ISTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

LAND ASSESSMENT OF KOYCEGIZ LAKE- DALYAN LAGOON WATERSHED TOWARDS INTEGRATED PLANNING AND MANAGEMENT

Msc. Thesis by
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Department : Environmental Engineering

Programme: Environmental Engineering

Supervisor : Prof. Dr. Ayşegül TANIK

SEPTEMBER 2003

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FOREWORD

I am deeply indebted to my thesis supervisor, Prof. Dr. Ayşegül TAN K, who helped me throughout my study with advice, guidance and encouragement.

It is difficult to phrase an adequate expression for the generous help and advice given by Assoc. Dr. Dursun Zafer Şeker during the study.

Warm thanks are expressed to research assistants Alpaslan Ekdal, Ali Ertürk and to Dr. Melike Gürel.

Finally, I would like to pay an affectionate tribute to my family and my friends for the generous support and encouragement they gave throughout my study.

September 2003 E İdI KARAGÖZ

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ÖZET

Günümüzde kıyı ekosistemlerinde artan kirlilik sorunlarının iyileştirilmesi ve sürdürülebilir bir havza yönetiminin hazırlanması gittikçe daha fazla önem kazanmaktadır. Sürdürülebilir bir havza yönetim sistemi; havzanın coğrafik durumunu, iklimini, meteorolojik yapısını, jeolojik durumunu, hidrolojik özelliklerini, sosyo-demografik yapısını ve tüm bunların havzadaki su kaynakları üzerine etkilerini göz önüne bütünleşik bir sistemdir. Böyle bir sistemin oluşturulmasında Coğrafi Bilgi Sistemi, CBS, büyük kolaylıklar sağlamaktadır. Bu çalışmada pilot bölge olarak, Türkiye' nin güneybatısında yer alan Köyceğiz Gölü-Dalyan Lagünü seçilmiştir. Bölge karmaşık, hassas ve dinamik bir yapıya sahiptir.

Çalışmada, bir havza yönetim modeli oluştururken gerekli olan kaynak ve veri envanterinin çıkartılması, verilerin CBS ortamına aktarılması, tematik katmanlarının oluşturulması ve sorgulanması, pilot bölge üzerinde yapılmıştır. Kara kökenli bilgiler, aynı zamanda toprak analiz sonuçları, ana toprak içeriği, toprak tipleri, toprak alt grupları, arazi kullanımı ve diğer toprak özellikleri katmanları olarak görselleştirilmiştir. Bu haritalar çakıştırılarak bir "Arazi Verileri Değerlendirme Tablosu" oluşturulmuştur. Bu tabloda her bir istasyonda analizler de gerçekleştirildiğinden verilerin doğrulanması da yapılmıştır. Arazi değerlendirme çalışmaları bir bölgenin kullanım potansiyeli hakkında bilgi vermektedir. Dolayısı ile, bu çalışmalar bütünleşik havza yönetim stratejilerinin belirlenmesinde önemli aşamalardan biri olan toprak-arazi değerlendirilmesine yer verilmiş ve bu konudaki çalışmalara rehberlik edecek tüm aşamalara değinilmiştir.

Çalışma aynı zamanda, AB ye girme süreci yaşayan ülkemizin bütünleşik ve sürdürülebilir havza yönetimi konusundaki eksikliğini de giderme amacını taşımaktadır.

LAND ASSESSMENT OF KÖYCEĞİZ LAKE-DALYAN LAGOON WATERSHED TOWARDS INTEGRATED PLANNING AND MANAGEMENT

SUMMARY

Remediation of increasing pollution problems at coastal ecosystems and establishment of a sustainable watershed management have nowadays gained interest and importance. An efficient watershed management system considers the geographic condition of the watershed, climate, meteorologic status, geological condition, hydraulic properties, socio-demographic structure and also takes into account the impact of these factors on the receiving water and on the water resources. Geographical Information Systems (GIS) highly contribute and aid to accomplish the establisment of such system. Use of GIS is one of utmost signifance as it allows to transfer new data to the system, to develop various scenarios and to share information.

In this study, Köyceğiz Lake-Dalyan Lagoon watershed, located at the southwest part of Turkey, is selected as the pilot region. The region has a quite complex, sensitive and dynamic structure.

In this study, the required resource inventory, data collection and gathering and transfer of data to GIS, establishing thematic layers and querries are conducted on the pilot region during the formation of a watershed management model. Land-based information are also visualized in terms of layers consisting of soil analyses results, main soil groups, soil types, sub-soil groups, land-use and other soil characteristics. These maps are overlaid to form a "Land Data Evaluation Table". In this table, the validation of the currently conducted analyses are also done. Such land evaluation studies give an idea on the land-use potential of a region. Therefore, in this study, emphasis is given to soil-land evaluation which is an essential aspect in determining the strategies of integrated watershed management and also points out all the steps that would act as a guide to similar studies.

The study will at the same time satisfy the lacking experience for sustainable and integrated watershed management in Turkey which is also one of the requiremetns of European Union (EU).

1. INTRODUCTION

Decisions on land-use, have always been a part of the evolution of human society. In the past, land-use changes often came about by gradual evolution, as the result of many separate decisions taken by individuals. In the more crowded and complex world of the present, they are frequently brought about by the process of land use planning. Such planning activities take place in various parts of the world, including both developing and developed countries. It may be concerned with converting environmental resources to new kinds of productive use. The need for land-use planning is frequently brought about, however, by changing needs and pressures, involving competing uses for the same land.

The function of land-use planning is to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, while conserving those resources for the future. This planning must be based on an understanding both of the natural environment and of the kinds of land use envisaged. There have been many examples of damage to natural resources and of unsuccessful land-use enterprises through failure to take account of the mutual relationships between land and the uses which land is put. It is a function of land assessment to bring about such understanding and to present planners with comparisons of the most promising kinds of land-use.

Inappropriate land-use leads to inefficient exploitation of natural resources, destruction of the land resource, poverty and other social problems. The land is the ultimate source of wealth and the foundation on which many civilizations are constructed. Society must ensure that land is not degraded and that it is used according to its capacity to satisfy human needs for present and future generations while also maintaining the earth's ecosystems. Part of the solution to the land-use problem is land assessment in support of rational land-use planning and appropriate and sustainable use of natural and human resources. Land assessment is the process of predicting the use potential of land on the basis of its attributes. A variety of analytical models can be used in these predictions, ranging from qualitative to quantitative, functional to mechanistic, and specific to general.

Land assessment which forms part of integrated watershed management, may be defined as "the process of evaluation of land performance when [the land is] used for specified purposes" (FAO, 1985), or as "all methods to explain or predict the use potential of land" (Van Diepen *et al.*, 1991). Once this potential is determined, land use planning can proceed on a rational basis, at least with respect to what the land resource can offer (FAO, 1993).

Thus, land assessment is a tool for strategic land-use planning. It predicts land performance, both in terms of the expected benefits from and constraints to productive land-use, as well as the expected environmental degradation due to these uses.

Land assessment is only part of the process of land-use planning. Its precise role varies in different circumstances. In the present context, land assessment plays a major part in the identification of aims, formulation of proposals, recognition and delineation of the different types of land present in the target area and comparison and assessment of each type of land for the different uses, which is then utilized in developing management strategies.

Land use planning and land assessment could be done for the whole country, for provinces, for districts and also for watersheds in detail. Geographical information systems (GIS) is the most effective tool for land use planning and land assessment. The term "geographic information system" is currently applied to computerized information storage, processing, analysing and retrieval systems that have hardware and software specifically designed to cope with geographically referenced spatial data and corresponding attribute information. Spatial data are commonly in the form of maps depicting topography, water availability, soil types, forests and grasslands, climate, geology, population, landownership, administrative boundaries, infrastructure (highways, railways, electricity or communications systems), etc. The capability of combining different maps in a single operation, known as "overlaying", is one of the most important GIS functions, together with modelling and site selection. Thus, nowadays, GIS is used widely as an effective tool for land assessment throughout the world, including Turkey.

In this study, land assessment is seen as one of the essential parts of integrated watershed management. First, integrated watershed management is defined. The role of, GIS in integrated watershed management is mentioned and some recent application examples are given. Finally, a land assessment study is done in detail the selected watershed namely, in Köyceğiz Lake-Dalyan Lagoon Watershed.

1.1. Significance of the Work

Land is an essential natural resource, both for the survival and prosperity of humans, and for the maintenance of all terrestrial ecosystems. Over millennium, people have become progressively more expert in exploiting land resources for their own needs. The limits on these resources are finite while society demands on them are not. Increased demand, or pressure on land resources, shows up as declining crop production, degradation of land quality and quantity, and competition for land.

Attention should now be focused on the role of humankind as stewards rather than exploiters, charged with the responsibility of safeguarding the rights of future generations and of conserving land as the basis of the global ecosystem.

Integrated watershed management strategies have an important role in sustainable planning systems and land use planning is one of the key concepts of integrated management systems.

An effective land-use planning is based on land assessment processes. The reliability of a land assessment process can be no greater than the data on which it is based. Ideally, recent and updated data should be obtained to answer all questions raised by the study, although time and expense usually prevent this being done as thoroughly as it is possible.

The essence of land assessment is to compare or match the requirements of each potential land use with the characteristics of each kind of land. The result is a measure of the suitability of each type of land-use for each type of land. These suitability assessments are then examined under the light of economic, social and environmental considerations to develop an integrated watershed management for the selected area. When this has been done, development can start in an accelerated manner.

The pilot area of this study is the watershed of Köyceğiz Lake - Dalyan Lagoon, located at the southernwest part of Turkey. Part of this area has been declared as a Special Protection Area and is one of the sensitive and vulnerable coastal regions of Turkey. This work forms an example for better evaluating the current environmental situation, assessing the land use suitability and constituting an important part of the integrated watershed management for the selected area. It will also act as a guide for those who want to initiate a land assessment study.

1.2 Objectives and Scope of the Study

In order to plan and develop an integrated watershed management in a sustainable manner for the management of land and water resources, a clearly formulated objective is necessary. Once the objective is clear, details of the components of the plan will begin to fall into place. Objectives are typically scale-dependent and will be different at the national, sub-national, and local level, but they should still be complementary and not contradictory.

The main objectives of this study are;

- to manage all the data about the pilot area, like geographical data, meteorological data, geological and geomorphologic data, flora and fauna of the region, soil structure etc.;
- to focus on the data that are essential to the land assessment with the technology of geographical information systems (GIS);
- to search out and make maximum of the recent soil data using GIS;
- to implement soil survey and make maximum utilization of soil data thrpugh GIS;
- to make a land suitability assessment.

All these objectives are fulfilled resulted in a comprehensive database, which provides useful information for agriculture, forestry, land use planning, for integrated watershed management, environmental protection and many other applications. The data collected in the database allow for different kinds of spatial analyses, which are necessary in land management. The database has been developed using ArcGIS, a common GIS software package, thus it will be easy to combine the database with other data sets, existing or in preparation, for a variety of different applications.

The preparation of a such database adds further value to the study. Furthermore, this database could be an example for decision-makers and planners dealing with watershed releated projects.

2. INTEGRATED WATERSHED MANAGEMENT (IWM) AND GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

2.1. IWM and Objectives

IWM involves the coordinated management of land resources of a watershed undertaken in such a way to optimize the long-term protection of these resources while maintaining the watershed environment. Figure 1 shows the overall components for an IWM system.

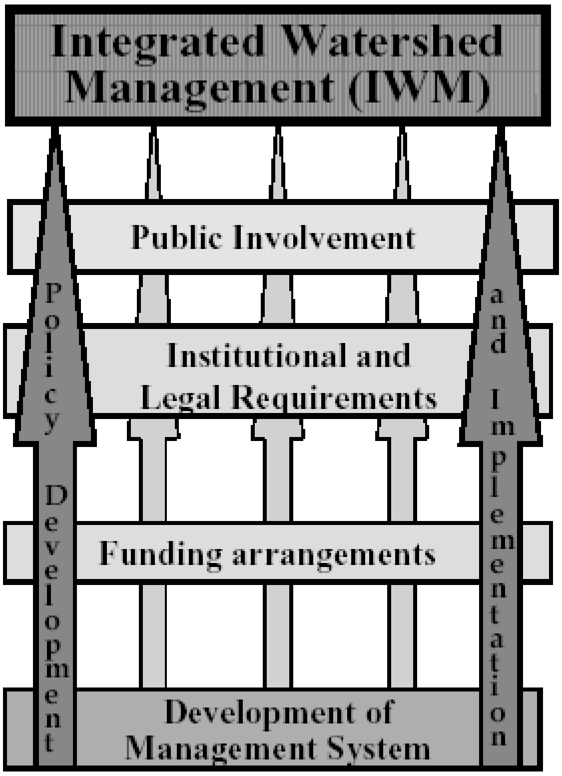

Figure 2.1 A strategic approach to IWM (ESCAP, 1997)

The objectives of an IWM system are:

- Encouraging proper management of the country's resources, which include natural areas, forests, minerals, agricultural and urban lands, water and other resources;

- Promoting the social and economic welfare of the community;
- Sharing the responsibility for environmental planning between all levels of government; and
- Providing opportunities for community involvement in planning.

IWM system is concerned with providing conditions or guidelines in those areas where there are potential impacts on the land resources, in order to minimize these impacts and maintain the long-term integrity and productivity of the resources. The concept of IWM may be incorporated into a series of land-use plans.

These plans should detail the physical resources of a watershed and the environmental impacts, such as loss of productivity, degradation of land, reduction of water quality, etc. that should be controlled so as to proceed on with proper development activities.

2.2. Development of IWM

The preparation of IWM strategies may involve two principal elements: an inventory of physical resources and a series of interpretive maps of combinations of resources. These strategies will provide a basis for planning purposes and environmental evaluations.

The core functions of an IWM are;

- Inventory of land resource data;
- Determination of specification for the establishment of conditions attached to the use of the land;
- Development of strategies and priorities;
- Coordination between organizations (ESCAP, 1997)

2.2.1. Inventory of Land Resource Data

Land resources can be defined as including all the elements of the physical environment which influence the potential for land-use. They, therefore, refer not only to the soil or earth mantle but also to relevant features of geology, geomorphology, landforms, climate, hydrology, vegetation and fauna.

The management of such resources in an integrated and effective manner, needs a detailed information regarding the nature, quantity and quality of these resources be available. The collection and presentation of such information is the purpose of natural resources survey or resource inventory activities.

2.3. Evaluation of IWM Using GIS

Over the past twenty years, the increased amount of resource evaluation and assessment data, from the various types of remote sensing system, much of it available directly in computer-accessible format, and the increasingly widespread availability of low-cost computer equipment, has encouraged the development of techniques for the archiving, analysis, mapping, presentation and visualization of such data. Where these techniques relate to the collection, analysis and presentation of geographical data and information, they are called geographical

information systems (GIS).

A GIS has four functional components, which comprise;

- A data input subsystem, which collects and processes spatial data from sources such as existing maps and remote-sensing imagery;
- A data storage and retrieval sub-system, which organizes data in a structured form and allows it to be retrieved in various forms for subsequent manipulation, analysis or display;
- A data manipulation and analysis sub-system allowing the modification or reorganization of data according to given rules and providing a basis for the preparation and manipulation of models of the geographic area;
- A data-reporting sub-system capable of displaying all or selected parts of the data base in chosen tabular or cartographic formats.

A key advantage of the GIS approach is that it permits the integration of a wide range of categories of data, and the merging or overlaying of various groupings of data, which greatly facilitates the use of the data for design, planning or policy-implementation purposes. By way of example, plans of urban and industrial development can be superimposed on topographic maps and plans of communication systems. A further key advantage is that the GIS system permits the aggregation of spatial and attribute data into models of the land or resource systems under investigation and provides a basis for the simulated operation of such models according to a variety of scenarios as a basis for planning, management and problem-solving.

2.4. Recent Applications of Various IWM Studies

2.4.1 Applying Geographical Information Systems (GIS) to Environmental and Resource Economics-United Kingdom

This work, from United Kingdom, illustrates the functionality provided by GIS, can considerably enhance the incorporation of spatial issues within applied environmental and resource economics (Bateman et al., 2002). However, it must be emphasised that a GIS is not a universal panacea for improving data analysis. Indeed, the quality of results obtained, depends upon a range of factors common to any quantitative analysis, such as the accuracy of the input information, the appropriateness of the data structures used to store it, and the choice of analytical tools employed. In addition the application of GIS introduces a set of new concerns that include issues of spatial representation and data confidentiality. These matters are significant and warrant some consideration here.

Decisions regarding the appropriate spatial data scale, level of data aggregation, and frequency of measurement must be made at an early point in any GIS analysis (Chrisman 1997). These decisions are not trivial, and indeed may have a significant impact on the manner in which the results ultimately obtained can be interpreted. On a theoretical level, the appropriate units for spatial analysis depend upon the questions being asked (Rindfuss and Stern 1998). For instance, issues of population travel and migration tend to turn on the decisions of individuals and households, whilst questions of equity of access to environmental quality may require analysis at the scale of neighbourhoods. Indeed some problems require consideration at multiple scales. For example, enquiries into changes in land-use and land-cover typically require simultaneous information at the level of the individuals and households that may own the land, the local administration bodies that regulate land-use and make decisions concerning infrastructure, and the regional governments that dictate strategic development strategies (Rindfuss and Stern 1998). In practice however, the presence of limitations regarding the availability of data often has at least as great influence on the choice of aggregation employed as does any theoretical consideration regarding the appropriateness of different scales.

In cases where remotely sensed data are being employed, the characteristics of the sensing instrument will place the greatest limitations on the spatial scale of analysis, as they will dictate the resolution of the available images and the frequency with which measurements can be made (Ryerson 1998).

Recent improvements in civilian satellite systems mean that imagery with a resolution of 10 meters or better is increasingly common, although even at the finest levels there can be difficulties in determining the location of objects such as utility lines and transportation infrastructures, or in distinguishing subtle land-cover differences. Furthermore, from a social perspective, there is certainly no remote sensing unit equivalent to the individual, and house- holds can only be identified from the location of the buildings within which they reside. Where vector data that has been digitised from paper maps is employed, then the scale and detail present will be dependent upon issues such as the precision of the digitising process, the scale of the original maps and their degree of cartographic generalisation (the selective depiction of objectives so as to preserve visual clarity). Hence the topological relationships depicted in the GIS may be a considerable simplification of those present in the real world.

Even in cases where the scale and resolution of data are acceptable, further limitations may arise as many spaces within which social interactions take place cannot be easily depicted in a GIS; cartographic depictions of the real world tend to represent physical entities, not social activity spaces. Whilst some social units, such as urban areas or delineators of land ownership, do have a natural georeferent, the majority do not. For this reason, the delineation of spaces such as communities or neighbourhoods can be problematic. This issue is commonly circumvented by the use of pre-existing aerial units such as census tracts. However, such units have often been developed to expedite local administration activities rather than delineate areas of a particular social character. An alternative and more sophisticated view is to define neighbourhoods based on some measure of mobility. In, say, a developing world setting where the chief economic activity is farming and the primary means of transportation is walking, the delineation of a neighbourhood based on a measure of walking distance may be sensible. However, as modes of transportation evolve to enable travel over ever greater distances, the validty of defining neighbourhoods in this way becomes questionable for many purposes. In the USA the average daily commuting distance is now almost 30 kilometres from home to workplace (Rindfuss and Stern 1998). A question arises as to whether such spatial scales should constitute neighbourhoods. Even in situations where neighbourhoods can be delineated based on travel to work measures, the units generated will undoubtedly contain many individuals who are immobile or are unable to travel more than a short distance from their house. Hence perceived neighbourhoods will be present at a wide range of overlapping spatial scales.

There is rather little understanding of how complex spatial structures such as overlapping neighbourhoods can and should be represented in a GIS. A solution to this problem is to represent features at a highly aggregated scale by depicting large geographical units within which it may be assumed that social activity spaces are more likely to be confined. However, many potentially important process may not be visible at these high levels of aggregation. Issues regarding the abstraction and representation of certain aspects of the 'real' world by digital means are by no means unique to GIS; the matters are universal in many kinds of information system (Martin 1996). It must nevertheless be recognised that the assumption that a single objective reality exists and can be measured is a naive view; the choices made regarding the way in which information will be incorporated into the system will always be grounded in either subjective or arbitrary reasoning. Hence any GIS representation can only provide a selective view of reality.

A second issue for the application of GIS technologies to the field of environmental and resource economics concerns issues of data confidentiality and access to the technology. Remotely sensed data are increasingly becoming available for public use, fostering the ability of researchers to discern in ever more detail the footprints of economically important activities (Rindfuss and Stern 1998). This trend, coupled with the growing availability of socio-economic data that has been disaggregated to small geographical areas (an example being the output of national censuses of population), means that there are increasing opportunities to link observed environmental features such as the change in use of parcels of land, with their social drivers. Whilst this capacity for linkage is undoubtedly opening up many novel research possibilities, it is also generating new conflicts and uncertainties. Although there are some legal precedents regarding privacy rights with respect to high resolution aerial photography, there are many unresolved issues of international law. Even in countries like the UK that have relatively well defined data protection legislation, it is unclear whether the provision of postcodes constitutes a breach of spatial confidentiality. In the USA concerns have been expressed by landowners that data from remotely sensed images analysed in the research environment could be used to expose confidential information regarding land-use practices, possibly revealing to government officials that those practices are violating land-use regulations (Rindfuss and Stern 1998).

