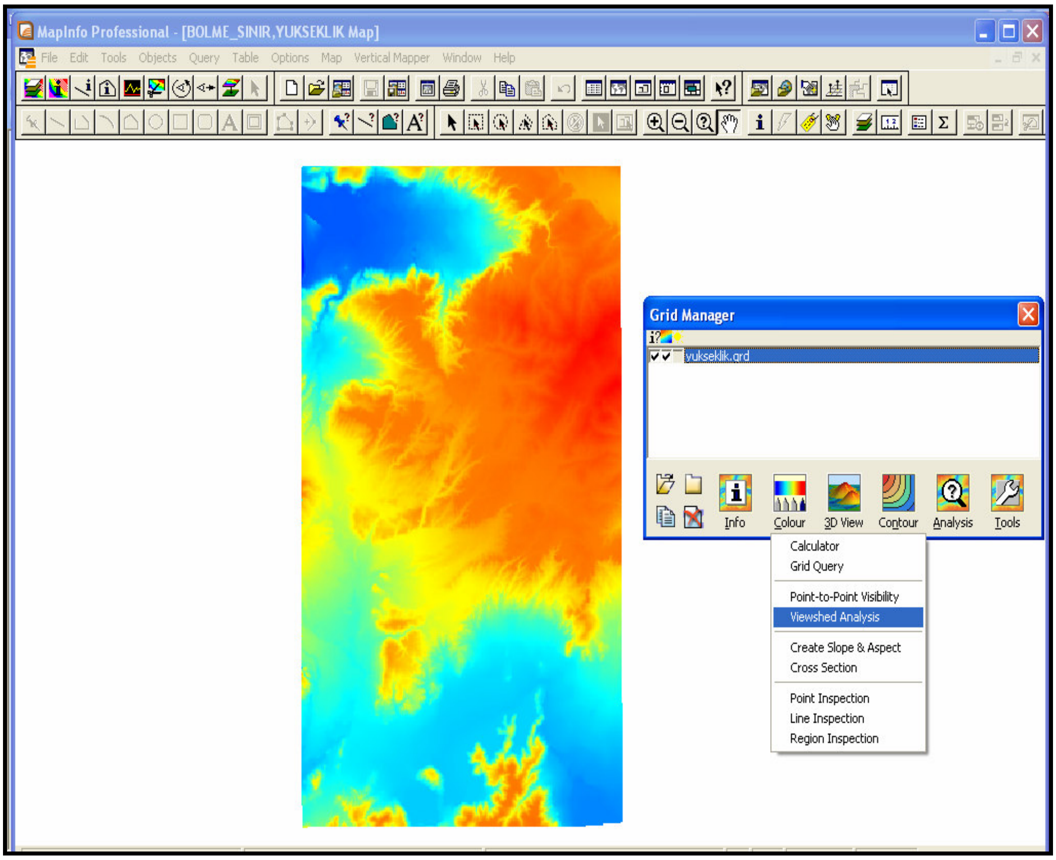

Figure 4.116 Visibility analysis.

Figures 4.117, 4.118, 4.119, 4.120, 4.121, 4.122, 4.123 and 4.124 show steps followed and the results obtained for the points selected from the north, south, west and east region of the study area.

Figure 4.125 summarizes potential usage and decision process of visibility analysis done in this heading.

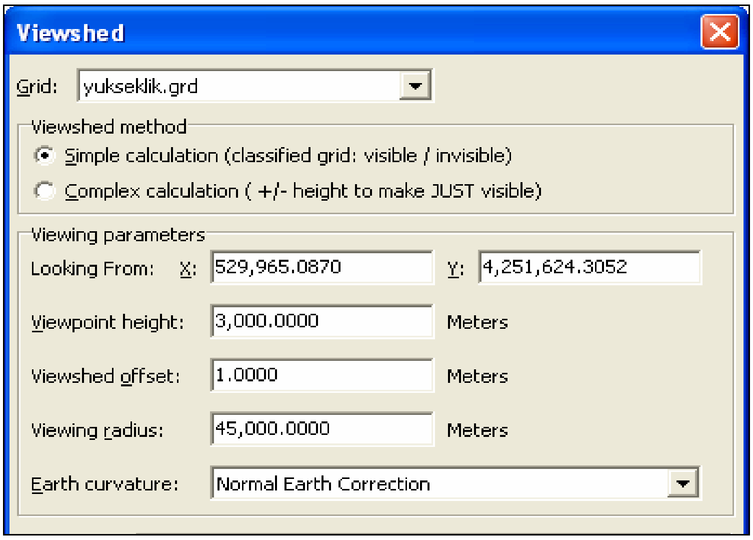

Figure 4.117 Coordinates of point chosen from north.