In addition to issues of data confidentiality, GIS have been criticised as being undemocratic due to the fact that the technologies and their associated data are generally only available to 'elite' individuals situated in commercial, administrative, and research environments (Pickles 1995). Recent advances, such as the development of internet based GIS solutions may partially redress these concerns. However, the fact remains that, whilst observational research may be somewhat impervious to this analysis, projects involving the development of market interventions or those that may play a direct role in policy formation do carry equity related concerns.

Notwithstanding the above caveats, there is, we believe, very considerable scope for the continuing development of GIS applications in the field of environmental economics. The techniques directly address many of the limitations in data handling and modelling that have restricted previous investigations. As illustrated by the work presented in this article, a wide variety of research papers have been produced using GIS based techniques during the past few years. These exemplify how the functionality provided by GIS packages allows the researcher to incorporate spatial complexity directly within applications. The ability to incorporate detailed isochrones into travel cost studies, to assess what can and cannot be seen from each property in a hedonic pricing study, or to include the aspect angle in models of timber yield, and to conduct all of these various assessments in an automated fashion, constitutes a substantial improvement in the data availability and consequent robustness of all such studies.

It is writers' belief that further advances in the computing power and functionality of GIS packages will stimulate development in further areas of environmental economic research in the future. At the moment one particularly active area of development concerns techniques for the production of virtual reality representations from GIS databases. Such Virtual Reality GIS (VRGIS) systems are beginning to be marketed. These allow the two dimensional output of traditional systems to be transformed into three dimensional 'virtual' environments which can be viewed or explored by users (Fisher and Unwin 2002; Appleton et al. 2002). The development of VRGIS opens up the possibility to convey environmental information in new ways, and may deliver particular benefits in expressed preference techniques such as contingent valuation and choice experiments where such systems could be used to deliver scenarios depicting the likely future states of environmental goods being considered.

Furthermore, a current emphasis on the integration of GIS technologies into World Wide Web sites will open up more opportunities for the sharing of both experience and data, and for the design of new survey methodologies that are able to capture much more heterogeneous samples of individuals that it has been possible to include in the past.

This paper has sought to highlight to environmental and resource economists the great potential which GIS techniques offer for incorporating the spatial dimension into applied studies. The diversity of studies discussed illustrates the great flexibility and applicability of such techniques to a range of issues. Such application offers the potential to significantly enhance the ability of economists to successfully incorporate the complexity of the environment within their empirical analyses. Indeed the promise of GIS is to turn the spatial dimension from one to be either ignored or inadequately represented, into a key element of empirical economic investigations of the real world.

2.4.2 Monitoring and Assessment of Land Use Status by GIS-Turkey

There is bound to be conflict over land use (Ozcan, 2002). Demands for any kind of land use are greater than the land resources available. In the developing countries, these demands become more pressing every year (FAO, 1993). How people or nations use their land depends on complex, interrelated factors which include the characteristics of the land itself, economic factors, social, legal and political constraints, and needs and objectives of the land users (FAO, 1980).

Many current land use systems are not sustainable in developing countries as they contribute to the land degradation problems. Considering the ever increasing population in the developing countries, there is an increasing urgent need to match land types and land uses in the most rational way possible, so as to maximize sustainable production and to satisfy the diverse needs of society while conserving fragile ecosystems (FAO, 1993).

Monitoring the spatial and temporal changes in the Land Use Types (LUTs) and finding out cause and effect relations of the changes are the crucial information in determining whether or not the land is used potentially. In addition, the knowledge of the land suitability assessment is one of the aspects for sustainable agriculture. The set of information needed for the land evaluation could be grouped as: physical land resources, socio-economic issues and present land use. Gathering and evaluating these data in conventional methods could be time consuming, costly and subject to some errors in processing data.

That causes some difficulties in land evaluation and monitoring the changes of LUTs. Therefore, many land evaluation computer models were developed by Schulthink (1987), Van Diepen et al. (1988), Rossiter and Van Wambeke (1989), Yizengaw and Verheye (1995), and Zuhdi (1999). Monitoring is usually conducted using remotely sensed data and ground observations. These data can be evaluated either manually (Ozcan, 1998) or by the use of recent technologies such as Geographic Information System (GIS) (Kosmas et al., 1997; Thwaites and Slater, 2000) that may reduce the processing time and the errors. Furthermore, larger areas could be assessed easily and rapidly. Using GIS, enables decision makers and researchers to monitor the changes in LUTs and other changes such as environmental, social and economical situations resulted from the land use changes. In Turkey, there are some land evaluation and land use planning studies. However, they are not practiced in real life; and it is not a common practice to use GIS techniques in monitoring and assessment of land use status, yet it is practicable.

The principle objectives of this paper are to monitor and assess the spatial and temporal changes in LUTs by using GIS, and to determine the main factors affecting the changes. The paper also aims to determine whether the present land use status conforms to land potential or not.

In the study area, farmers need to irrigate agricultural crops grown in the period from April to November due to the lack of rainfall. Three major soil series were determined: Canakci, Arikli and Mursel, out of which Canakci and Mursel series are highly suitable (S1) for all kind of LUTs grown potentially in the region.

Twelve different LUTs were identified. Corn was the most widely cultivated LUT because it needs lower production costs and labor. Produced maps showed that LUTs changed in space and time. Spatial and temporal changes in LUTs could cause serious problems at the peak irrigation season, especially in view of irrigation and drainage canal capacity. As indicated by other researchers, spatial maps of LUTs depicted highly clustering attributable to the farmer's habit and neighbor effect. Monitoring of LUT change could be used for future development and remodeling studies.

Land suitability results indicate that Canakci and Mursel series have S1 and Arikli series has S3 suitability classes for citrus plantation potentially. Matching soil series maps with citrus plantation maps demonstrated that the land was not used according to the potential. Land suitability assessment showed that if any farmer uses Arikli series for citrus plantation, a 40% yield reduction would likely occur.

Documented actual citrus yield data upheld the conclusion. Considering all the factors affecting land suitability, benefit/cost ratio and economical conditions in Turkey 58% of land is not used at its potential. The findings of this study could be employed in the areas where the agro-ecological and economical situations are the same as the study area.

2.4.3. GIS-based Information Flow in a Land-use Zoning Review Process-Taiwan

This work, from Taiwan, describes a geographical information system (GIS)-based information flow for a land-use zoning review process (Lin, 2000). GIS technology is employed not only to edit and display maps as conventional GIS applications, but also to enhance work quality. These enhancements include an exploration of hidden information, the production of tentative zoning maps, recognizing potentially problematic areas, conducting crucial site investigations, facilitating informative public hearing, and presenting potential policies.

In the case of the Yang-Ming-Shan (YMS) National Park, Taiwan, a GIS-based information flow is employed to assist in the land-use zoning review process.

This GIS-based information system reveals several features including:

- a new, more complicated and effective information flow;
- close coordination of computing and noncomputing sub-processes;
- prior identification of over and under-regulated areas to avoid potential appeals and conflicts;
- economical and effective site investigations;
- potential policies established for both private and public land.

GIS-based information flow as shown in Fig. 2.2, takes advantage of the GIS technology by fully utilizing the spatial information and extensively interacting with the noncomputing information, including landholders' appeals, public hearing, committee opinions, and site investigations.

After obtaining the digital data sets and spatial criteria, the techniques of spatial analyses in GIS are employed to:

- construct tentative zoning maps;
- identify the potentially problematic areas;
- test "what-if" relations,

- propose possible policies for the areas of classes 3 and 4 in developable zones.

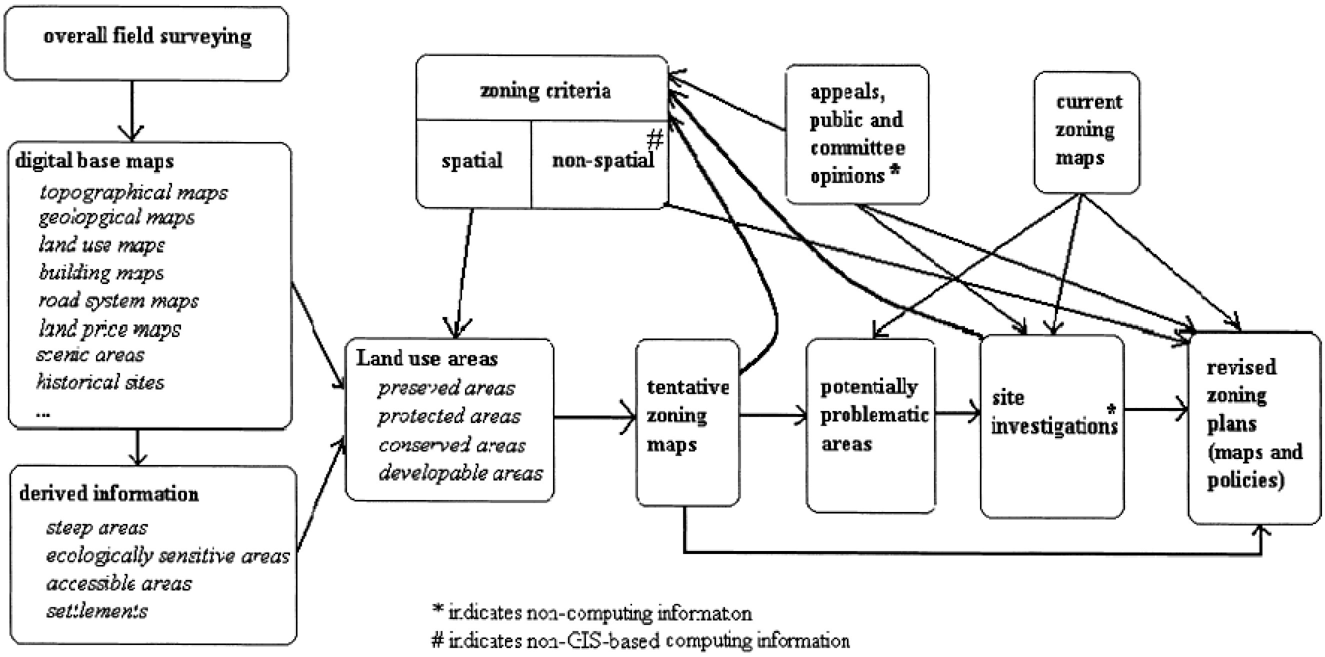

Figure 2.2 GIS-based informational flow in zoning review process (Lin, 2000).

A GIS-based land-use zoning review process that is described in this article, demonstrates a feasible approach to integrate computing and noncomputing processes residing in the zone planning. The GIS-based computational flow implies a possible implementation of planning support systems in the future. This work also demonstrates how spatial criteria can be specified in an operational way. Particularly, concepts of accessibility, settlement clusters, and vegetation-sensitive areas are clarified in terms of GIS computation.

However, the GIS-based process may be modified or improved if additional databases or new technologies are available. Furthermore, the case of the YMS National Park illustrated that GIS technology helped the planning agency a lot. By adjusting the work flow, providing sufficient information and analyzing potential problems in a systematic way, noncomputing processes, including field investigations, public hearing, and zone plan review, proceeded informatively and effectively. This experience is encouraging. It is expected that the GIS-based process can be further generalized so that not only other national parks but also general city planning can take advantage of GIS technology.

2.4.4 Landscape Information System: A GIS Approach to Managing Urban Development - South Korea

In the case of the Seoul, the capital of South Korea, Landscape Information system (LSIS) is employed to manage the urban landscape information and analyze the visual impacts of proposed development projects (Oh, 2001). Employing Geographical Information system (GIS) and computer graphics simulation techniques, LSIS performs such functions as, input and management of graphic and attiribute data, query analyses of attributes related to urban landscape elements, and visual impact (view obstruction) analysis of development proposals as given in Figures 2.3, 2.4 and 2.5 respectively.

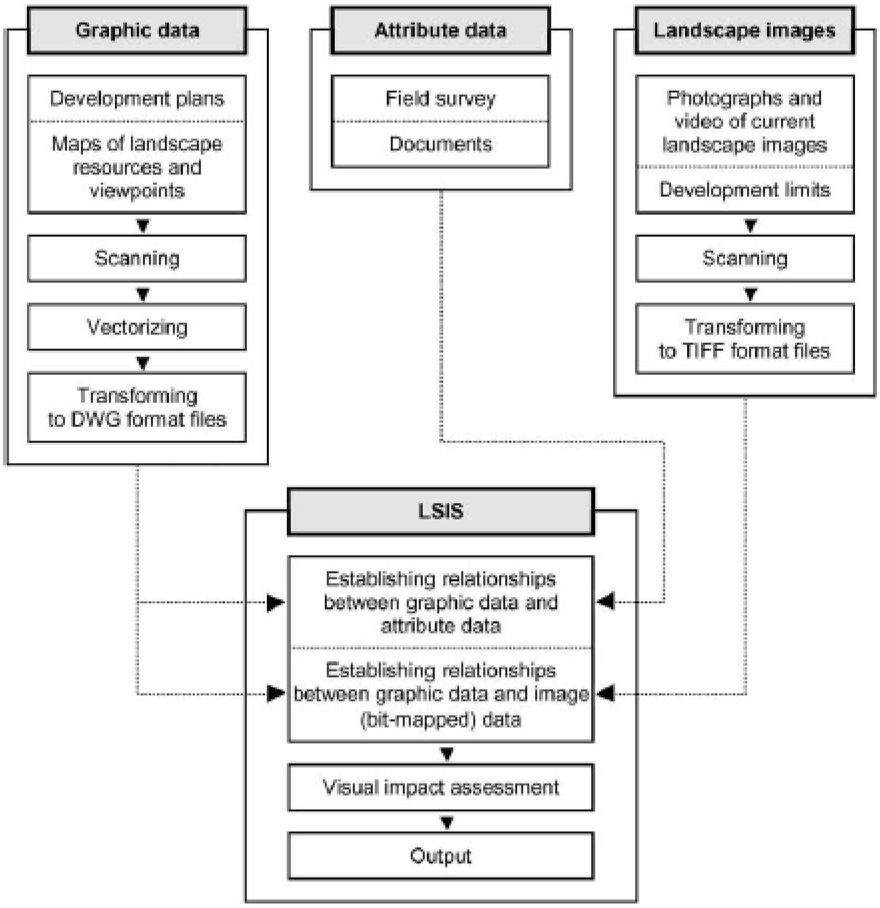

Figure 2.3 Data integration for LSIS (Oh, 2001)

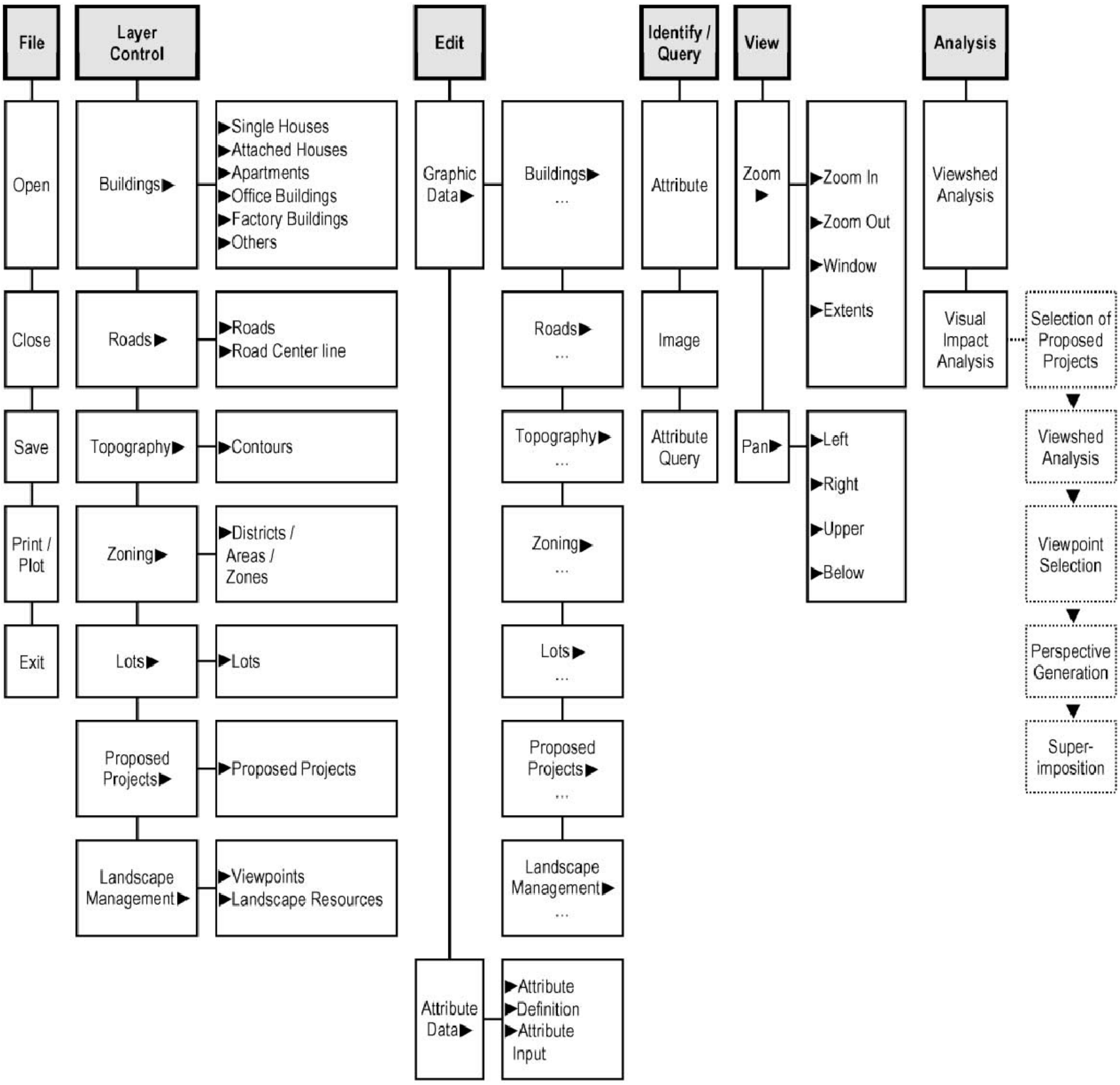

Figure 2.4 Main functions of LSIS (Oh, 2001)

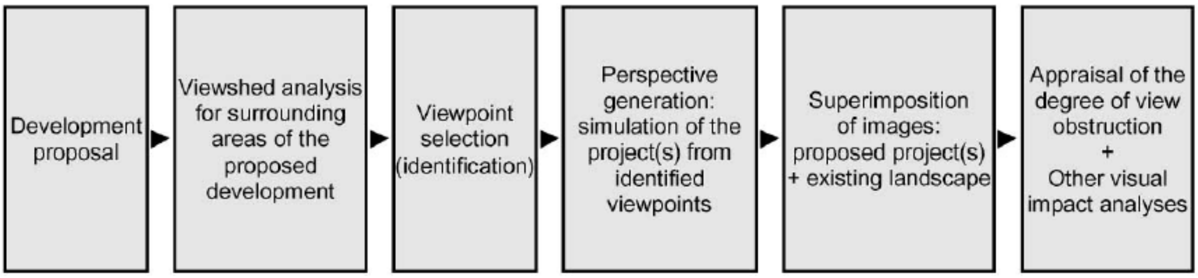

Figure 2.5 The process of visual impact analyses within LSIS (Oh, 2001)

The LSIS in this study was developed with the aim of being a significant tool which can meaningfully contribute to practical and efficient urban landscape management of local governments.

The contributions of LSIS may be referred as follows;

Using LSIS, a compherensive landscape analysis can be implemented by integrating various landscape data in a systematic manner. The application of computer techniques like GIS and computer graphics simulations to the urban landscape analysis and management process, in the form of a decision-support system, can help to simplify complicated visual analyses. This in turn can allow for rapid and accurate appraisals of impacts of proposed development projects.

Impacts on the landscape by development projects can be predicted interactively and comparisons with the simulations of "before" and "after" can be presented visually, fostering the production of more sound resolutions.

Long-term changes in the landscape can be constantly monitored through updating data regulary, and vulnerable landscape resources can be effectively managed by conducting landscape analyses and appraisals in advance. In fact, substantial portions of the database of LSIS can be regularly maintained by other independent sources due to data sharing, and thereby improving the efficiency of data management.

Examinations can be rendered on visual aspects in the urban landscape, as well as for legal relevancy of development proposals, such as issues relating to architectural and planning regulations.

Social, economic and demographic aspects, used jointly with LSIS, can help to provide professionals with a more through understanding on how to successfully cope with increasingly complicated urban landscape management problems.

2.4.5. Assessing Pollution Risks to Water Supply Intakes Using Geographical Information Systems (GIS) - Britain

This paper (Foster and Mcdonald, 2000), has illustrated the potential application of geographical information systems to the assessment of risks to a public water supply intake in Britain. The examples given include GIS overlay to identify areas of potential hazard, the use of GIS in the probabilistic modelling of risks, and the prediction of stream water quality. The functionality of the GIS has also been shown to be suitable for the derivation of raw water monitoring strategies.