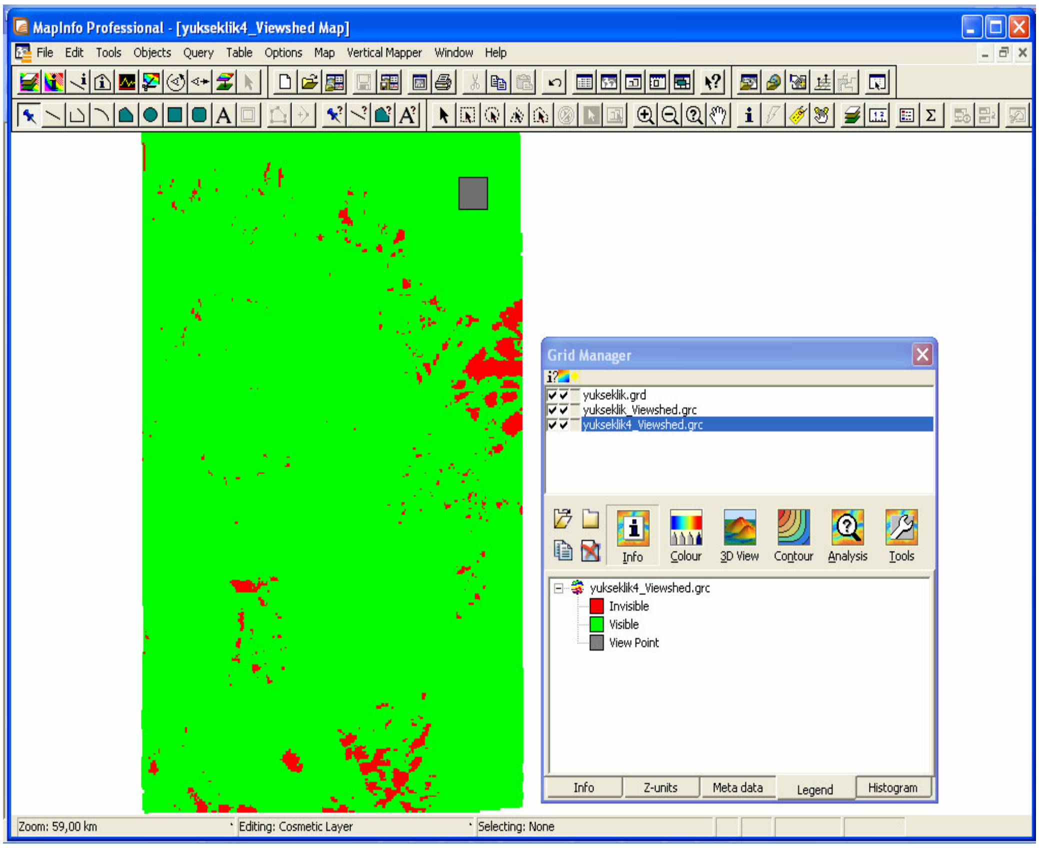

Figure 4.118 Result of visibility analysis for north region.

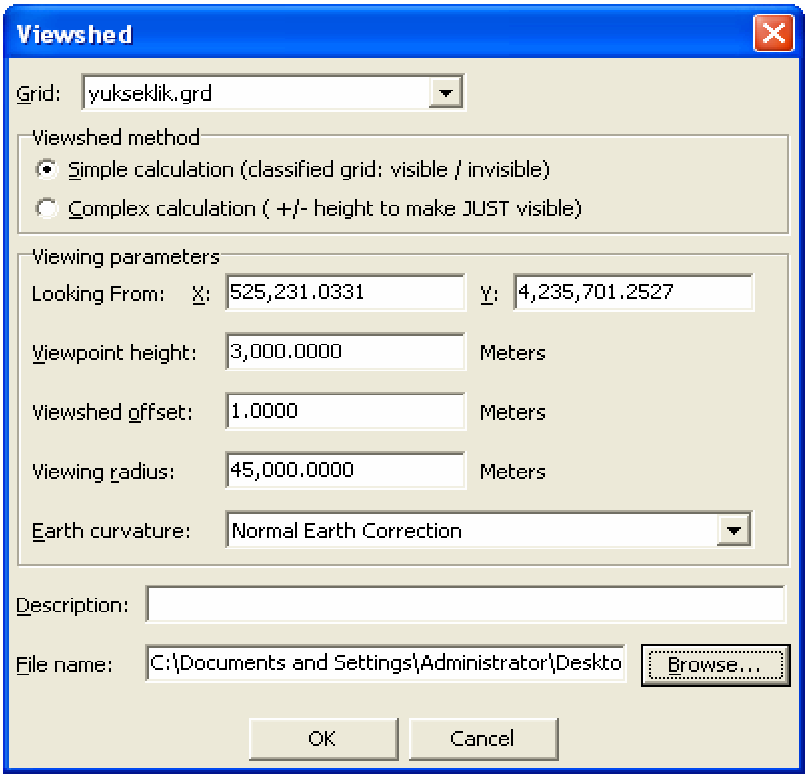

Figure 4.119 Coordinates of point chosen from south.