The approaches described in this paper illustrate the potential use of computing techniques, and GIS in particular, in pollution risk assessment for water resource protection. The potential for such approaches to be applied to all stages of a risk assessment process has been identified. Geographical information systems therefore have considerable ability to enhance pollution risk assessment through the storage, analysis and management of environmental data. Two GIS software packages have been utilised together here, each with individual strengths and weaknesses. The MapInfo software proved to be vital in the analysis of the raw data due to the ability to combine cells based on both their geographic location and their associated attributes. In addition, the desktop mapping capabilities of WINGS combined with the innovation of GISLAB provides realistic potential for the output from a pollution risk 'expert system' to be available across a corporate-wide intranet.

This research also demonstrated that the computing power now commonly available on desktop and laptop PCs has the potential to analyse and display geographically referenced output from environmental models, and for this information to be made available to a significant number of users across a large utility company, including mobile and home workers.

2.4.6. Sustainable Land-use Planning in Protected Rural Areas-Italy

The study (Senes and Toccolini, 1998), is concerned with evaluating the possibility of extending the application of the method to an area, such as the 'Parco del Serio' Italy , characterized by an environment rich in natural features but profoundly modified by human intervention, in order to define a 'plan of the environmental preconditions' to be adopted during a sustainable planning process and which indicates the restrictions and the potential for development of human activities (with particular regards to tourism and recreational activities) in relation to the existing environmental resources and the ecological stability of the territory. This application of the Ultimate Environmental Threshold, UET, method made use of the GIS technology for the analysis and processing of the data acquired and the presentation of the results.

The aim of the study was to identify those areas suitable for the expansion of the human activities already present within the park compatible with the ability of the environment to absorb the impact the various activities.

The project involved the following phases:

- Identification and evaluation of the resources present in the territory; with particular reference to the natural resources of water, soil, vegetation, fauna and landscape and the human resources expressed the various land uses,
- Definition of the activities to be developed in the area; with particular attention being paid to residential, industrial, agricultural and recreational developments; and the subsequent analysis of the interrelationships between resources and activities in order to identify the demands and the effects of the developments, which are presented in graphical form in Figures 2.6, 2.7 and 2.8.
- Definition and identification of the areas suitable the expansion of the various activities.

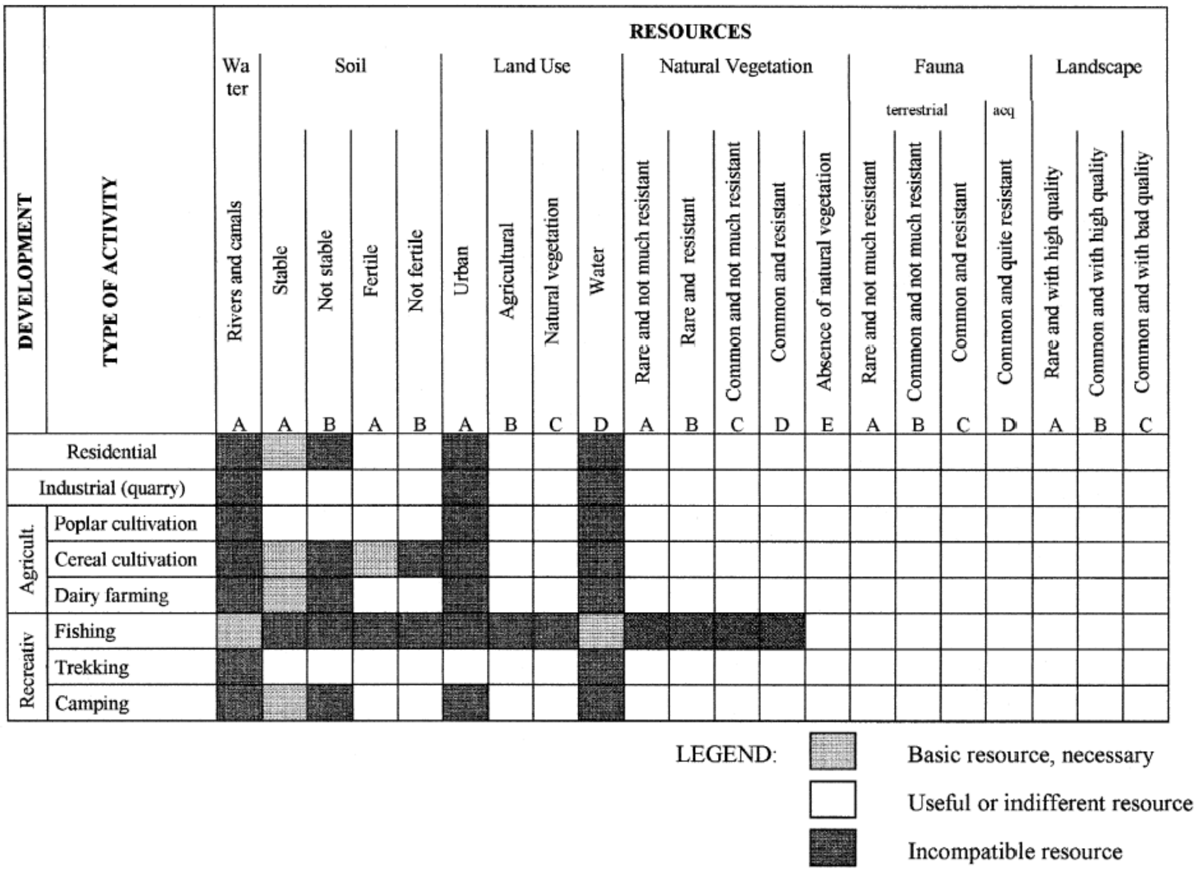

Figure 2.6 Environmental resources required by human activities, Matrix 1 (Senes and Toccolini, 1998)

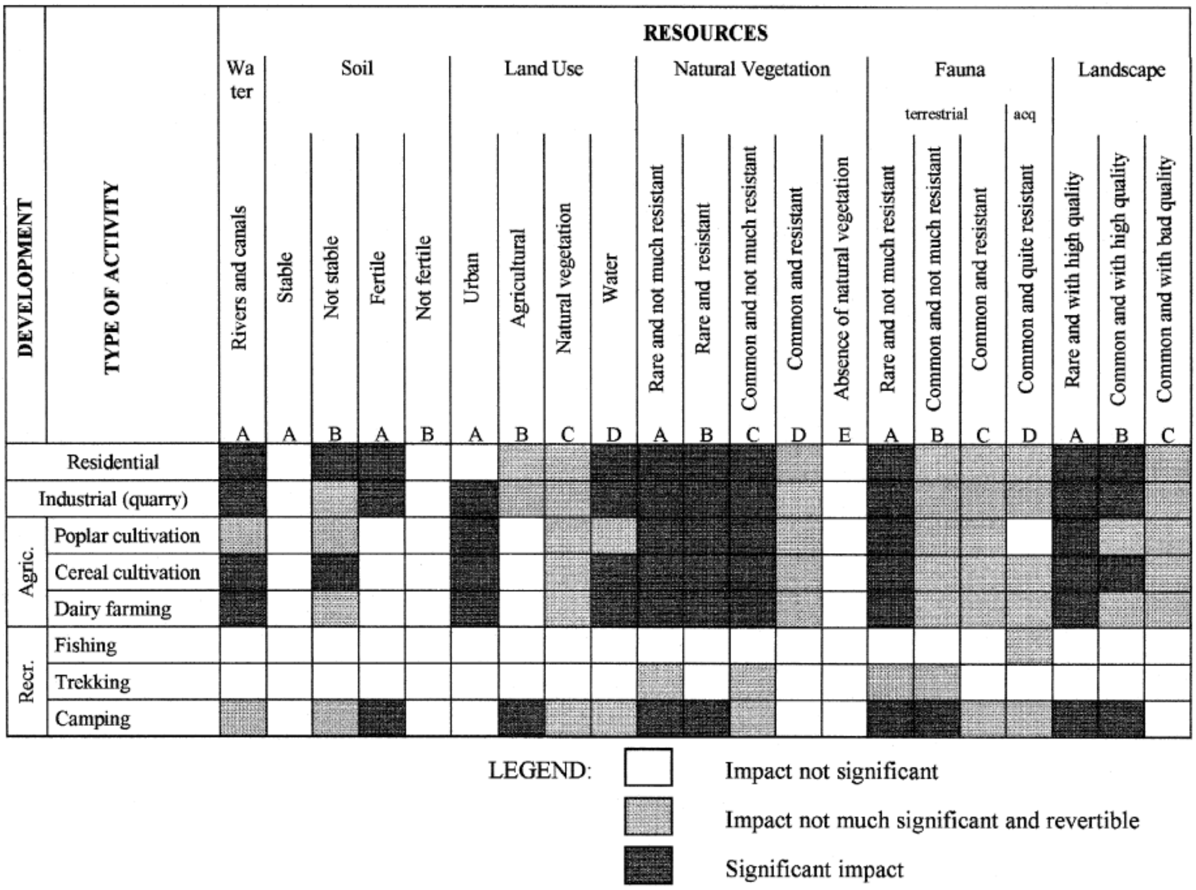

Figure 2.7 Impacts of human activities on environmental resources, Matrix 2 (Senes and Toccolini, 1998)

In the last phase, the areas suitable for hosting the development of the various human activities were identified in relation to the limits imposed by the resources of the natural and human environment present in the territory (Paoletti et al., 1989).

To this end, the information contained in the synthetic map of each resource edited during the resource analysis and evaluation phase were processed with the GIS (pc ARC/INFO) through an overlay procedure utilizing the criteria emerging from the matrices. In this way, a digital map is obtained continuing all the possible combinations of the resource maps (pc ARC/INFO coverage).

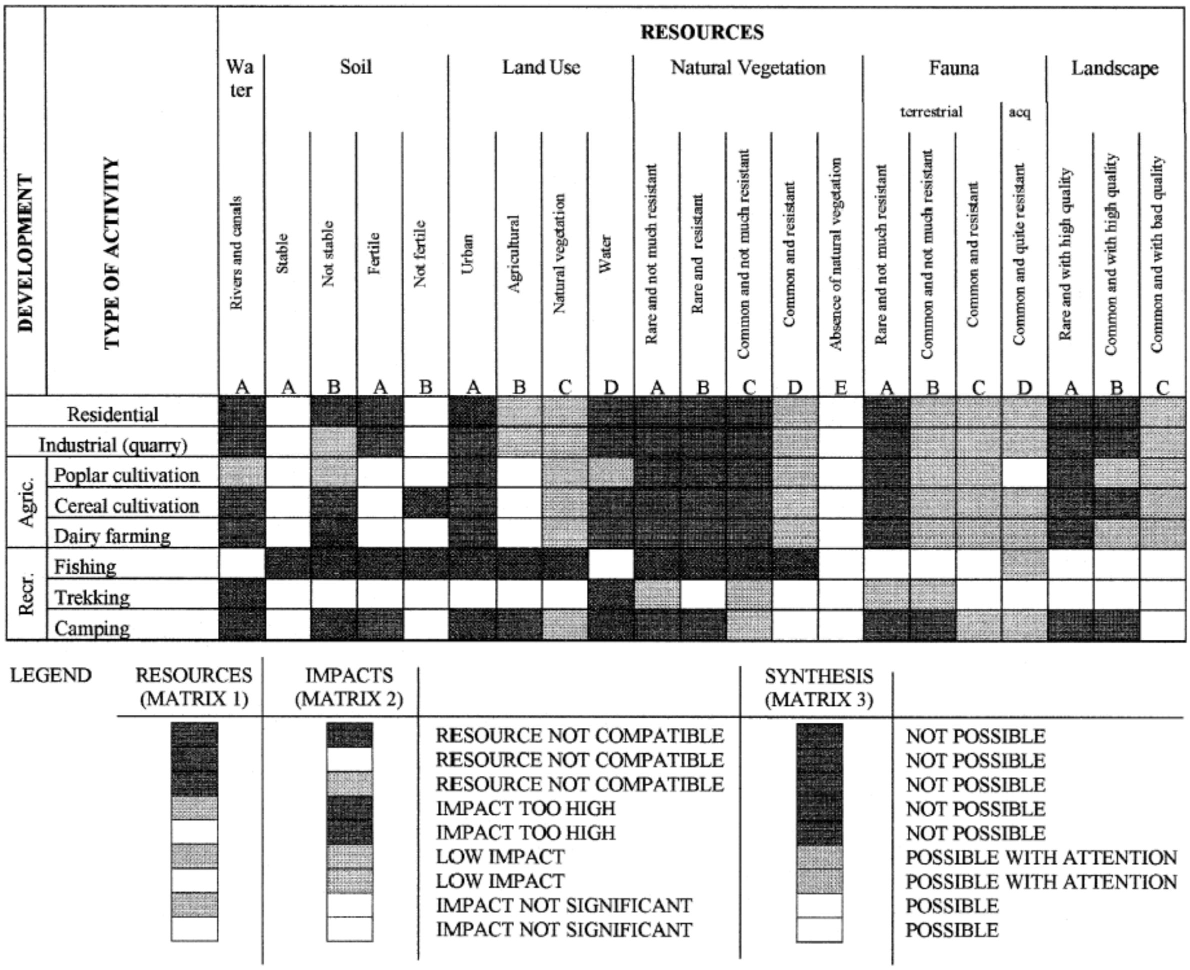

Figure 2.8 Synthesis of the relationships between the resources and the activities, Matrix 3 (Senes and Toccolini, 1998)

Comparing the information deriving from the compilation of the matrix of synthesis with this digital map, it is possible to identify the areas suitable for expansion of each type of human activity; the activities may be developed in the areas in which the existing resources are compatible in terms of availability and impact sensitivity (Huyck, 1993).

This project demonstrate that the philosophy of the UET method adapted to the Italian situation can be very useful for a sustainable land-use planning. In fact, the conclusive results of the application can represent the basis for a plan of the environmental preconditions to be adopted during the planning process and which indicates the restrictions and the potential for development of human activities in relation to the existing environmental resources and the ecological stability of the territory.

The use of GIS technology in applying this kind of parametric methods represent a fundamental and powerful tool in the planning process for considering a very large and exhaustive range of thematic layers (Senes and Toccolini, 1998). Three examples are land-use capability for various human activities are given in Figures 2.9, 2.10, 2.11.

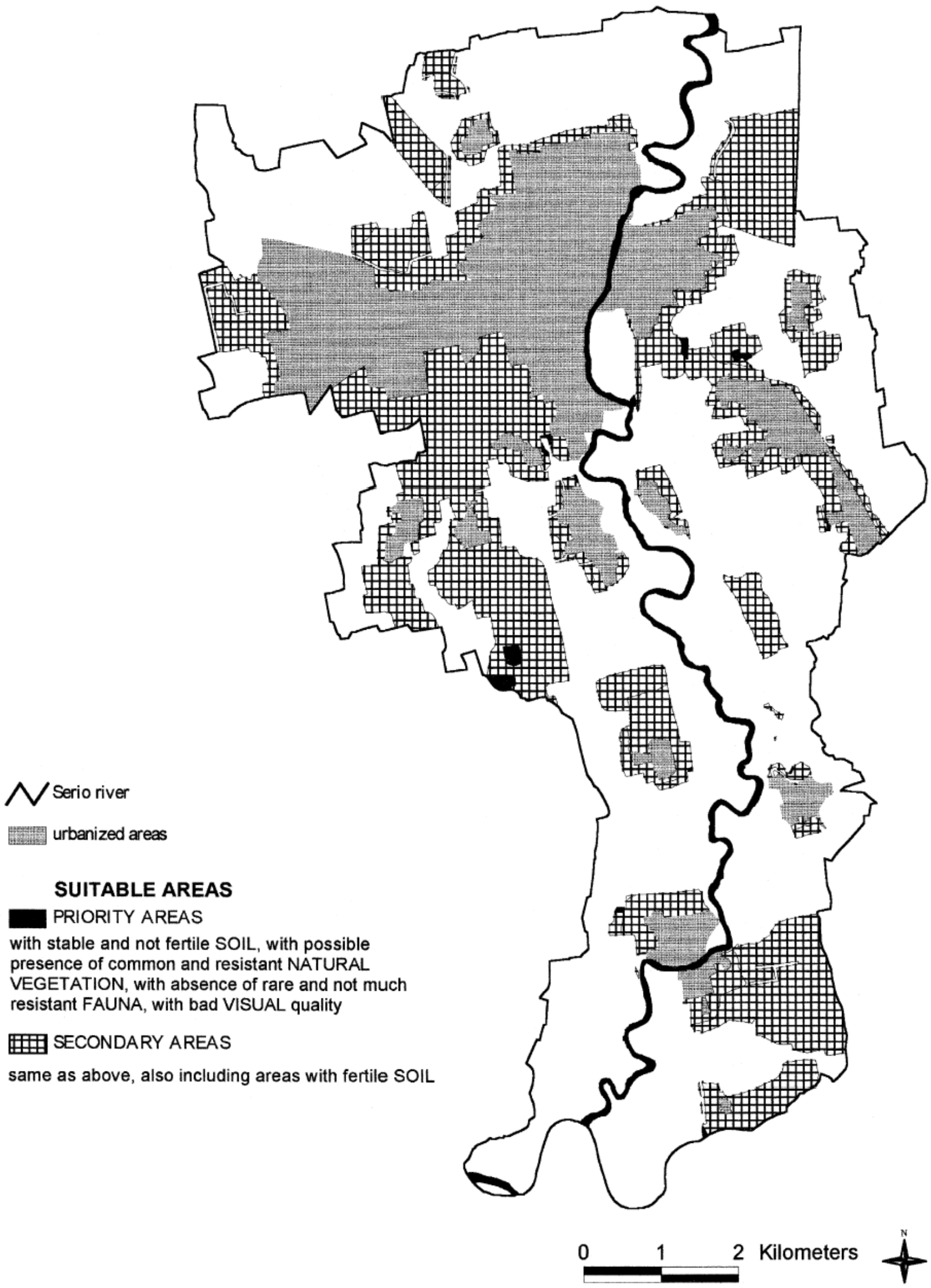

Figure 2.9 Areas suitable for residential development (Senes and Toccolini, 1998)

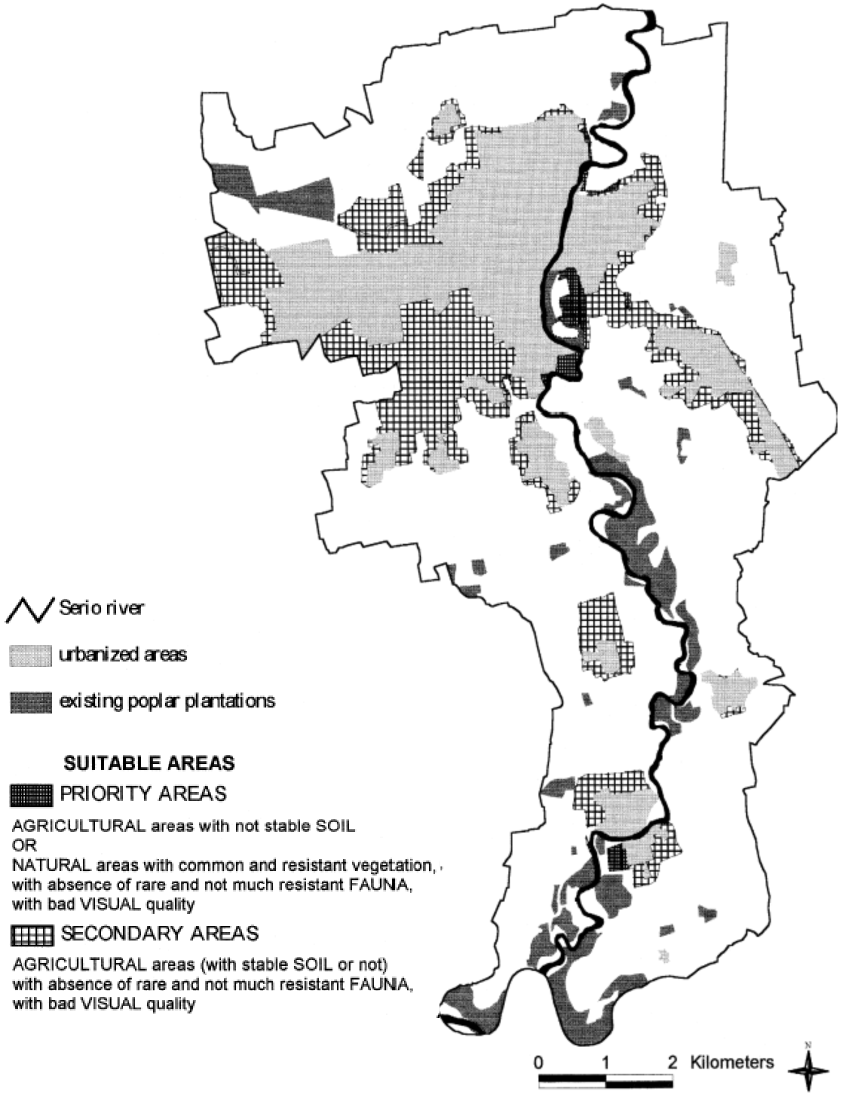

Figure 2.10 Areas suitable for poplar cultivation

(Senes and Toccolini, 1998)

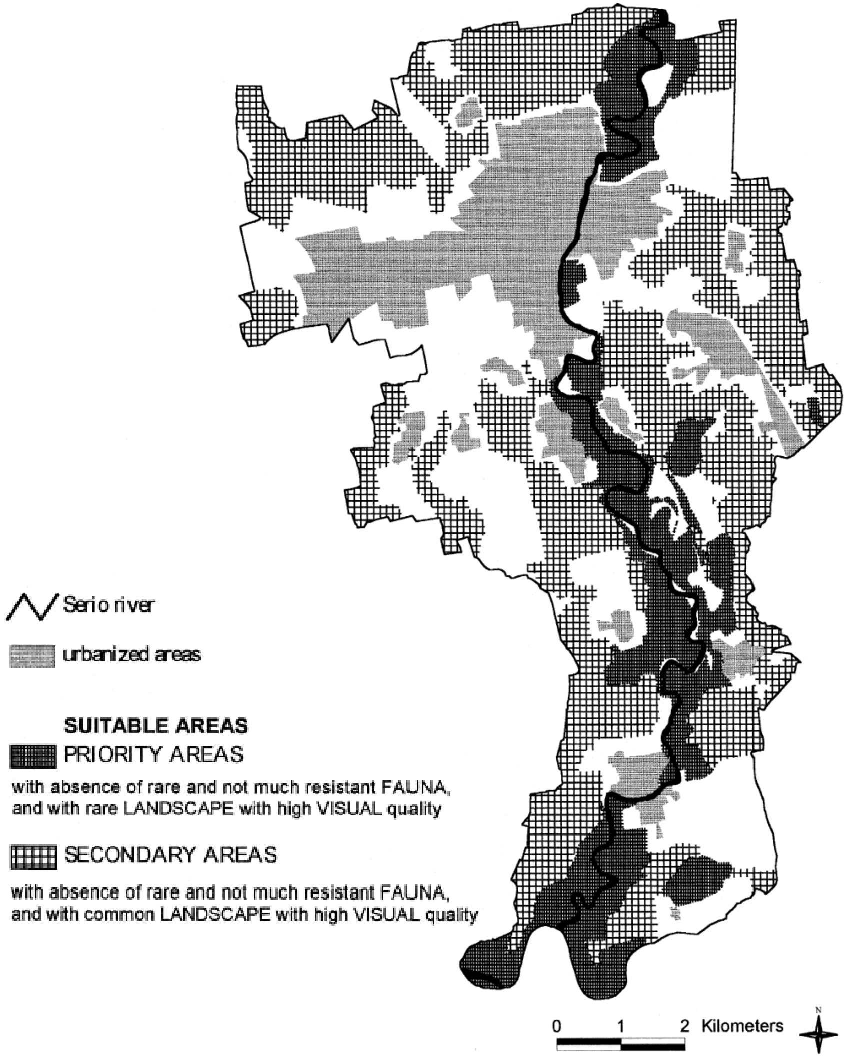

Figure 2.11 Areas suitable for trekking

(Senes and Toccolini, 1998)

2.4.7 The Application of GIS to Air Quality Analysis in Taichung City-Taiwan

This paper by Lin and Lin (2002), presents a preliminary study for the evaluation of transport-related air pollution situations in an urban area. Submodels used in this study are integrated in a GIS, which is able to utilize the spatial information and describe the urban road network and the distribution of the pollutants in the atmosphere. The estimation of mobile source emissions and pollutant distribution analysis in Taichung City, Taiwan, are used as a case study. The main GIS mapping features are also described.

The model developed in this research integrates several submodels such as the emission estimation model, dispersion model, backward trajectory model and relevant spatial and attribute data in a GIS framework. The entire system is then applied to estimating emissions from motor vehicles and analyzing the spatial distributions of air pollutants in an urban area. The structure of the entire system is shown in Fig. 2.12. The GIS platform used in this research is the ArcView package developed by ESRI which provides both raster and vector systems.

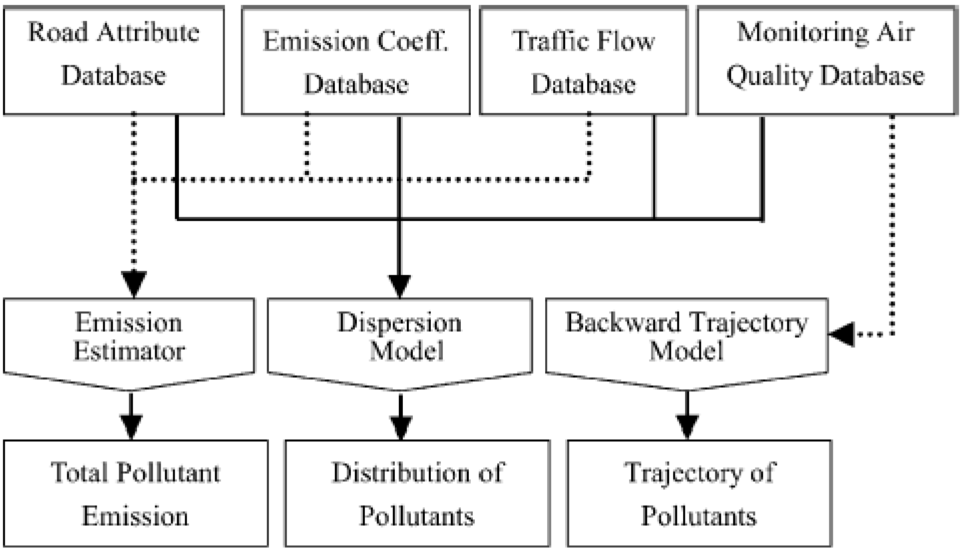

Figure 2.12 The structure of the integrated GIS model (Lin and Lin, 2002)

The model developed in this study can also be used to assess the impacts of different traffic management policies on air quality.

Since air pollution produced by road traffic has become a major concern to urban planners, developers and health officials, it is necessary to check more frequently on the pollutant emission quantities and their spatial distributions and also to evaluate the variation of these situations caused by changes in certain traffic management policies or traffic conditions. Hence, there are growing needs for tools that can provide an easy access to obtain up-to-date mobile source emissions information.

The integrated model which combined emission estimator, dispersion model and databases in a GIS framework should be a suitable tool to satisfy the needs mentioned above. The results of this research show that the visualization and analytical features of GIS did provide more information and convenience to users. It also makes the model more efficient and flexible.

2.4.8. Habitat Evaluation Using GIS: A Case Study Applied to the San Joaquin Kit Fox- California, USA

This work of Gerrard et al. (2001) use GIS data and modelling to define a spatially explicit analysis of habitat value, using the San Joaquin Kit Fox of California (USA) as an example. In this paper, the data is applied from Northern California to derive a small-cell GIS raster of habitat value for the kit fox that incorporates both intrinsic habitat quality and neigborhood context, as well the effects of barriers such as roads. Such a product is a useful basis for assessing the presence and amounts of good and poor quality habitat and for eventually constructing GIS representations of viable animal territories that could be included in the future reserves.

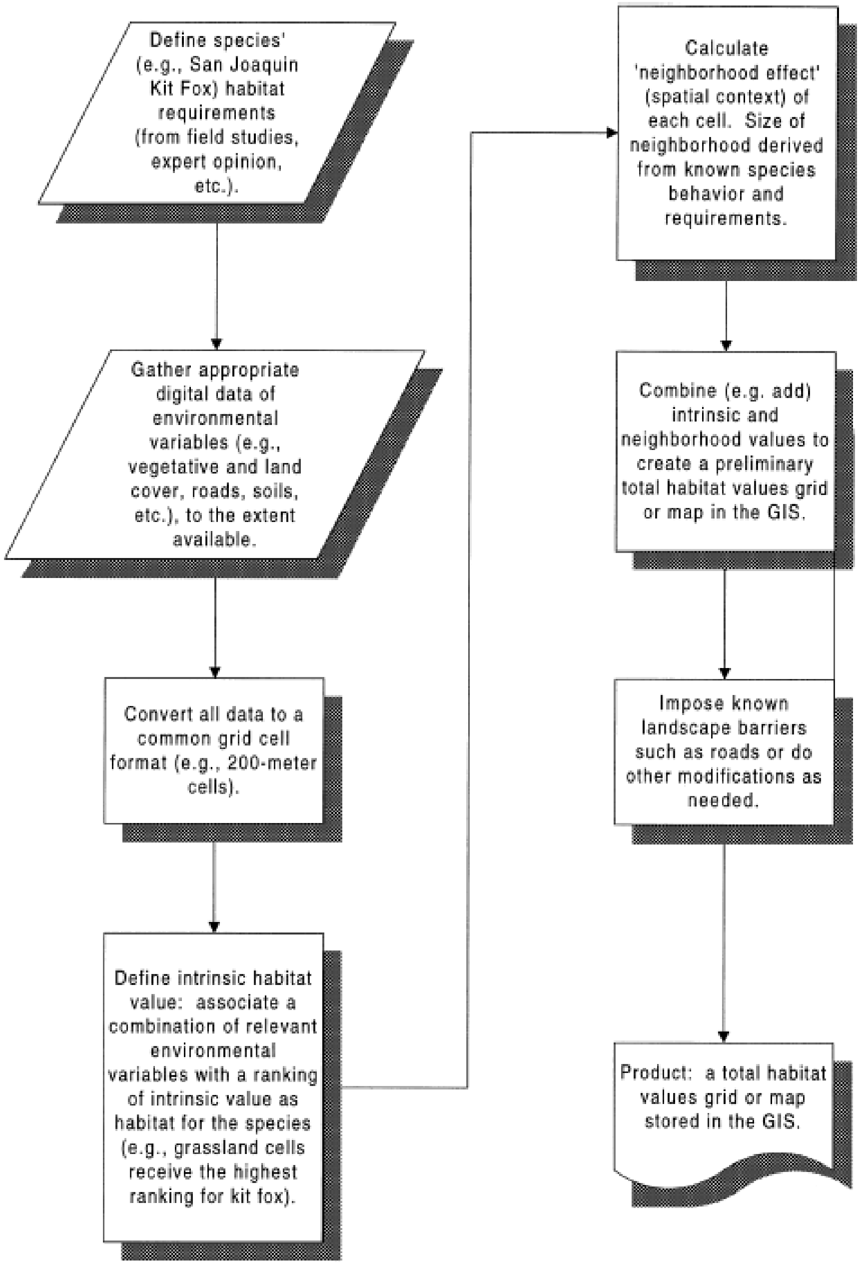

Figure 2.13 Process overview (Gerrard et al., 2001)

The strategy in this paper was to incorporate as much biological information as possible to create a model of spatial habitat value in a GIS format. The vegetation map was the main environmental layer because of known feeding behavior and habitat use by the kit fox. The intrinsic cell values are assigned and then used the GIS to pass a spatial filter over the instrinsic habitat values, leading to a "neighborhood effect" that measured the spatial context of each cell. The final result was a map of potential habitat value for the kit fox that combined instinc and neigborhood value and also incorporated road barriers. The total habitat values for the region is shown in Figure 2.14.

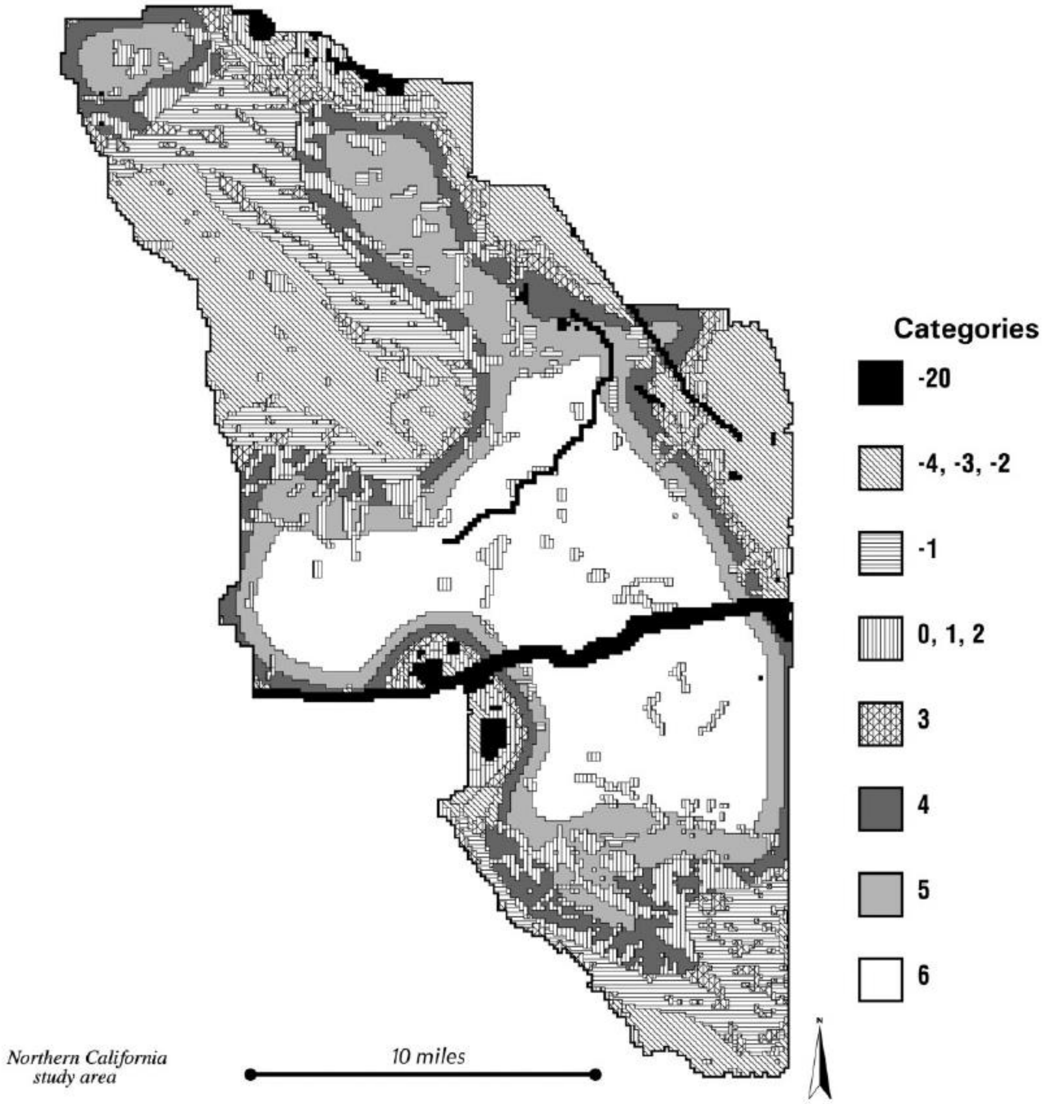

Figure 2.14 Total habitat values for the San Joaquin Kit Fox (Gerrard et al., 2001)

The analysis of potential habitat herein is ultimately an input to other questions such as: what size, type and number of blocks of habitat would be necessary to conserve this relatively wide-ranging species? How much of the best quality kit fox habitat is in the most imminent danger of loss?

Assuming planned development projects go on, how much kit fox habitat would remain within the next 10 years hence and in what spatial configuration? What areas should be considered for acquisition if mitigation funds become available? The GIS habitat value model derived in the paper can provide a needed basis for regional assessment of this important mammal. Furthermore, many other species could have their potential habitat evaluated using the same basic approach.

3. CASE STUDY

The direct and or indirect effect of human activities on coastal ecosystems have accelerated considerably in recent years and the impact of such changes on these sensitive and economically important environments is now of major concern. Coastal waters usually receive high amounts of nutrient loads originating from either point and or non-point sources that have led to rapid increase in eutrophication in almost all around the world.

To cope with this phenomenon, ecological modeling studies have also gained significance in parallel to environmental deterioration. Scientists working in this field are nowadays dealing with the eutrophication concept in a wider sense, taking into consideration the environmental conditions related both to internal and external factors such as soil haracteristics, geographical and hydrological conditions, land-use, social characteristics of the area, and climatic conditions. Up to date, traditional attention has been given to the water body itself, with spatially consistent parameters. However, it is now obvious that the drainage area should be well defined in all aspects so as to obtain sufficient input data needed in ecological modeling for sustainable management. Definition of the current properties of the region together with the current water quality data would then lead to modeling studies.

The methodology of determining the land based sources of pollution and the water quality to obtain sufficient information on the understanding of the ecology of the area are described in the following parts uing the Köyceğiz Lake- Dalyan Lagoon as an example.

3.1. Description of the Watershed

Köyceğiz Lake-Dalyan Lagoon watershed (Figure 3.1) is located at the southwest of Turkey where the Lake joins the Lagoon and the Lagoon joins the Mediterranean Sea. Part of the area has been declared as Special Protection Area by the Turkish Government in 1988, because it is a unique area and is a good example of an important ecosystem with high diversity of species and of intense biological activity. The watershed covers approximately 1200 km^2 of land including Sülüngür, Alagöl and İztuzu Lakes. The lakes and Dalyan Channel system are utilized for fishery and recrational purposes. The area possesses the beatiful ruins of Ancient city of Caunos and 4^{th} century BC Lycian rock tombs near the seaside. Iztuzu Beach at the Mediterranean coast of the srea is one of the most beatiful beaches of Turkey and is the nesting and breeding ground of Caretta Caretta sea turtles.

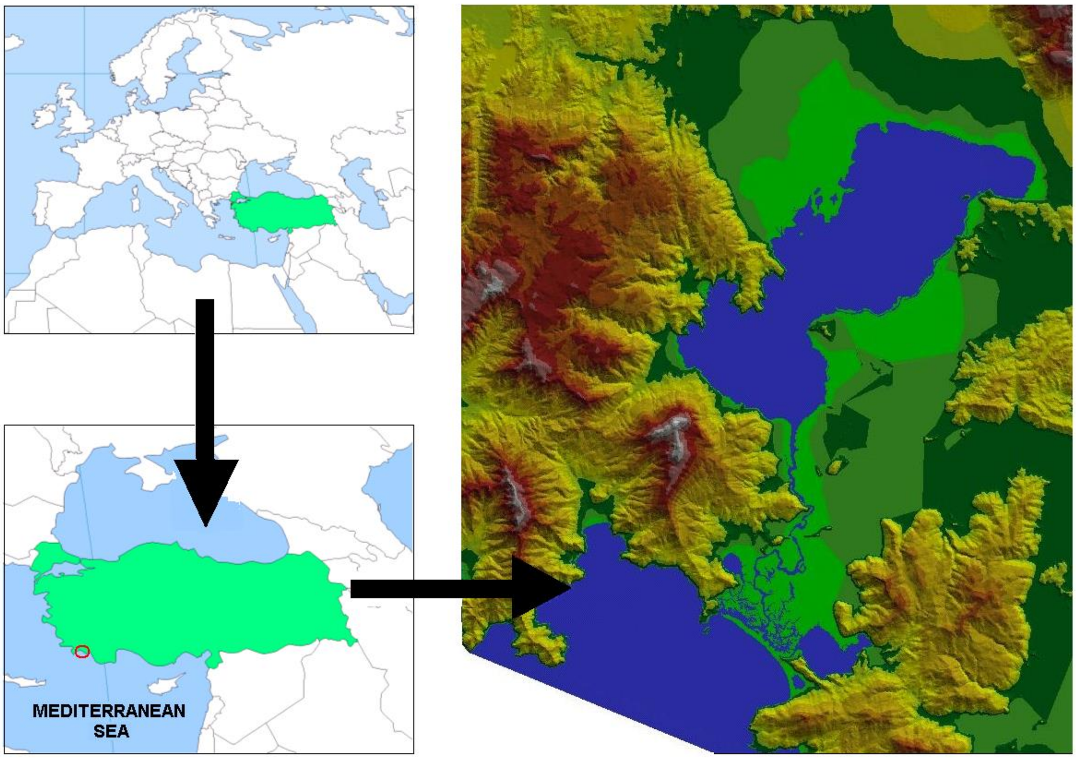

Figure 3.1 Location of the watershed in Turkey and its 3D plan view (Şeker et al. 2002)

3.1.1. Climatic Conditions

Climatic conditions are one of the important external factors of a drainage area, as meteorological data are used in determining the physical, chemical and biological mechanisms and region rates occuring both on land and in water.

The area is characterized by the typical Mediterranean climate. Dry and hot summer season, warm and rainy winter season is the main caharacteristics of the Mediterranean climate. The region is controlled by the terresterial, marine or semi-marine and semi-terresterial low and high pressure systems, but high pressure system is more effective.

The higher average temperature (2-3^{0}C) of the Mediterranean water that constitutes the south border of the watershed, than air temperature together with the properties of the pressure systems are the two dominant factors affecting the climate of the watershed.

Köyceğiz meteorological station is selected as the representative station of the watershed. The annual average temperature (28-year averages) is 18,2^{0}C with an average rational humanity of 4%.

Annual precipitaiton, evaporation and average temperature values of Köyceğiz station for years 1983-2000 are given in Table 3.1.

In Köyceğiz station, the annual average wind speed is 1,3 m/sec for 22-year period. When the number of blowing winds are compared, the maximum value for the wind is found as SSE direction with an annual speed of 2,0 m/sec. On the other hand, the wind with a maximum speed of 2,3 m/sec has a direction of NNE.