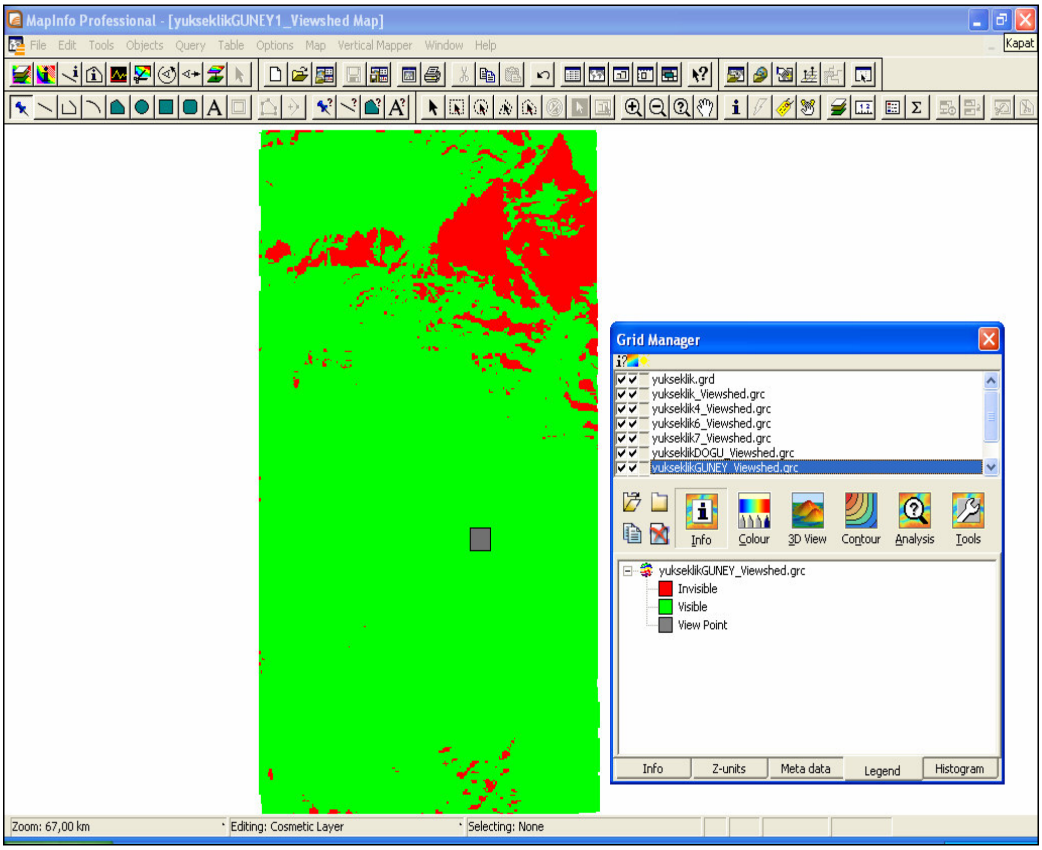

Figure 4.120 Result of visibility analysis for south region.

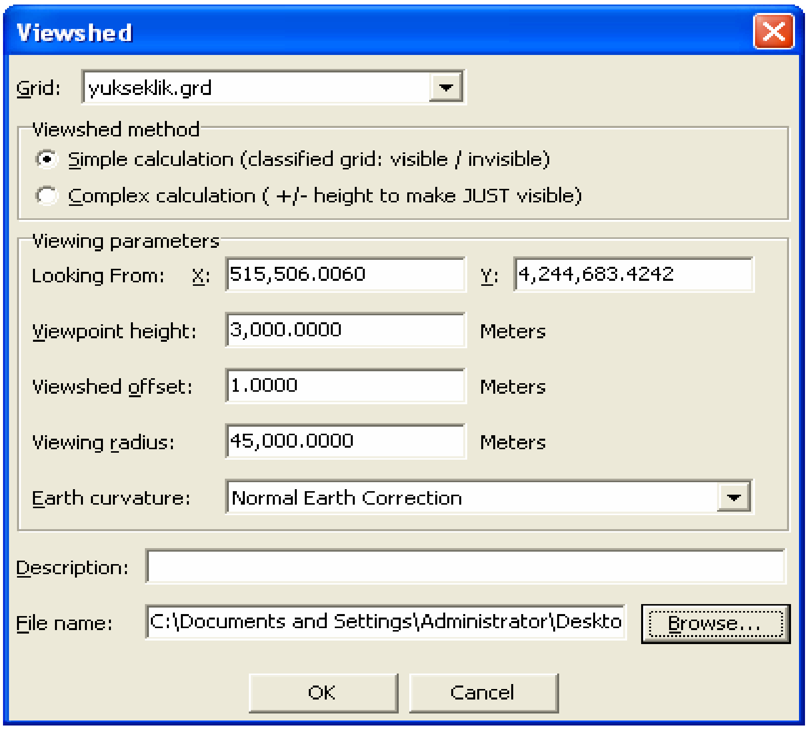

Figure 4.121 Coordinates of point chosen from west.