Table 3.1 Meteorological Data of Köyceğiz Station for Years 1983-2000 (SMW, 2000)

Years	Annual Precipitation (mm)	Annual Evaporation (mm)	Average Temperature (^{0}C)
1983	1119,6	1115,2	23,15
1984	1027	1412,8	23,88
1985	1007,4	1459,4	24,16
1986	868,7	1396,2	24,21
1987	916,9	1340,2	23,32
1988	1263,6	1360,7	23,79
1989	783,3	1274,2	24,33
1990	685,4	1377,4	24,3
1991	931,4	1274,8	23,46
1992	720,2	1159	23,29
1993	832,7	1217,9	24,37
1994	1421,2	1213,3	24,74
1995	1069,5	1090,5	24,58
1996	1356,8	1330,9	24,42
1997	1123,7	1062,2	23,6
1998	1534,3	1071	24,76
1999	954,3	1085,3	25,2
2000	862,3	1042,2	24,84

3.1.2 Hydrological and Hydrogeological Structure

Köyceğiz Lake, with a surface area of 54,5 km^2, has characteristics of a slightly salty lake. It is fed by various water resources such as; creeks, groundwater, springs and water carried by drainage channels. The main creeks which feeds the Lake are; Namnam, Yuvarlak, Kargıcak, Yangı, Değirmendere, Çamlıdere, Kocaöz and Çakmak.

Namnam is the most important of them with an average flow rate of 10,83 m^3/sec and drainage area of 283 km^2. The Lake has a maximum depth of 30 m. There also exists regional holes up to 70 m.

The Lake is basically fed by groundwater. The hydraulic slope of groundwater is straight to the Köyceğiz Lake, the sea and Dalyan Lagoon. The seasonal gorundwater level variations are 0,5-6,55 m between May and November (Gönenç et al., 2002).

The only outlet of the Lake is the Mediterranean Sea through Dalyan Lagoon. The Lagoon which combines the Lake to the sea has a length of 14 km and depth of 1,5-2 m.

Hydrogeological structure of the watershed is significant in terms of understanding the movement of groundwater and in determining the surface run-off constituents. The characteristics of a system are closely related to the soil properties of land, which is in turn, based on geological structure of the region. Thus, geology and hydrogeology of a region affect water transportation mechanisms and water constituents.

Geological structure of this system permits seawater instrusion to the Dalyan Lagoon system. There also exists hot springs in the region. Sultaniye, Velibey, Çavuş and Kokargirme are the most important ones among them. Sultaniye has a high level of radioactivity.

3.1.3 Flora and Fauna

As the whole watershed is affected by the Mediterranean climate, it has the typical Mediterranean flora. The majority of wetlands are covered with rushes and reeds, whereas the hills are forest zones. *Liquidamber orientalis* forests are in the northwest of Köceğiz Lake, which is peculiar to southwest anatolia and rhodes Island.

The main vegetation cover of the watershed are;

- rushes and reeds that cover the wetlands and marshes, in and around the Köyceğiz Lake and Dalyan Lagoon delta,
- typical Mediterranean scrub vegetation,
- forests.

Almost all the plain or close to plain land is devoted to agriculture, and the main agricultural crops like citrus fruits, cotton, sesame, corn and wheat, and higher regions olive groves enrich the vegetation cover.

Iris xanthospuria, an iris species peculiar to the region, is spreading in the aquatic zones, marshes and *Liquidamber orientalis* forests.

Red pine and *Liquidamber orientalis* are of great importance in the watershed as they are endemic trees in Turkey. There is a *Liquidamber orientalis* forest of 8 ha in the northeast of the Lake, which is under protection.

There is a long dry period due to Mediterranean characteristics, mosses found at the bottom parts of leafy trees and pines are important to keep soil moist.

It is estimated that there are 700 flower plants, needles and fern species in the region; environmentally important species of the region are given in Table 3.2.

Table 3.2 Environmentally Important Flora Species in the Watershed (Seçmen and Leblebici, 1980)

Cistus cretius	*Liquidamber orientalis*
Colchicum	*Lunipus angustifolius*
Cyclemen trochopteranthum	*Pinus brutia*
Erica	*Sternbergia eischeriana*
Hyacinthus orientalis	*Typha sp.*
Iris xanthospuria	

Till now, 180 bird species are observed in the watershed (Buhan, 1998). *Holycon smymensis* and *Cryle rudis* are the two major species among them. *Holycon smymensis* is one of the rare species of birds and its population in Turkey is about 100-150 couples. The watershed is among the 5 regions where 75% of this amount is found intensely. Spread area of *Cryle rudis* is limited in Turkey; it has a population of about 250 couples.

An important bird species *Francolinus francolinus* has not been observed since 1960. the number of species thet breed or has the possibility to breed in the watershed decreases. Some of the water birds spend winter in the region.

The most impotant fauna group is reptiles since almost all the Dalyan Lagoon and its coasts are under protection.

Iztuzu beach is the nesting and breeding area of Caretta caretta sea turtles, which is an endangered species, the beach is among 17 important sea turtle breeding regions of Turkey. According to the studies conducted in the region 5 turtle, 2 frog, 9 snake and 12 mammal species are determined (Gönenç et al. 2002).

Blue crab is an important species due to its economic value. As it consumes dead fish and similar wastes, it prevents bad smell and decy in the environment, ehich is of high importance, in its sensitive region.

3.1.4. Socio-Demographic Structure

Total population of the whole watershed area is 43585 according to 1997 census among which 74 % belong to Köyceğiz Lake drainage area and the rest belongs to Dalyan Lagoon drainage area.

The largest town in the Lagoon drainage area is Dalyan with 3357 habitants according to 1997 census, whereas Köyceğiz is the largest town in the Lake draiage area with 7526 habitants (SIS, 1997).

The population increase in the Lagoon does not reflect a rapid and huge increase like some other regions of Turkey where industrial activities are significant.

As expected, there are no significant industrial activities within the area, which is an important factor promoting high population increase. The economy is mainly based on agriculture, tourism, fishery and forestry.

Totally 7111 ha irrigated or rain-receiving area is spared for agriculture in Köyceğiz. The agricultural activities are similar to other Mediterranean countries based on polyculture; basically cotton, citrus fruits, wheat, corn, pea and horticulture are being cultivated. Land distiribution according to the crops grown is as follows: 2630 ha citrus fruits, approximately 550 ha horticulture, 700 ha greenhouse, 1580 ha olive, 5 ha vine gardens, 20 ha poplar constitutibg area are athe major activities in the area; the rest of the agricultural land is spared for potato, melon, onion and garlic production. 3259 ha land is used for agriculture in Dalyan and product distribution is identical to Köyceğiz.

A cooperative name as Dalyan Fishery Cooperative conducts fishing activities in the region. The cooperative owns a total of 66 wooden boats of variable sizes. Fishing in the Lagoon is done by printer and trammel nets in additon to weirs with total production capasity of around 200 tons/year. Mullet species are of primary importance. Apart from mullets, the other species of impotance are sea bass, cel and crab (Bilecik et al, 1994). Almost 7-8 tons of caviar is produced annually.

3.1.5. Soil Properties

Soil, with its structure, formation and natural/agricultural vegetation is vital for many aspects in watershed management, like ecosystem modelling, watershed hydraulics, land-use and quality characteristics of water bodies. The initial step towards understanding the soil characteristics of the area had been a literature survey, through which results of previous field studies executed by related institutes of the General Directorate of Rural Affairs of the Turkish Republic (TRGDRA) have been acquired. These data, which are assembled over central administrative segments namely Ula, Köyceğiz and Ortaca, provided preliminary information on the spatial distribution of soil structure. A summary of this data is presented in Table 3.3.

Land use distribution of a watershed is an important aspect as it widely affects the calculation of land-based sources of pollutants arising from various land types and activities. The current land use of the Dalyan Lagoon subwatershed is given in Table 3.4.

Table 3.3 Sub-provinces and Characteristic Major Soil Types (Büyükbay, 2002)

Major Soil Types	Köyceğiz		Ortaca		Ula		Total	
	ha	%	ha	%	ha	%	ha	%
Alluvial Soils	4133	2.62	10141	35.7	1787	4.2	16061	7.0
Hydromorphic Alluvial Soils	1100	0.7	1194	4.2	162	0.38	2456	1.0
Collivual Soils	8610	5.30	1147	4.0	5017	11.7	14774	6.3
Wetlands	50	0.03	-	-	-	-	50	0.02
Brown Forest Soils without Lime	113401	70.3	4952	17.4	13916	32.6	132269	57
Red Brown Mediterranean Soils	23380	14.50	10402	36.6	20628	48.3	54410	23.4
Red Mediterranean Soils	-	-	-	-	432	1.0	432	0.2
Other Soils	4803	3.55	123	0.4	726	1.7	5652	2.4
Water Bodies	5723		471	1.6	58	0.1	6252	2.7
Total	***161200***	***100***	***28430***	***100***	***42726***	***100***	***232356***	***100***

Table 3.4 Current Land Use of the Dalyan Lagoon Subwatershed (Gönenç et al., 2002)

Land use	Area (km²)	% distribution
Forests	80,93	62,55
Agriculture	29,7	22,95
Wetlands	6,56	5,07
Sülüngür Lake	3,01	2,33
Alagöl Lake	0,55	0,43
İztuzu Lake	0,19	0,15
Dalyan Lagoon	2,5	1,93
Others (historical places & springs)	5,94	4,59
Total	***129,38***	***100***

As the towns and small communities of the subwtareshed are scattered in agricultural lands, they cannot be shown seperately. As a result, forests and agricultural land cover approximately 85 % of the area. In the previous studies conducted at the region, emphasis has been given to the Dalyan subwatershed. In this study, the whole watershed is considered and more detailed information flow about land-use and its distribution will be mentioned in the preceeding sections.

3.1.6. Land Based Sources of Pollution

Due to lack of industries in the area, domestic wastewater is considered to be the only source of point pollutant. Almost all of the sensitive watersheds in the world, as seen in this area, are not observed as highly populated and urbanized districts. Tourism and agricultural activities gain significance which necessitates the detailed investigation of non-point sources of pollution with utmost care of especially the nutrient discharges to the water environment. Among these effects, excess nutrient and pesticide loading originating from agricultural activities is of major concern.

The occurrence of reactions and their rates concerning the excess loads depend on the main transportation and transport mechanisms of nutrients on soil till they reach the water environment. In the previous studies (Karak, 2000; Güvensoy, 2000; Tanık et al., 2000), efforts are paid to the identification of excess loads, and furthermore to the estimation of the surplus nutrients that may enter the receiving water.

A detailed survey on forests has not been carried out yet, as the mechanisms are too complex in these systems. Unit polluting loads are selected from relevant literature, to represent and reflect similar climatic conditions and forestry regarding the two nutrients, nitrogen and phosphorous. All the previous studies on land based source pollution, have been based on the Dalyan Lagoon Subwatershed.

3.2. Resource Inventory

The methodology used to build the resource inventory, requires that data should be gathered over a topographical base map and that, thematic maps should be used to indicate hydrodynamics of aquatic environment, geologic and geomorphologic conditions, vegetation and land-use, socio-economic data like administrative boundaries and population, soil structure involving soil classes, soil types, sub-soil groups and other characteristics, and finally climatic and meteorological data being the most important external factor that affects the fate and behaviour of the watershed.

To manage such resources in an integrated and effective manner, it is essential that detailed information regarding the nature, quantity and quality of these resources be available. The collection and presentation of such information, is the purpose of resource inventory activities.

3.2.1. Data Collection

Data collection comprises mainly of processing elevation data, acquiring digital thematic maps, and delineation of watershed boundaries. The elevation data which has a scale of 1:25 000, is taken from the Turkish Armed Forces General Command of Mapping (TAFGCM), which had developed these digital maps using photogrammetry techniques. Most of the data mentioned above, which are crucial for land assessment and hydrological modelling (Seker et al., 2002), are provided within the thematic maps received from the National Information Centre (NIC) of the General Directorate of Rural Affairs of the Turkish Republic (TRGDRA). These maps are based on UTM (Universal Transverse Mercator) coordinate system.

The layer for watershed boundaries was initially delineated on an analogue map. In the study, this analogue map was digitized and furthermore, the produced digital map was then verified via Watershed Modelling System 6.1 (WMS) developed by US Army and Brigham Young University, UK (Akbulut, 2002). This software with extensive capabilities for watershed delineation and runoff modelling, better suits for applications in small watersheds and accomplishes its process at quite a high accuracy.

However, in order to base the inputs of the modeling study on more realistic grounds, several field visits were made in order to assess the validty of information provided via these maps.

3.2.2. Gathering of Data

Gathering of data consists of three steps. The overall flow diagram of the GIS methodology is given in Figure 3.5 (Ripple, 1994). Step 1 involves the integration, manipulation and transformation of elevation data, sub-basin boundaries and coastlines. Since the significance of storing updated environmental data in a reliable and user-friendly platform, became inevitable, ArcGIS was preferred for this purpose because of its solely complete and integrated system for geographical data creation, management, integration and analysis. Thus within Step 2, the data developed in the precedent step are then converted to ArcGIS file format. Finally, in order to enable queries via the GIS environment, in Step 3, attribute tables are prepared for all map layers.

- Step 1

The elevation data is digitized with a photogrammetric technique (Figure 3.2). Lake and Lagoon catchment boundries are drawn in AutoCAD 2000 and then combined. As a result, one coverage, showing the overall watershed boundries, were produced. On this coverage the coastlines are also drawn with contours. AutoCAD 2000 file format is used as an interval step for passing into ArcGIS file format.

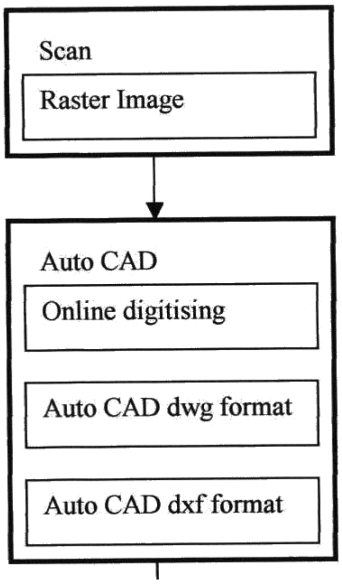

Figure 3.2 First step of GIS methodology (Ripple, 1994)

- Step 2

The data developed in the precedent step are converted to ArcGIS file format (Figure 3.3). The langtitute and longtitute values of the villages in the watershed were gathered from General Command of Mapping and recorded in ArcGIS

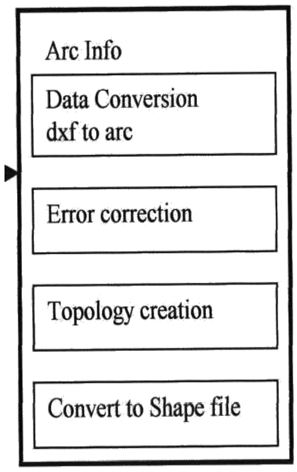

Figure 3.3 Second step of GIS methodology (Ripple, 1994)

- Step 3

Finally, in order to enable queries via the GIS environment, in Step 3, attribute tables are prepared for all map layers (Figure 3.4).

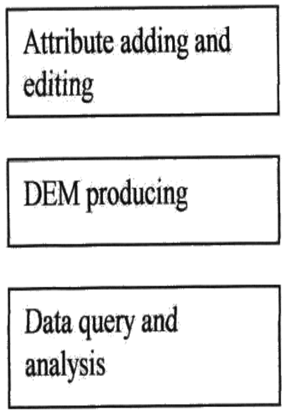

Figure 3.4 Third step of GIS methodology (Ripple, 1994)

The overall flow diagram of the GIS methodology used in the study is given in Figure 3.5.

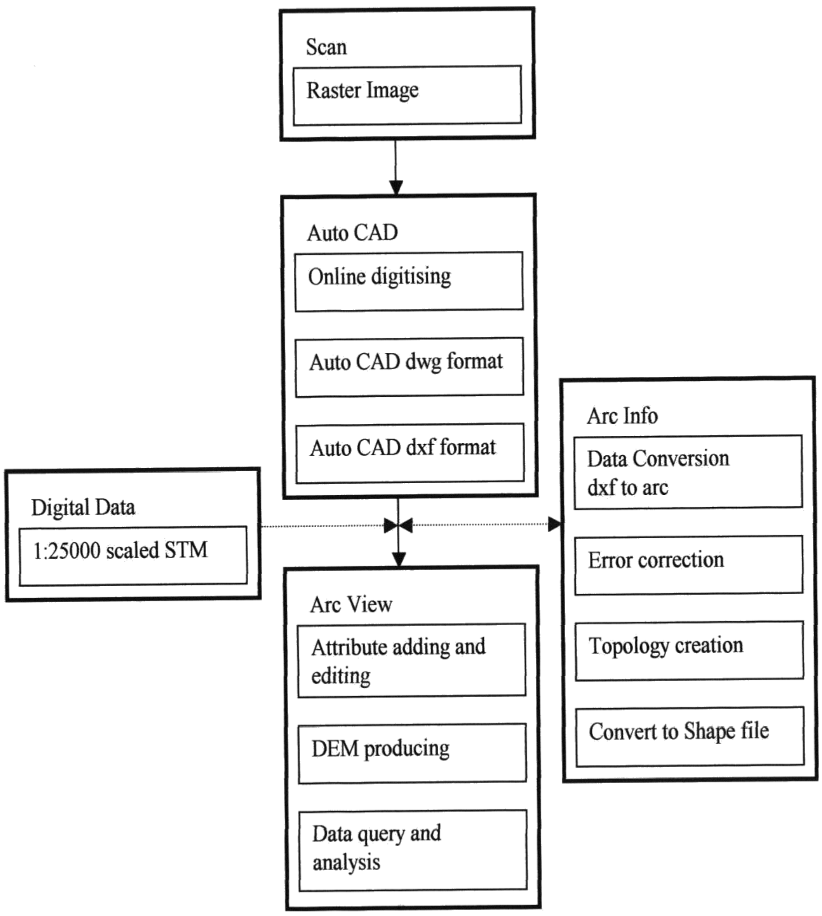

Figure 3.5 Overall Flow Diagram of GIS Methodology (Ripple, 1994)

3.2.3 Mapping and Visualization

The output of the mapping and visualization process on the watershed and its sub-basins is presented in Figure 3.6. Even though the vast majority of the entire watershed was covered, some portion of the area could not be visualized, partly due to the lack of funding and technical problems aroused during integration of data and partly due to military confidentiality.

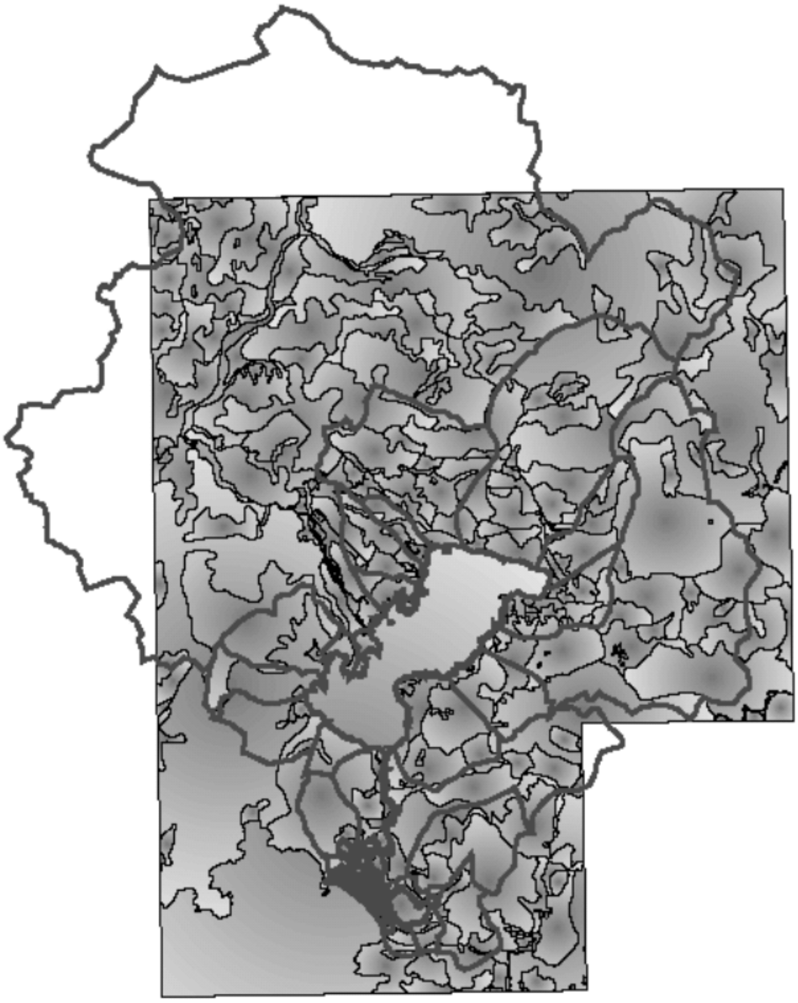

Figure 3.6 Mapping and Visualization of the Watershed

The gathering of resource inventory initiated with the topography of the watershed, shown in Figure 3.7. This layer is important in determining the appropriate irrigation method and efficiency, run-off characteristics as well as erosion and flood risks.