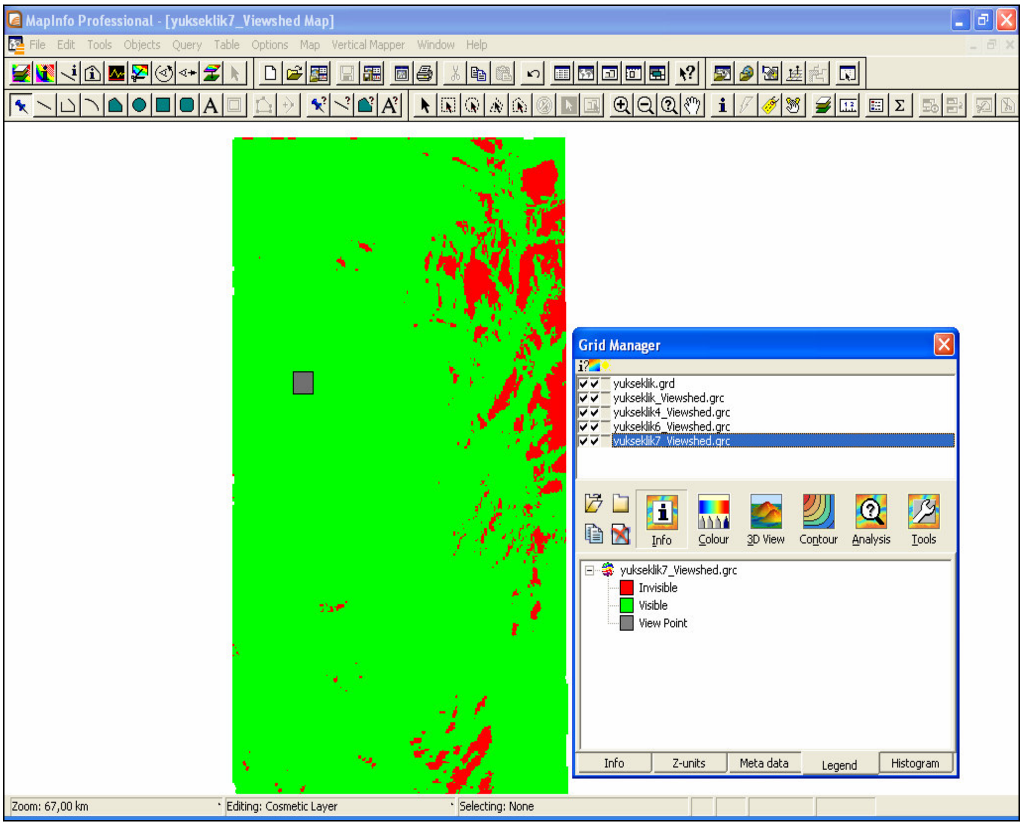

Figure 4.122 Result of visibility analysis for west region.

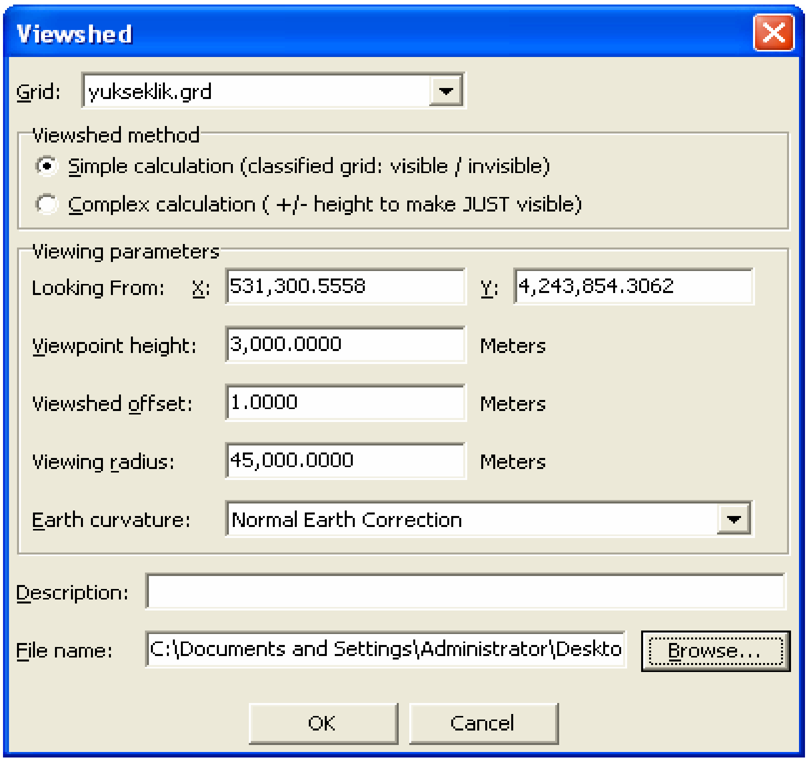

Figure 4.123 Coordinates of point chosen from east.

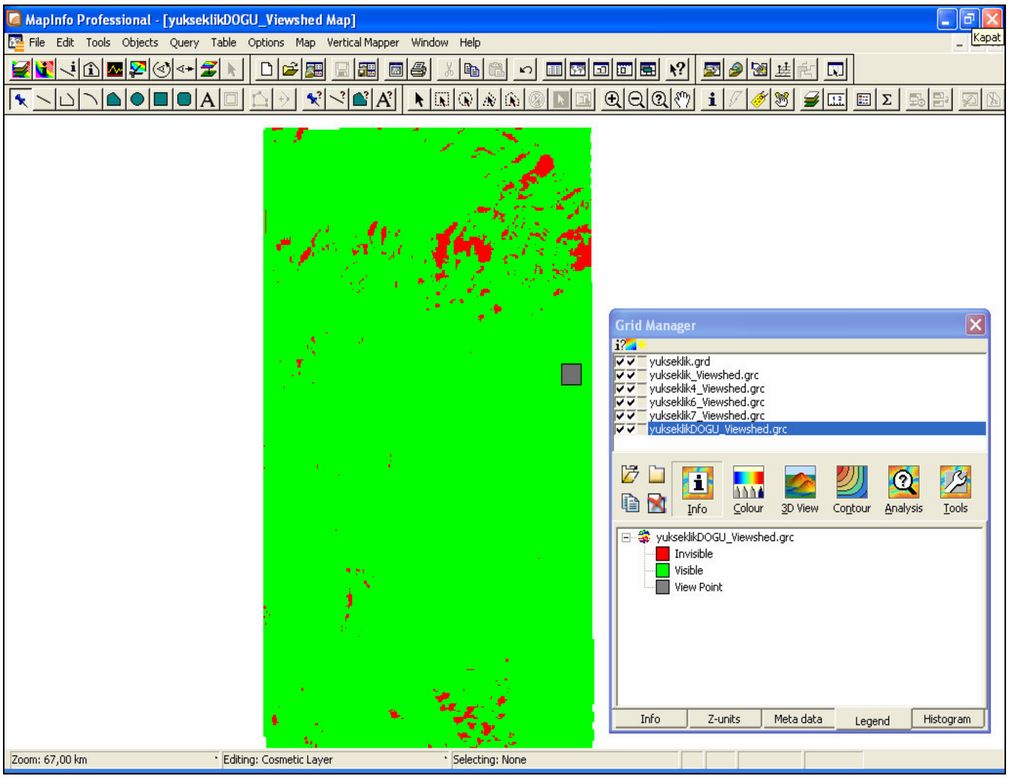

Figure 4.124 Result of visibility analysis for east region.

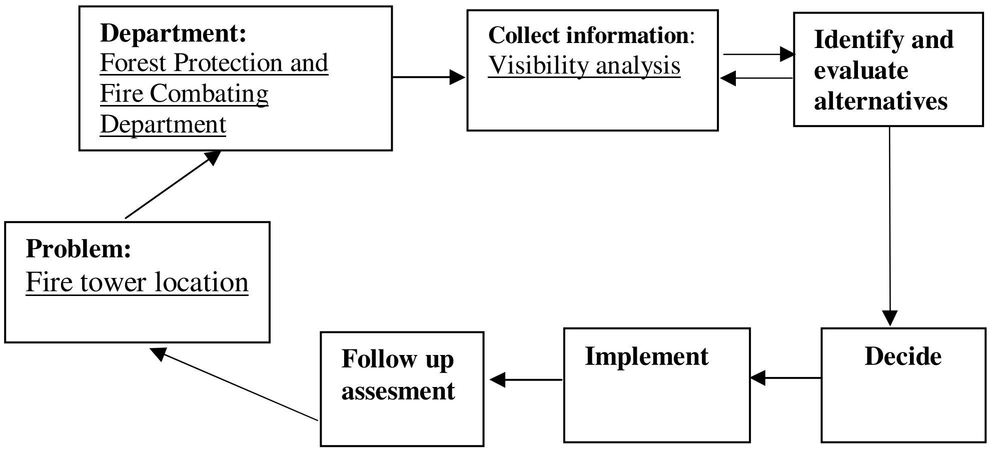

Figure 4.125 Decision process of visibility analysis.