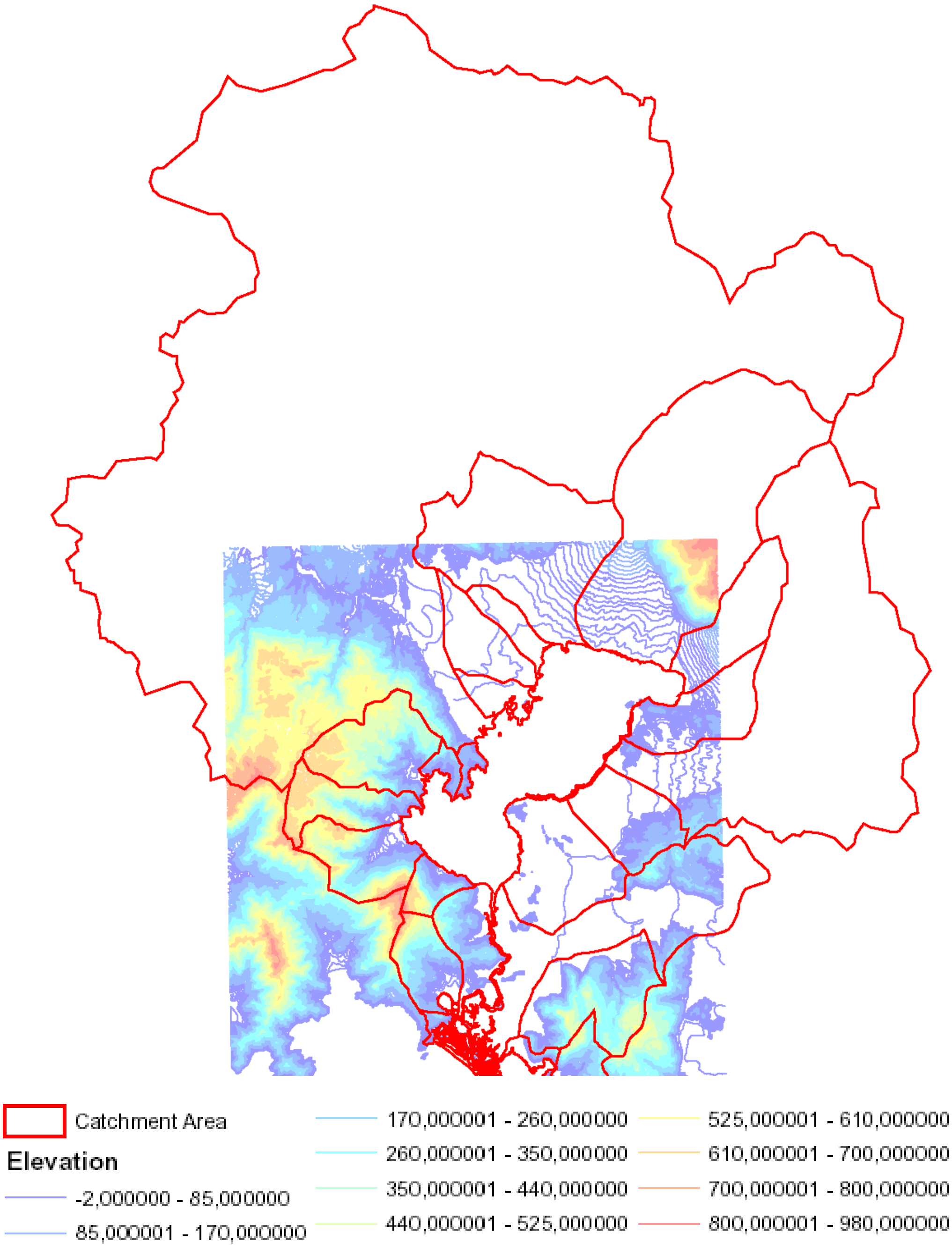

Figure 3.7 Topography map layer

Climatic and meteorological data layer, shown in Figure 3.8, is significant, as these aspects drive irrigated agriculture. This layer also supplies information on soil-water balance, erosion risk and limiting conditions for plantation. The data sets for precipitation, evaporation, air and soil temperature, and humidity are required by almost every study related to watershed modelling, planning and management application, whereas more specific data such as wind speed and direction, cloudiness, and solar radiation, would be necessary for discharge plume modelling, agricultural practices, and plankton growth, respectively.

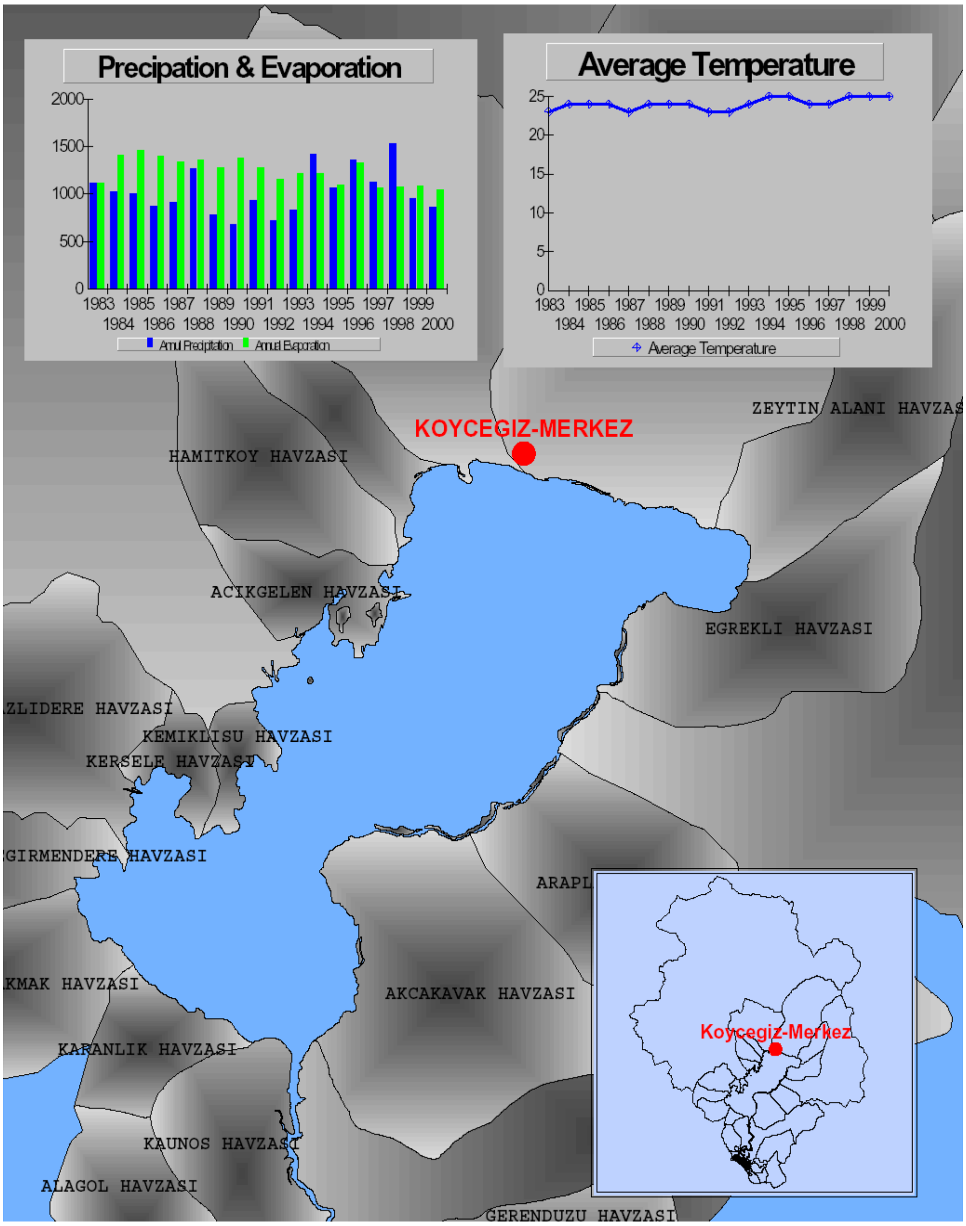

Figure 3.8 Climatic and Meteorological Data Layer

Natural monuments and human-made infrastructure characteristics of the watershed must also be known to better understand the land and water properties. Such a survey will act as a guide during development of a management strategy. One of these layers presents the rivers and streams in the watershed (Appendix A), which was received from TRGDRA-NC and originally produced by the State Hydraulic Works of Turkish Republic (TRSHW). The map has a scale of 1:100000 and is delimited by the administrative boundaries of Mugla, the province in which the entirety of the watershed resides. The major earthquake history and the significant mining zones of the area are similarly provided in province-based thematic maps (Appendix B and Appendix C). Both maps are gained from the General Directorate of Mineral Research and Exploration of the Turkish Republic (TRGDMRE). The hot springs, which are characteristic to the watershed, are introduced to the GIS database as point data as shown in Figure 3.9. They are aligned alongside the Lagoon within a close distance to its banks. Seawater intrusion to the Lagoon occurs seasonally due to its hydrodynamic characteristics; therefore the location of the springs is important (Gurel, 2000; Erturk, 2002).

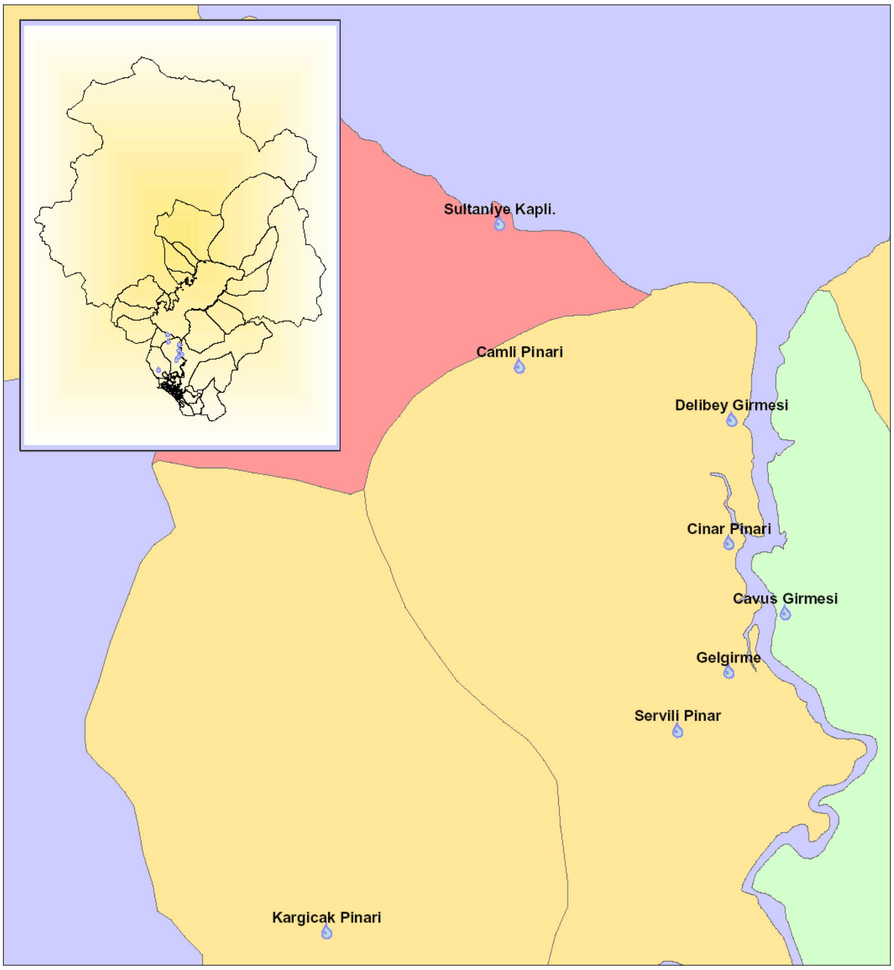

Figure 3.9 Hot springs map layer

The road map of Mugla is also added to the GIS database (Appendix D). If it is regarded necessary to develop a new land-use plan due to a detailed survey on the watershed, road maps would be considerable because of their significance to human-driven functions.

The socio-demographic data is another layer that shows the current status of population distribution in the watershed. There exist no populated cities in the watershed, but two larger towns, Koycegiz and Dalyan. Almost 75% of the population resides in the Koycegiz Lake sub-basin, whereas the rest lives in the Dalyan Lagoon sub-basin.

Villages and other settlements in the region are widely scattered across available agricultural land covers and are provided in a separate layer as shown in Figure 3.10 and Figure 3.11. The coordinates of villages are obtained from the TAFGCM and then transformed to UTM Coordinate System so as to integrate this layer with the rest of thematic maps.

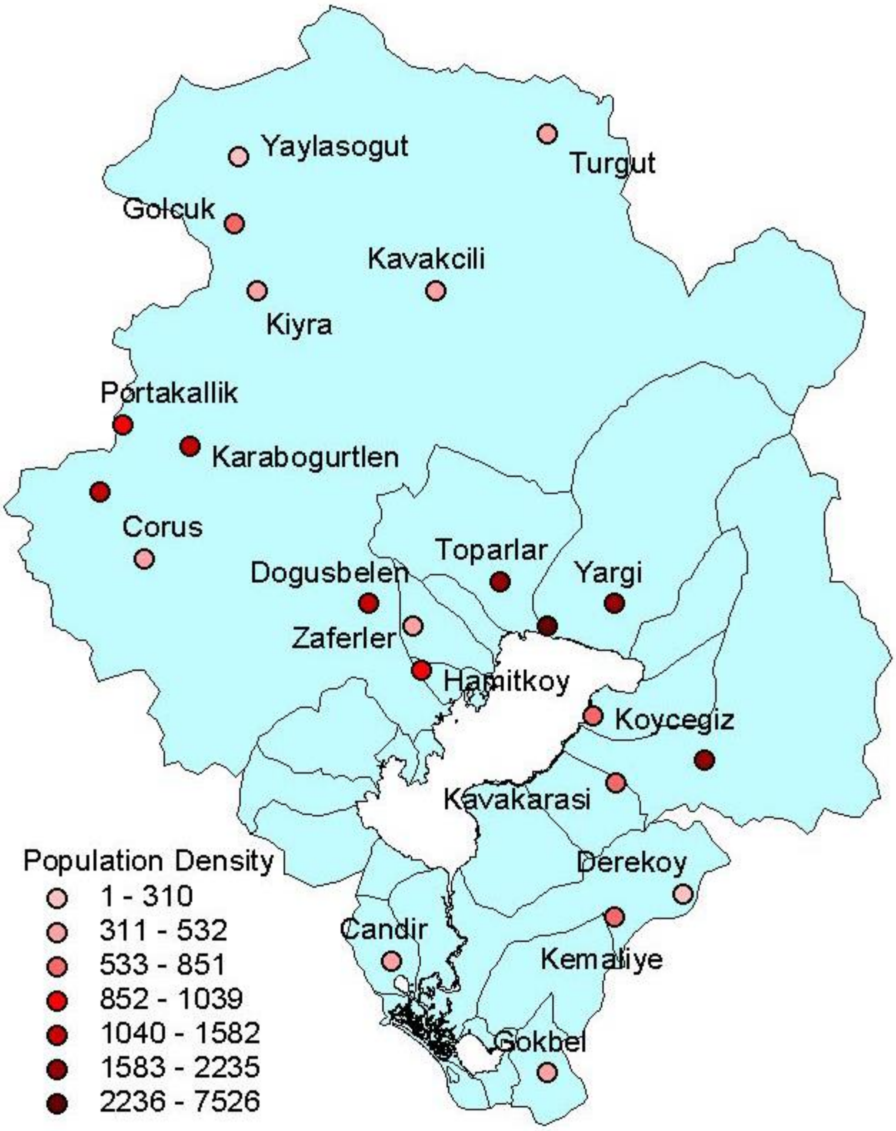

Figure 3.10 Villages of the watershed

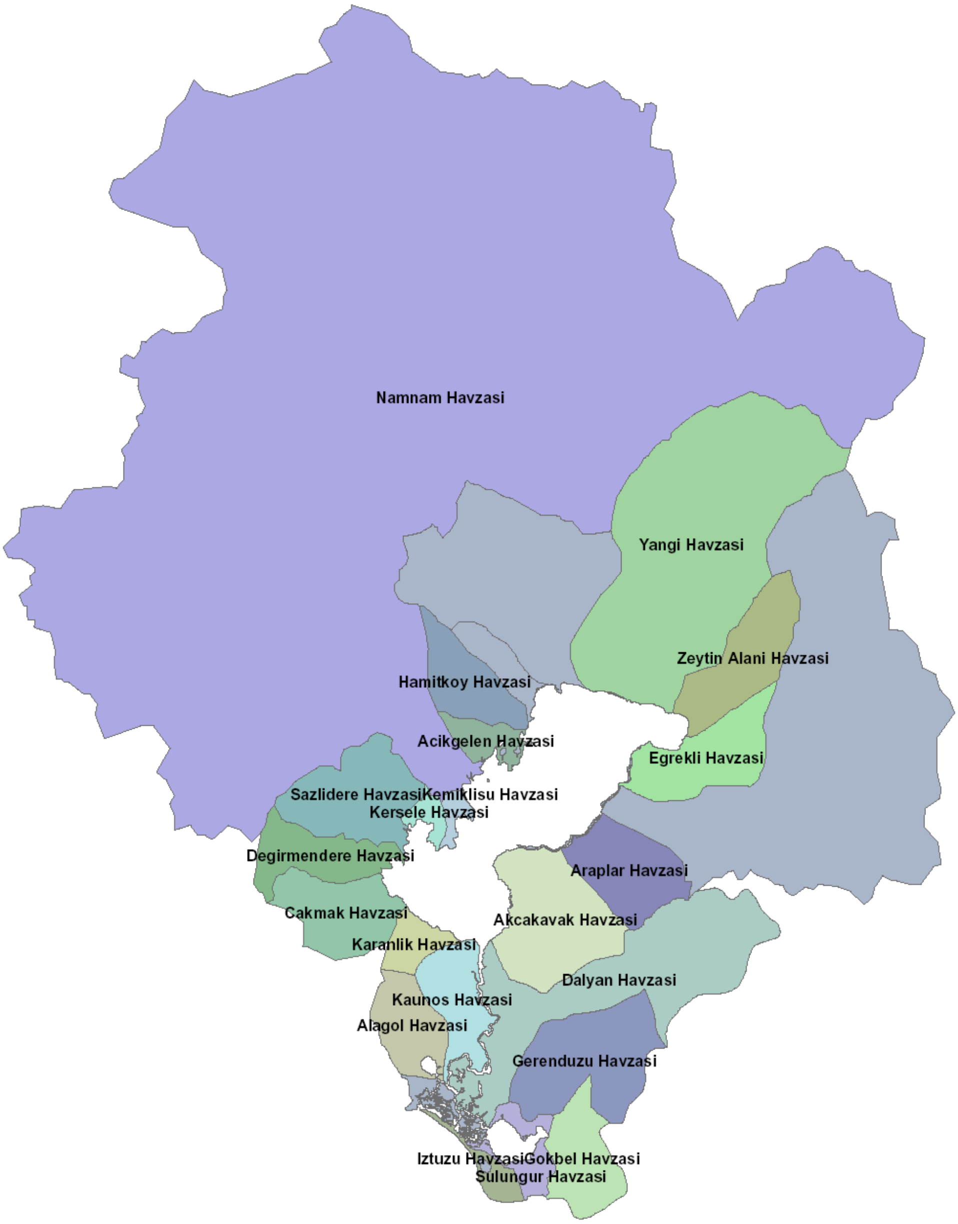

Figure 3.11 Sub-catchments of the watershed

As forests and agricultural areas cover nearly 85 % of the total area, non-point source pollutant loads are very significant in the watershed. No detailed investigation on the forest areas has been conducted so far, however, fertilizers and pesticides applications are examined annually on monthly intervals for the year 1998 (Karak, 2000; Guvensoy, 2000). This information is gathered from each agricultural village authority in the watershed and numerically introduced into the GIS as point data attributed to each village. The nutrient loadings arising from agricultural areas are recorded in tabular format and presented in charts for each village. These attribute tables provide calculated figures for residual monthly loads after the reduction by crop uptake and other various reactions are also presented on village basis.

15 of the most significant pesticides applied in the watershed are also listed in the GIS together with the basic physical, chemical and biological characteristics of each. In Figure 3.12, the endosulfan consumption of the watershed can be seen in the basis of villages, as an example.