4.4.10 Graphical User Interface-MapBasic Application

In this part of the thesis a special menu, İzmir Forest, was created in MapInfo GIS software by using MapBasic software to help decision makers and facilitate their decision making process. İzmir Forest menu provides graphical user interface utilities for decision makers to retrieve needed information in the shortest way. This menu summarizes analyses done in this part of thesis and can be expanded with different information according to information needs of departments. The menu is both informative and quite usable. It is user friendly also for people who do not know GIS. It enables decision makers who know and do not know GIS, to reach information in the quickest and the most effective way.

Headings of the İzmir Forest menu are shown in Figure 4.126. When it is clicked on, for example, stand menu, thematic map of the stand will appear on the screen, as shown in Figure 4.127.

Turkish version of İzmir Forest menu is shown in figure 4.128.

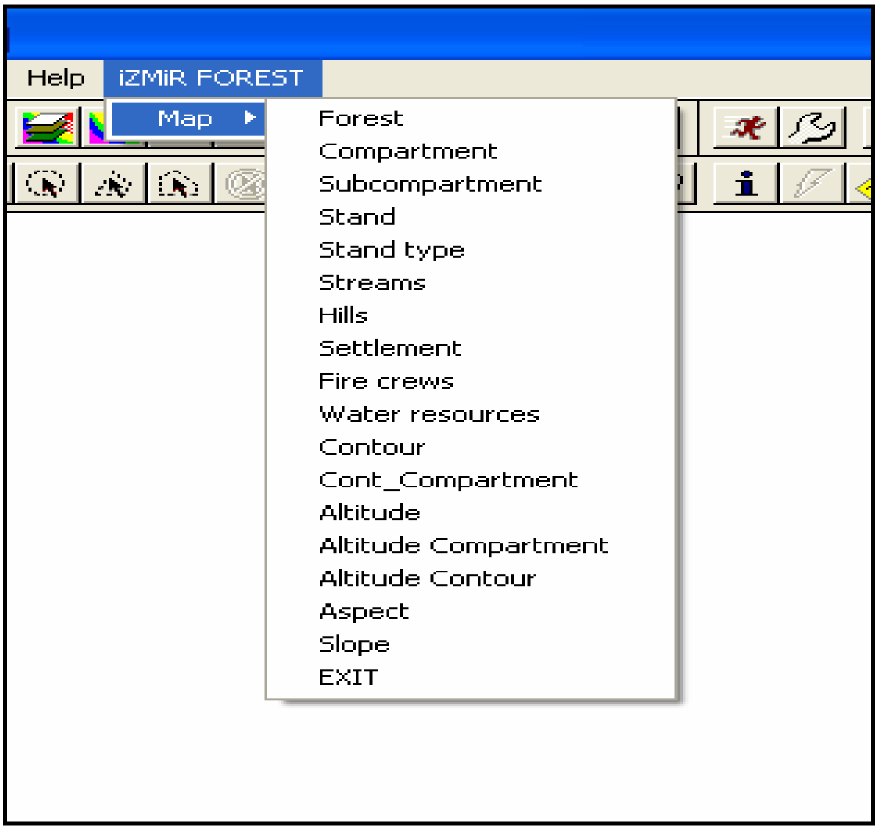

Figure 4.126 MapBasic application.