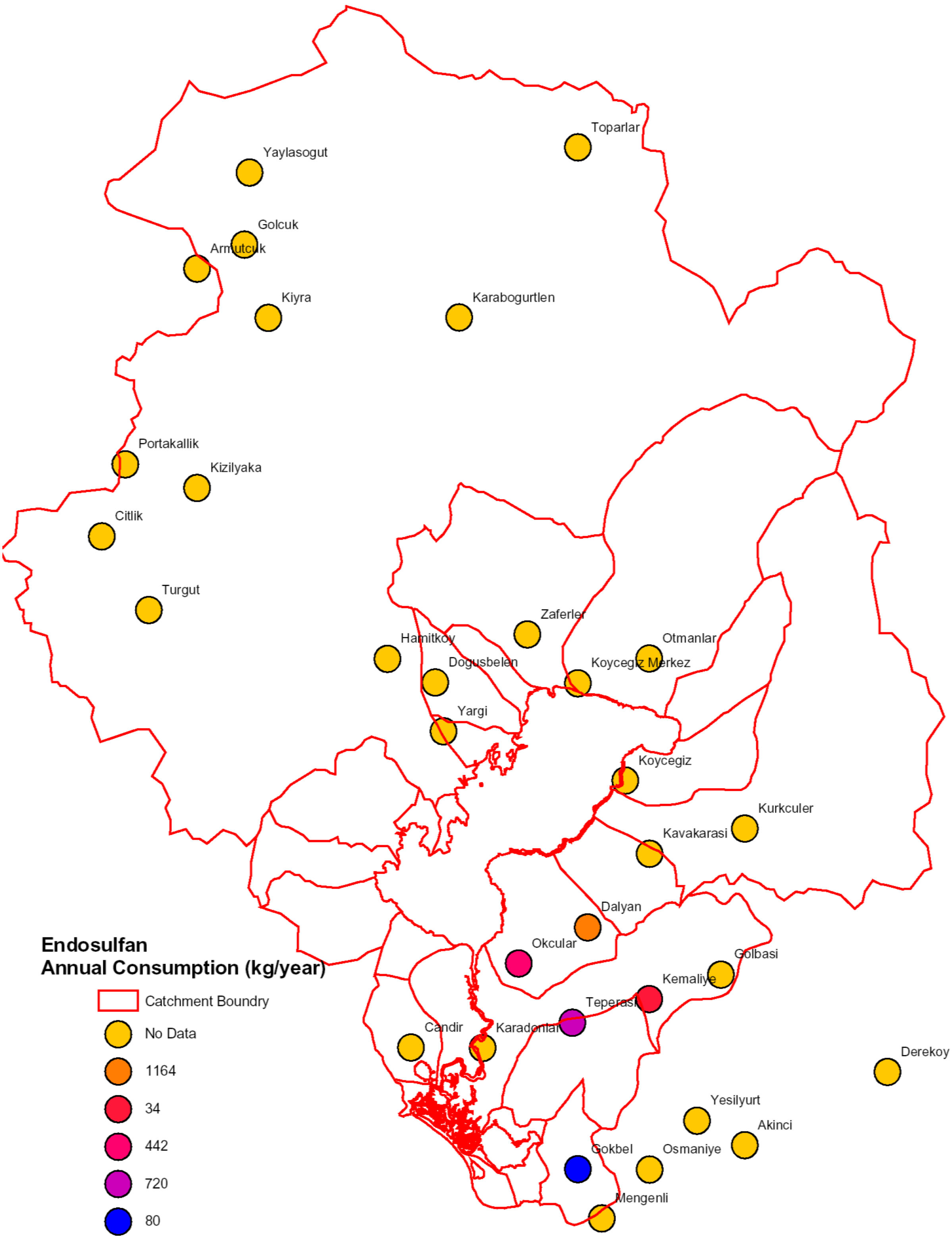

Figure 3.12 Land-based pollution

3.3 Implementation Of Soil Survey

The purposes for which land evaluation surveys are undertaken and the techniques used for this purpose vary widely according to national or local requirements. At watershed scale, such surveys are conducted in developing countries as a basis for major land-use change. In this study, an alternative approach is aimed for the assessment of not only the capability of land for various land-use purposes, but also of the suitability of land for specific land-use purposes. This approach used in developing countries is also appropriate for watershed management applications (ESCAP, 1997). Soil surveys are mainly used to analyze soil fertility, drainage and erosion conditions, and irrigation and fertilization requirements. In this study, land capability classification, soil types, soil sub-groups, land-use and other soil characteristics are studied and presented via different thematic maps.

Land capability classification is a method of land evaluation, which indicates the specified potential use of land. Such classification is usually presented as a thematic map with standard legends for land capability classes. There are eight standard major classes (I to VIII) universally accepted, ranking land-use potential on a "best" (I) to "worst" (VIII) basis for specified categories of agricultural uses. The land classification map for the watershed is shown in Figure 3.13. All the referred classes may be observed in the area. Class I indicates land suitable for regular cultivation where no special conservation measures are necessary, Class II refers to land suitable for regular cultivation requiring simple soil conservation measures, Class III states the land suitable for regular cultivation requiring intensive soil conservation measures, Class IV addresses land suitable for grazing and occasional cultivation requiring some erosion control measures, Class V points out land suitable for grazing and occasional cultivation requiring intensive soil conservation works, Class VI reflects land suitable for only grazing, Class VII presents land that is steep, infertile, or has shallow soils, and finally Class VIII describes land which should not be cultivated, and grazed (Frevert et al., 1993). Within each of these classes, sub-classes may also be used to indicate the nature of the land-use constraints. United States Department of Agriculture (USDA), uses the following sub-class categories; e: erosion hazard, w: excess water problems, s: soil root zone limitations (such as shallowness and stoniness), and c: climatic constraints. Figure 3.14 presents the international soil sub-groups classification standard used in this study.

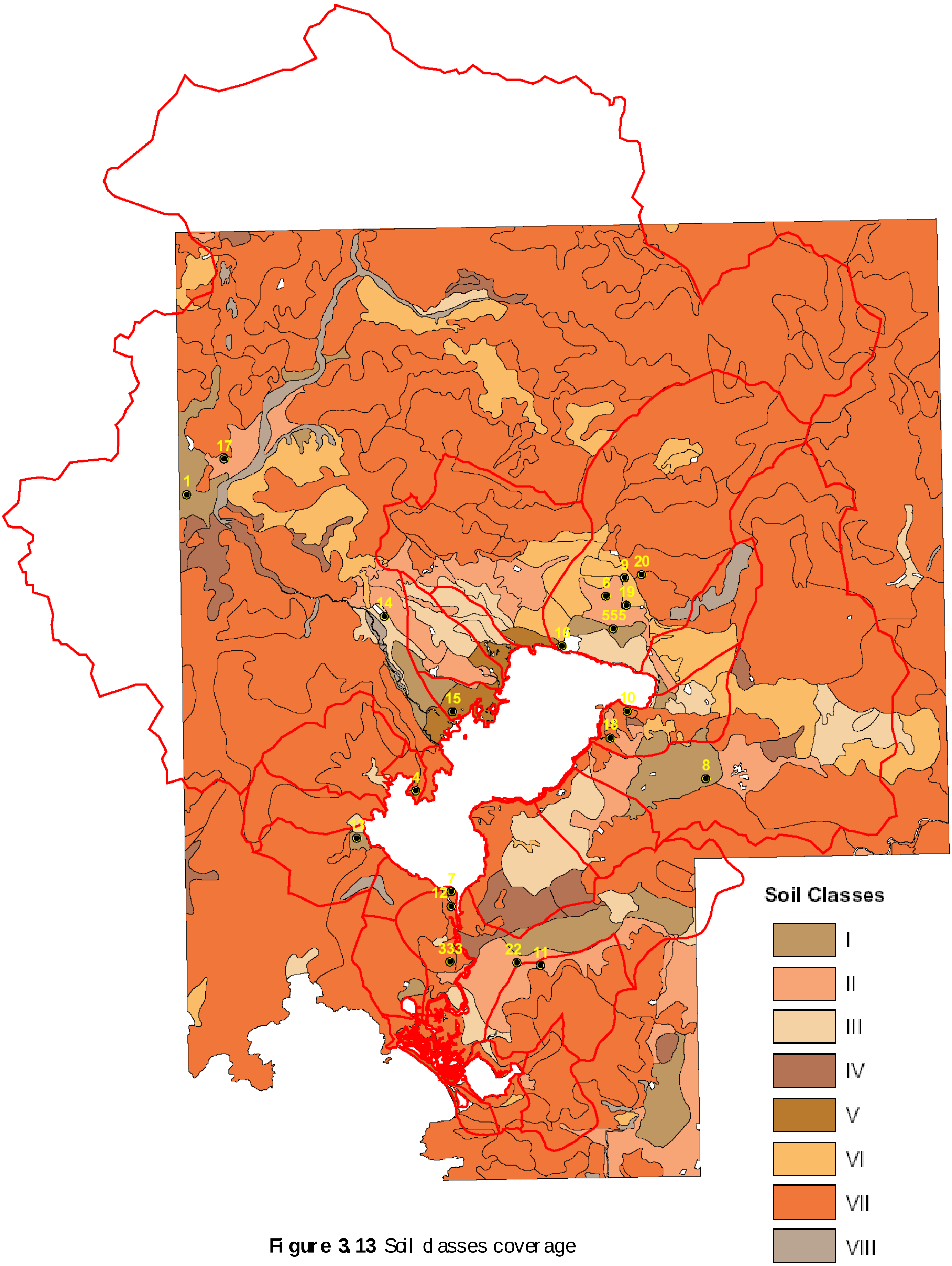

Figure 3.13 Soil classes coverage

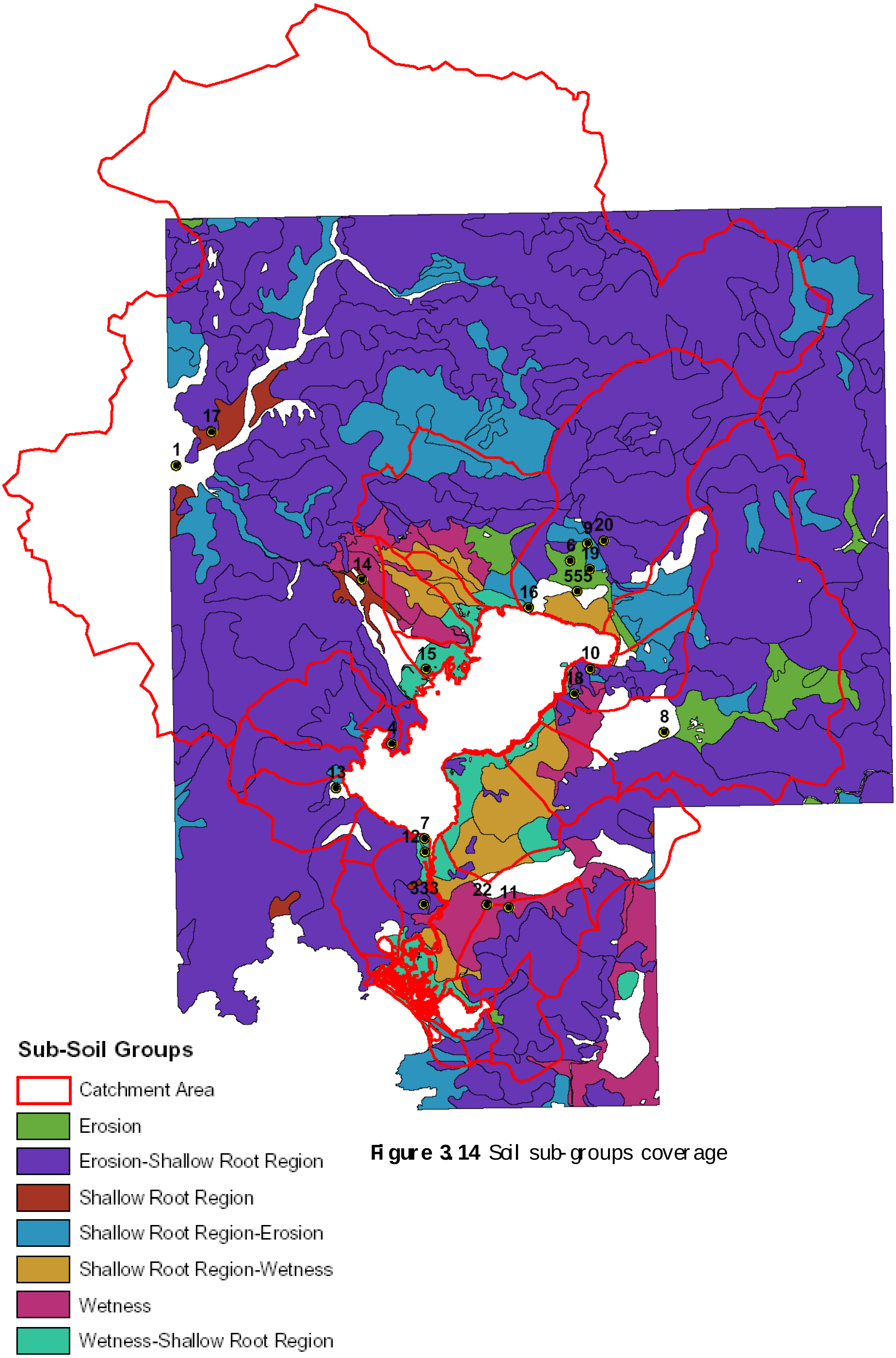

Figure 3.14 Soil sub-groups coverage

Soil types of the watershed are provided as a separate layer in the GIS, as shown in Figure 3.15. Lime-free brown soils are dominant in the area. This soil type is characterized by its high clay content and sometimes by stony clay texture with pebbles. The dominant plantation on such soil type is grass and bushes.

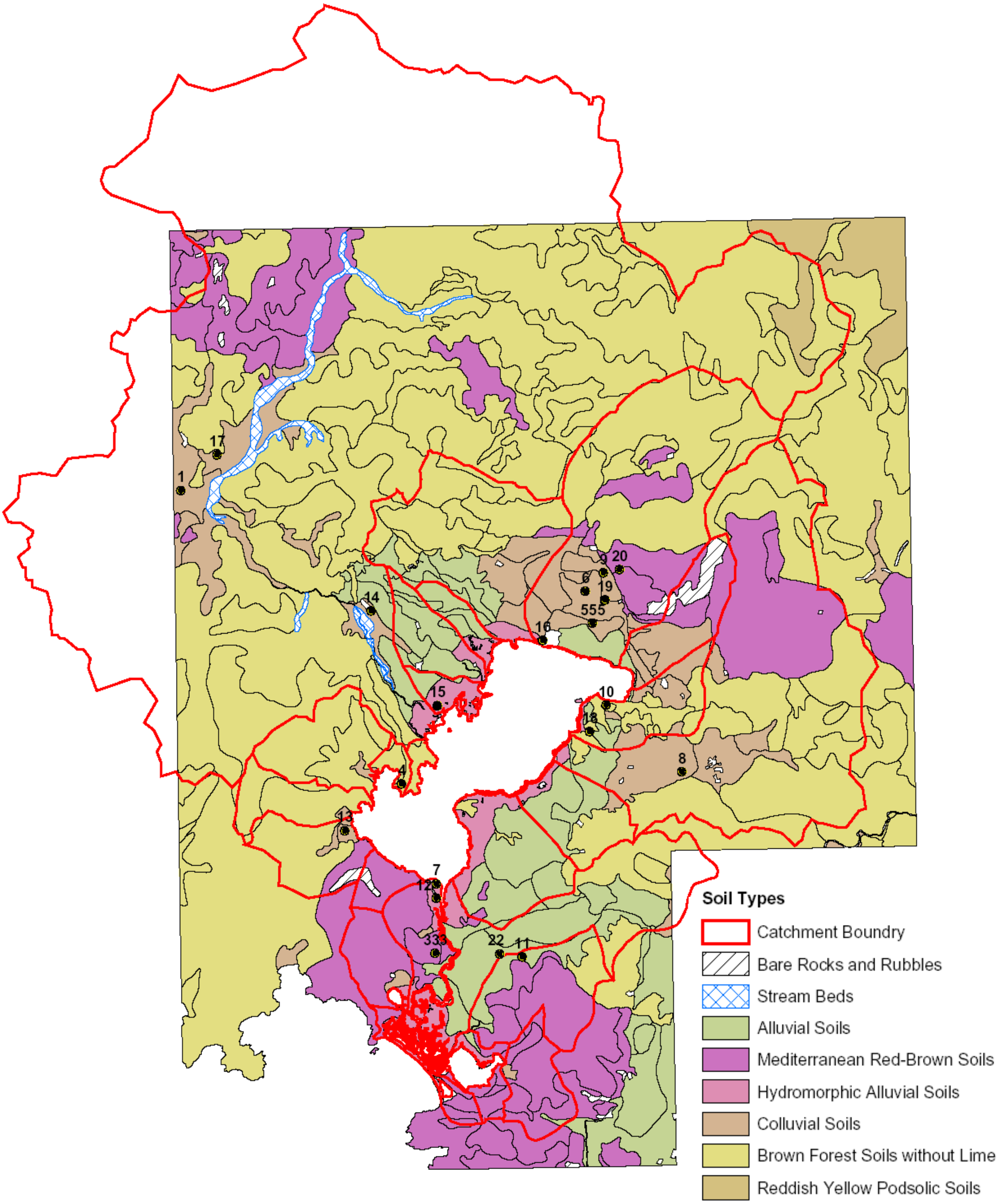

Figure 3.15 Soil types coverage

The second major type of soil in the watershed is Mediterranean red-brown soils, which are typically observed within regions with dry climate conditions. The red-brown soils are mainly composed of hard limestone, granites, and rocks.

Other soil characteristics, such as soil drainage, soil salinity and soil alkalinity, are demonstrated in Figure 3.16. Soil drainage is defined as the rate and extent of water movement in the soil, including movement across the surface as well as downward through the soil. Slope is a very important factor in soil drainage. Other factors include texture, structure, and physical condition of surface and subsoil layers. Soil drainage is indicated by soil color. Clear, bright soil colours indicate well-drained soils. Mixed, drab, and dominantly gray soil colours indicate poor drainage.

Soil salinity is expressed as the concentration of soluable salts in the soil. Soil salinity can, to some degree, be managed by irrigation practices providing the water is of acceptable quality and the flow of water through the soil can be controlled.

The concentration of soluble salts in the soil profile is increased as water is removed from the soil via evaporation and transpiration. Simply explained, soil surface desiccation by evaporation and transpiration creates a suction gradient that produces an important upward movement of water and salt. In soils where the water table is near the soil surface this process can become exaggerated.

Soluble salts increase or decrease in the plant root zone, depending upon whether or not the net downward movement of salt is less or greater than the net salt input from the irrigation water source. The salt balance in the soil as affected by the quantity and quality of the irrigation water, the effectiveness of drainage and leaching, which are the keys to managing saline or alkaline soils.

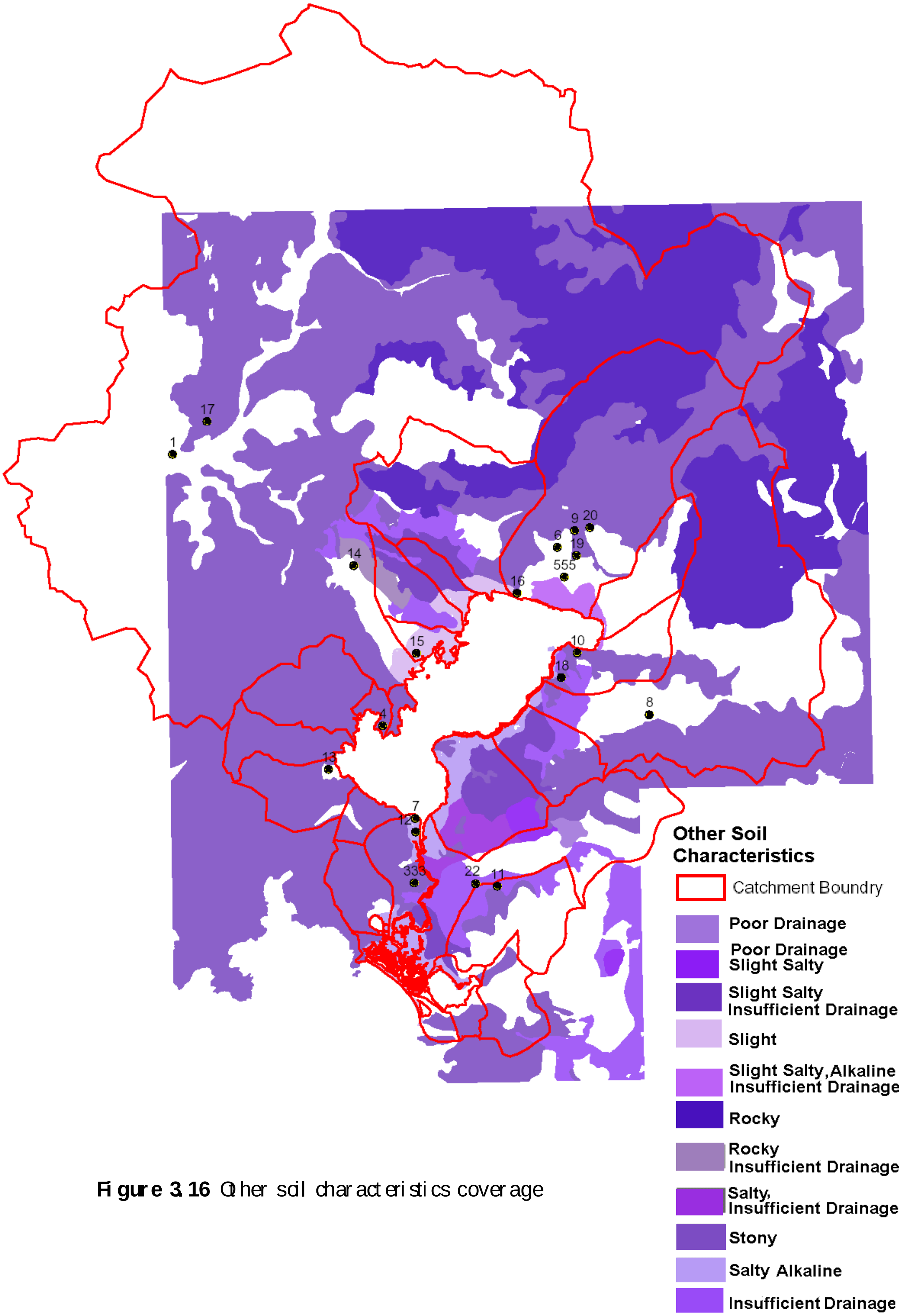

Figure 3.16 Other soil characteristics coverage

The pH condition of soil is one of a number of environmental conditions that affect the quality of plant growth. A near-neutral or slightly acidic soil is generally considered ideal for most plants. Some types of plant growth can occur anywhere in a 3.5 to 10.0 range. With some notable exceptions, a soil pH of 6.0 to 7.0 requires no special cultural practices to improve plant growth.