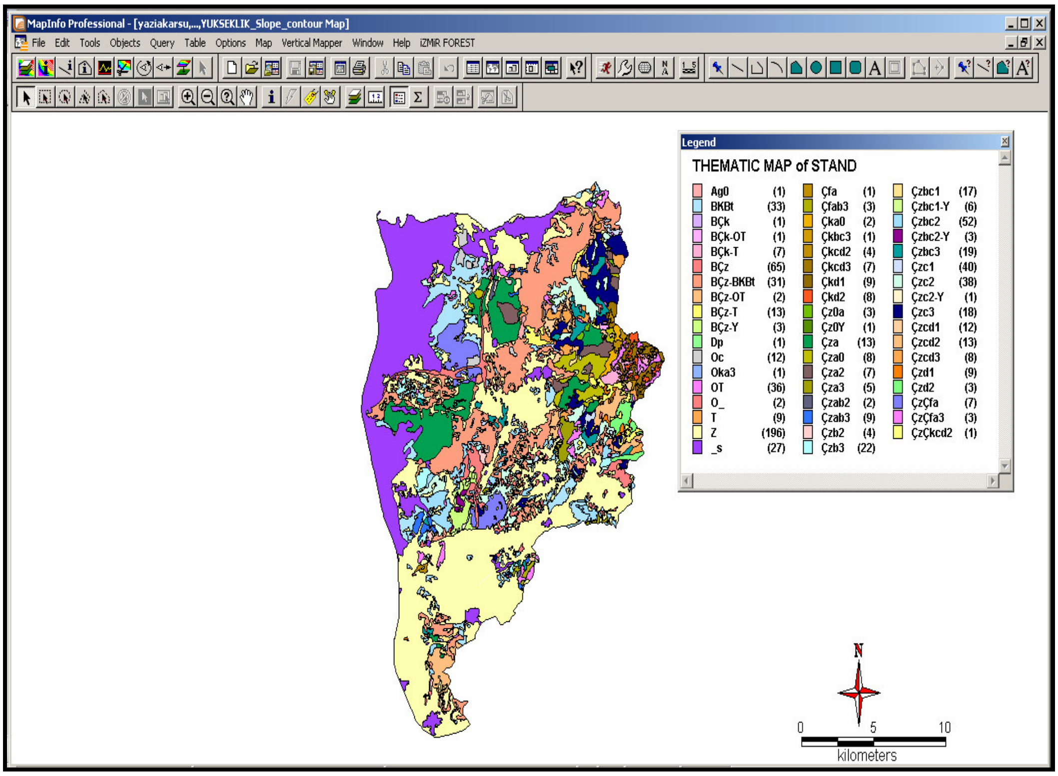

Figure 4.127 Representation of stand by thematic map.

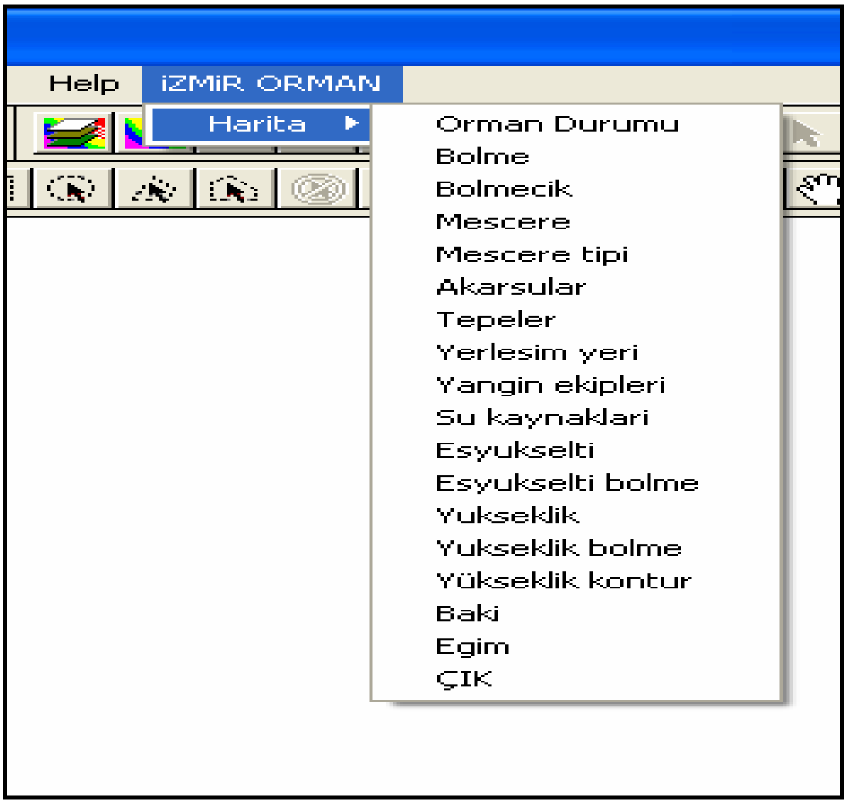

Figure 4.128 Turkish version of MapBasic application.

CHAPTER FIVE
CONCLUSIONS

Spatial Information Systems and technologies have become very important component of decision making in a wide variety of applications. They facilitate decision making process of spatial problems. GIS is a special class of information systems and has an important role for solving spatial problems by using spatial and nonspatial data. It is gaining wide importance as a decision support tool. GIS can not make decision on behalf of decision maker but it facilitates decision making process by combining data from different resources (RS data, aerial photography, multicriteria techniques, optimization models), enabling to do several analyses and allowing for visualizing problem situation. Seeing picture of the problem, decision makers can conceptualize problem and consequences of the problem. Then by producing different scenarios, alternative solutions can be obtained to the given problem. Decision support system developed with this thesis contains user interface, database, GIS, optimization models, and data visualization.

It is important to handle forestry problems by adopting system concept. Because forests are open sytems that can be influenced from external factors and can influence external factors. Many advantages of usage of GIS can also be observed in forestry. Huge amount of forestry data can be organized and managed easily by GIS. Because contemporary forest management requires more record keeping, wider access to information and integration of optimization models, it is clear that the use of GIS is invaluable in transition from conventional forest management to contemporary forest management. Because GIS provides not only organization and management of data but also integrates different optimization models into the problem solving environment.

It was attempted to solve all forestry related problems by using digital maps with this thesis. That is, it was tried to launch the first step of contemporary forest management concept for İzmir Forest Administration Chief Office. Forestry applications of not only GIS but also OR were shown and prototype study that integrated GIS and OR was presented.

As mentioned before, forests can not be managed without a forest management plan. This thesis aimed to show to the forest manager how to plan forestry in the short and long-term by using GIS and OR techniques. Then it was shown how to use new information tool for management.

Firstly a detailed study was performed to analyze general state of the study area on a digital map. For this reason several queries concerning altitude of hills, compartments and their general and statistical information, stands, streams, agricultural lands and settlement areas were done. Following this, databases of water resources and fire crews were designed and their representations were done on a digital map. Then by observing current locations of fire crews new locations were proposed for the south region of the study area by LSCP.

Different methods were used to minimize optimum numbers of fire crews found by LSCP. Each of these methods approached to the problem from different perspectives. One of the method used function of GIS, buffering, to minimize numbers of proposed fire crews. The objectives were to determine intervention area of each fire crew and total length of usable road in the buffered areas with buffering. Decision criterion was to select buffered area that has the longest usable roads (km). The other technique which was used to minimize numbers of proposed fire crews was clustering analysis. Firstly different areas were determined on the road map as potential fire areas. Then a new clustering algorithm, which was based on combinatorial search, has been developed and used to find an optimum solution for the fire scenario we have developed. According to points, (combination of both proposed fire crews found by LSCP and potential fire areas, total of 22 points) determined on a digitial map, a new clustering algorithm found optimum numbers of new fire crews as three. Result of this new algorithm proposed that fire crews must be assigned to the compartments 369, 379 and 435 for this fire scenario.

Different road analyses were done. One of them was to develop thematic road map of the study area. Then the shortest path analysis was performed. The shortest and the second shortest roads were determined from fire crews found by LSCP to the potential fire area. It was aimed to do some projections as to distances from fire crews to the potential fire areas and to help forest managers in deciding the best location of fire crews according to determined potential fire areas.

In the context of fire management, spatial multi criteria decision methods, boolean approach and AHP, were used to determine the most suitable areas that can cope with forest fires. The aim was to help forest managers to see the areas that were effective and ineffective in the study area in terms of defined set of criteria. It is considered that result of these analyses will be helpful in deciding assignment of resources in fire management planning. Ineffective areas in fire fighting will be more prominent by looking at the results obtained, and transfer of resources to these areas will be more important in order to strengthen the positions of these areas.

3D maps, slope and aspect maps are considered to support decision making process in aforestation, erosion control, forest road and fire fighting studies. Slope map gives information about degree of slopes and the aspect map gives the information that hillside looks. Steep areas will require more aforestation because they are more prone to erosion than the other areas. So aforestation of these areas is very important. Slope and aspect maps will also be helpful in forest road studies. In forest road studies the areas that have a slope between 2 % and 10 % and south aspect areas are preferred. From fire management perspective in steep areas it will be more difficult to cope with fire so fire crew allocation can be adjusted according to information that slope map gives. Aspect maps will be helpful in predicting spread of fire by looking at the aspect of hillside.

Visibility analysis will be helpful in fire management. By looking at the result of this analysis it will be possiple to determine the best locations for fire tower. In this thesis only a few visibility analyses were done to develop a prototype study. These analyses can further be expanded according to different points which are wanted to locate fire towers.

Finally, a special menu, İzmir Forest, was created in MapInfo GIS software by using MapBasic software to help decision makers and facilitate their decision making process. İzmir Forest menu provided graphical user interface utilities for decision makers to retrieve needed information in the shortest way. This menu is both informative and quite usable. It is user friendly for also non GIS users. The menu enables to decision makers who know and do not know GIS, to reach information in the quickest and the most effective way.

Contributions of this thesis to the study area and the literature can be summarized as:

- To launch steps of contemporary forest management in the study area.
- GIS based database design.
- Ability to update data and display it on the map.
- Geocoding of current water resources and fire crews.
- The use of optimization technique, LSCP, to propose new fire crews for the south region of the study area.
- The use of spatial multi criteria decision making to determine the suitable/unsuitable areas that can cope with forest fires according to defined set of criteria thereby deciding allocation of resources properly.
- To develop 3D, slope and aspect maps and to use these maps as a decision tool.
- To analyze roads in the boundary of İzmir Forest Administration Chief Office in a detailed way.
- To develop fire scenarios and find the shortest paths from the proposed fire crews to the potential fire areas.
- Buffering analses in order to determine intervention area of each fire crew, found by LSCP, and total length of usable roads inside of each buffer.

- Clustering analysis and development of a new clustering algorithm to find minimum number of fire crews for the south region of the study area.
- Visibility analyses.
- Development of a special menu in MapInfo GIS software package by using MapBasic software, to help decision makers and facilitate their decision making process.

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