The major impact that pH extremes have on plant growth is the availability of plant nutrients and concentration of plant-toxic minerals. The effect of pH on plant nutrient availability is shown in Figure 3.17 (The University of Arizona, http://ag.arizona.edu/pubs/garden/mg/soils/pH.html#pH).

In the figure, the thicker bar means more availability of the nutrient. In highly alkaline soils, micronutrients such as iron, zinc, copper and manganese become chemically tied up and are sparingly available for plant use. In highly acidic soils, calcium, phosphorous, and magnesium become tied up and unavailable, and manganese and aluminum can reach toxic levels.

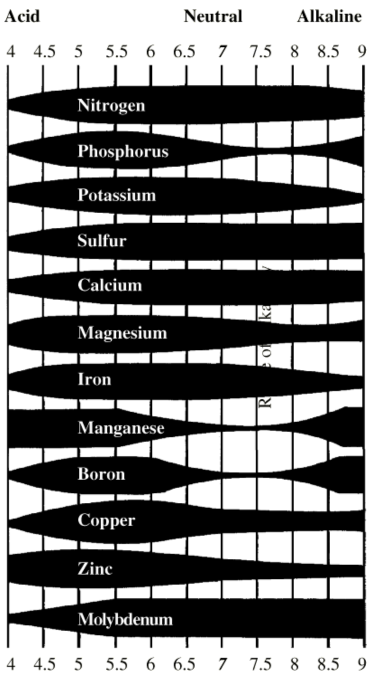

Figure 3.17 The effect of pH on plant nutrient availability
(The University of Arizona, http://ag.arizona.edu/pubs/garden/mg/soils/pH.html#pH)

Since the land-based pollutant loads may drastically vary with respect to recent land-use and its distribution, shown in Figure 3.18, as well as the variety of soil types, a comparison of soil types and land-use is made in the study by overlaying the two maps as shown in Figure 3.19.

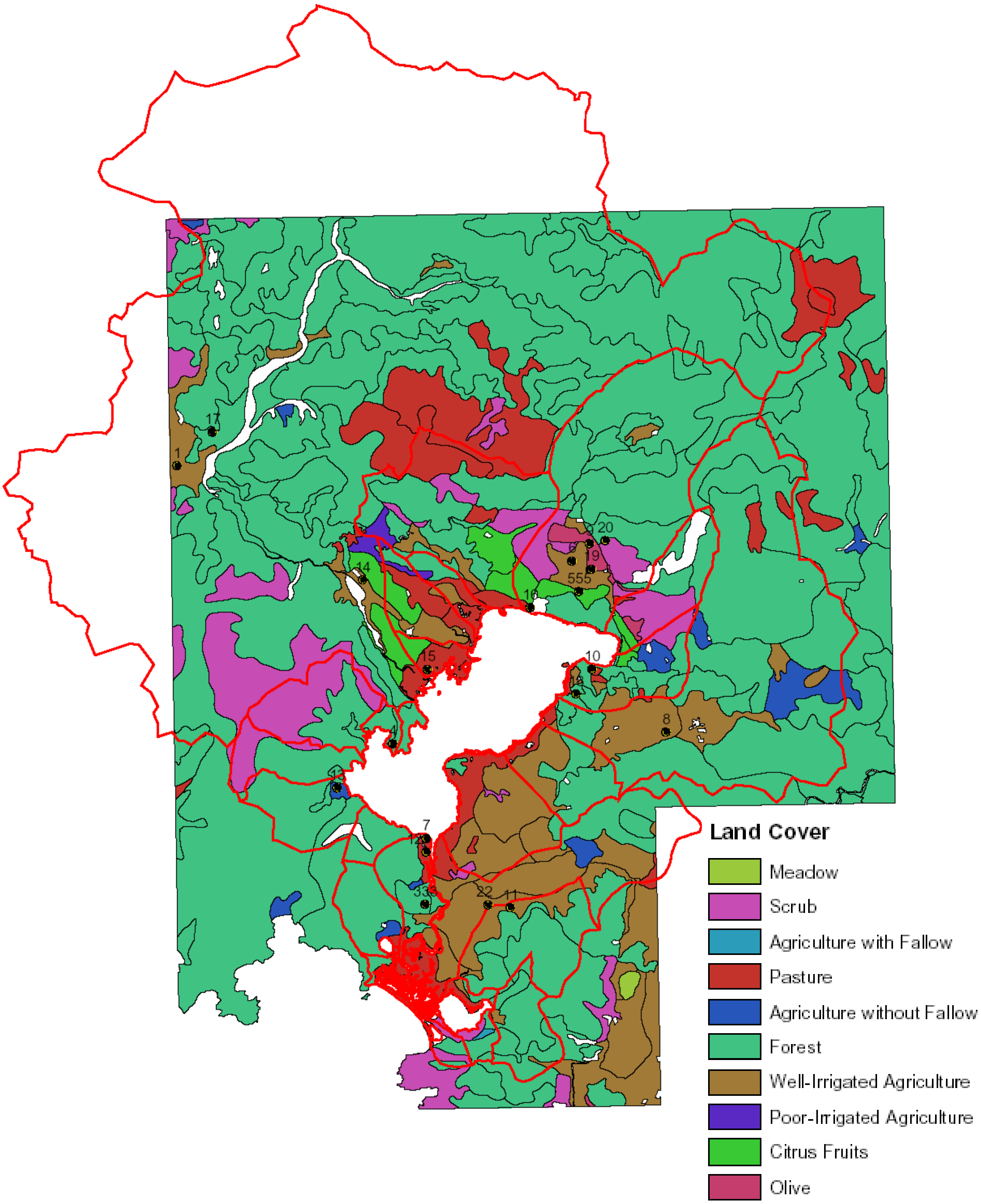

Figure 3.18 Land cover and its distribution

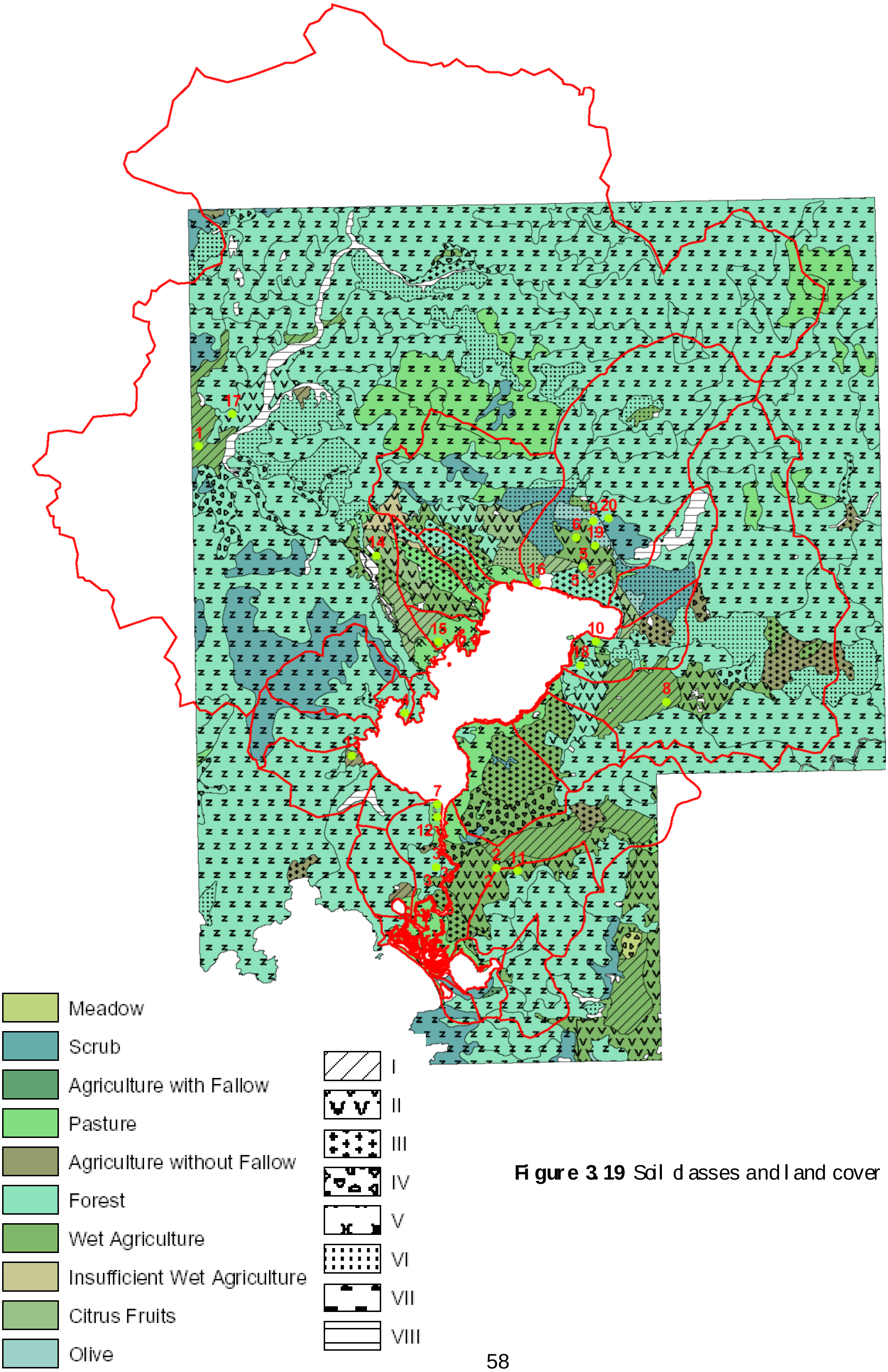

Figure 3.19 Soil classes and land cover

3.4 Land Assessment of the Watershed

3.4.1. Validation of Data

Mapping and visualization stage must be supported by field analysis in order to validate the gathered data including soil maps, as well as to determine more information on the physical and chemical properties of soil. Thereby, such additional data, apart from enabling a better land evaluation, could be utilized as input data, for instance, hydrological modelling studies. The number of sampling stations required for this purpose, are optimized so as to minimize the costs but to attain a broad representation of the watershed. This optimization was achieved by overlaying the five soil maps referred. As a result of theoretical study on superimposed maps and site visits, 20 representative sampling points were then defined and located as indicated in Figure 3.20.

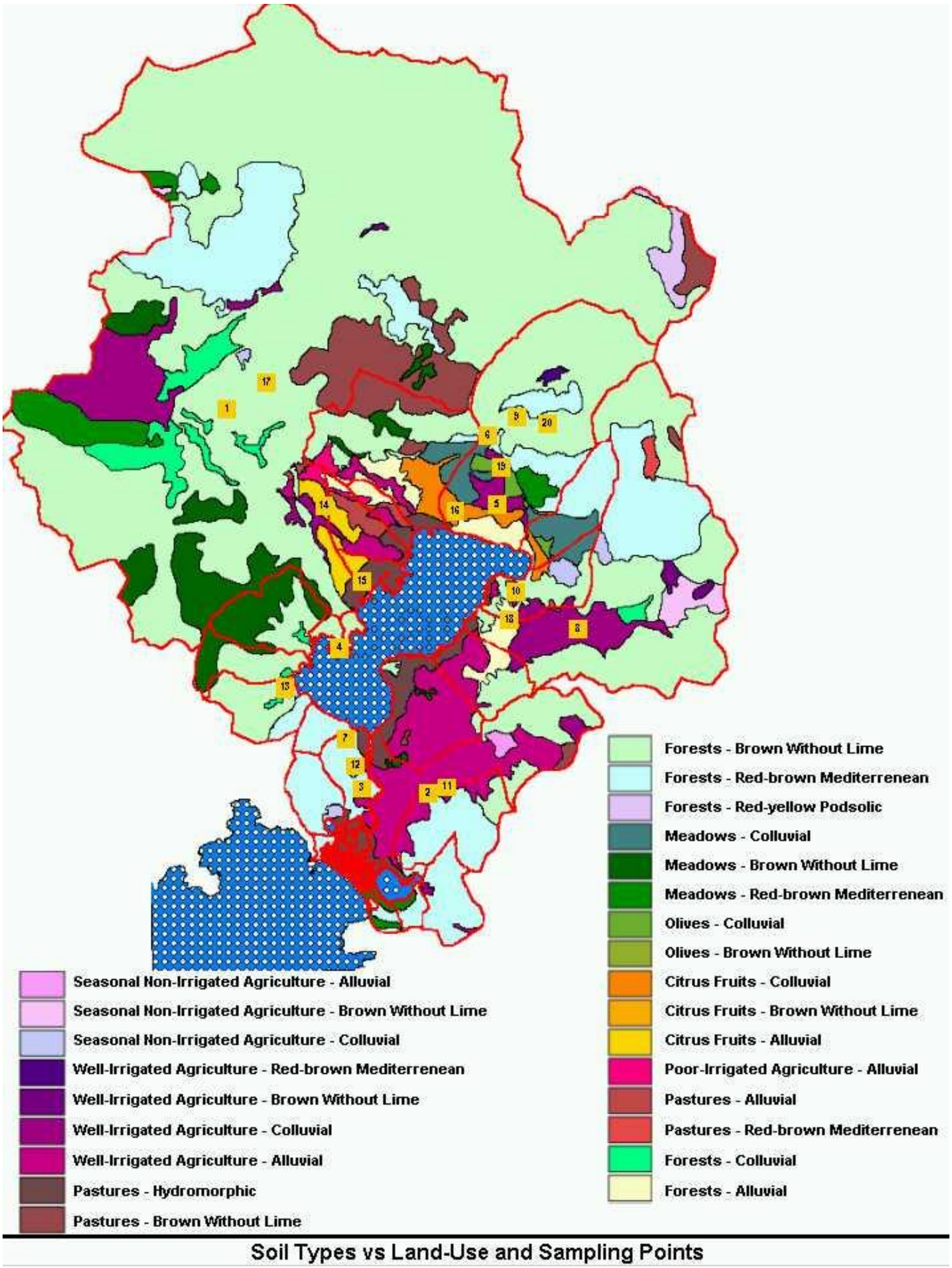

Figure 3.20 Soil Types vs Land-Use and Sampling Points

3.4.2. Land Evaluation

"Land Data Evaluation Table" is prepared by overlaying the five soil maps and further queries are done based on the reference stations. Such an approach is a process for assessing the relative suitability of indicated areas of land for actual land uses. However, it should always be considered in order to achieve a proper land assessment it is utterly vital to maintain thematic maps that are up-to-date and authenticated by field investigations and a representatively fine resolution soil monitoring system. Thus, the comparative analysis initiated in this study and summarized in Table 3.5, should be interpreted as a guideline towards a complete land assessment procedure. On the other hand, the information provided in Table 3.5 is still a good example for how the land-based information should be gathered to develop a strong basis for rational decision-making regarding the best land uses for the area under investigation.

Table 3.5 Land Evaluation Table

Sampling Points	Soil Classes	Soil Types	Land Cover	Sub-soil Groups	Other Soil Characteristics	Remarks
1	I	Lime-free Brown	Forest			Data is validated on site
2	II	Colluvial	Well-irrigated Agriculture	Wetness	Insufficient Drainage	Citrus fruits are dominant, but they are also applicable for this soil type
3	VII	Alluvial	Pasture	Erosion-Shallow Root Region	Stony	Data is validated on this site
4	VII	Lime-free Brown	Forest		Stony	Data is validated on this site
5	I	Collivial	Well-irrigated Agriculture			The sample is taken from a cornfield surrounded by citrus fruits
6	II	Mediterranean Red-brown	Forest	Erosion-Shallow Root Region		The sampling is in a narrow meadow zone, downhill to huge woods
7	VII	Hydromofphic	Pasture	Wetness-Shallow Root Region	Salty, Alkaline (v)	The wetlands allow raising cotton which necessitates well irrigation
8	I	Collivial	Well-irrigated Agriculture			The area hosts citrus fruits, which are also applicable for this soil type
9	VI	Lime-free Brown	Forest	Shallow Root Region-Erosion	Stony	Data is validated on this site
10	VII	Mediterranean Red-brown	Pasture	Erosion-Shallow Root Region	Stony	Meadows which are also expectable on this soil type, exist in the area

Sampling Points	Soil Classes	Soil Types	Land Cover	Sub-soil Groups	Other Soil Characteristics	Remarks
11	II	Colluvial	Well-irrigated Agriculture	Wetness	Insufficient Drainage	Data is validated on this site
12	VII	Colluvial	Well-irrigated Agriculture	Wetness-Shallow Root Region	Salty, Alkaline	Data is validated on this site
13	VII	Mediterranean Red-brown	Forest			Data is validated on this site
14	III	Alluvial	Citrus	Shallow Root Region		Data is validated on this site
15	V	Hydromorphic	Pasture	Wetness-Shallow Root Region	Slight Salty, Alkaline	There are also citrus fruit gardens in the area due to the nutrient-rich delta
16	V	Colluvial	Citrus	Shallow Root Region-Erosion	Slight Salty, Alkaline	Data is validated on this site
17	II	Lime-free Brown	Forest	Shallow Root Region	Stony	Data is validated on this site
18	VII	Alluvial	Forest	Erosion-Shallow Root Region	Stony	There exists a wheat plantation in the midst of forests
19	VI	Alluvial	Olive	Shallow Root Region-Erosion	Stony	Data is validated on this site
20	VII	Lime-free Brown	Forest	Erosion-Shallow Root Region	Stony	Rarely narrow wheat and dough fields exist in this sloping forested area

3.4.3. Ongoing Studies

The watershed selected as the focus of the study is one of the sensitive regions of the country and part of it has been declared as a Special Protection Area, thus, there appear almost no significant discrepancies in the land data evaluation table. However, some of the land portions may have alternative uses, which will further be discussed by the soil engineers and experts, after the entirely termination of soil analysis. Results of the soil analysis are given in Table 3.6. The results of the analysis have been accessed in GIS as point data. To make a spatial distribution analysis of each parameter, an interpolation between analysis results are made, but this interpolation method is not valid for soil parameters. The soil parameters are variable for each point. As a result, to make spatial distribution map for each parameter, more analysis results will be needed from more than 20 sampling points.

Table 3.6 Soil Analysis Results

Sampling Point	Moisture Saturation	Total %Salinity	pH	%Lime CaCO3	Phosph.	Nitrate NO3 ppm	%Total Nitrogen	%Organic Matter	%Sand	%Clay	%Silt	Texture	%Field Capacity	%Wilting Point	Soil Temp. oC
1	85	0,085	6,6	4,1	0,9	22,9	0,182	2,6	63,22	18,13	18,7	SL	47	36,4	
2	40	0,049	7,3	14,8	5,4	10,4	0,196	2,2	65,49	18	16,5	SL	17,5	11,5	20,3
3	75	0,226	7,6	16	19	64,9	0,182	2,2	12,59	56,62	30,8	C	37	25,6	21
4	88	0,059	6,6	0,4	4,1	58,3	0,406	5,7	39,44	26	34,6	L(CL)	36,7	24,3	20
5	44	E	7,4	0,4	1,7	15,3	0,168	1,7	49,19	20,66	30,2	L	20,2	9,2	17,8
6	44	E	6,4	0	1,1	27	0,182	2,1	51,15	22,7	26,2	SCL(SL)	20,3	11,4	
7	80	0,52	7,8	14,8	13,6	23,5	0,196	2,2	13,44	53,71	32,9	C	40,7	29,1	18,6
8	50	0,05	7,6	1,6	4,3	16,2	0,126	1,9	38,23	21,09	40,7	L	24,4	14	20,9
9	44	E	6,8	0	1,1	13,1	0,112	1,5	64,54	12,98	22,5	SL	19,9	12,4	15,6
10	88	0,136	6,9	0	1,3	62,7	0,154	3,1	42,9	33,08	24	CL	56,9	46,3	20,3
11	77	0,093	8	20,5	28,2	17,5	0,112	1,6	24,84	53,24	21,9	C	36,3	29,5	17,3
12	71	0,59	7,4	8,2	14,3	83,5	0,252	3,4	17,3	46,84	35,9	C	30,9	18,4	17,3
13	44	E	6,2	0	2,5	22,4	0,238	3,3	51,51	16,66	31,8	L	22,6	14,1	20
14	50	0,044	7,9	3,7	2,8	21,5	0,154	1,8	49,34	18,73	31,9	L	24,1	11,7	20,8
15	47	0,04	7,8	4,9	1,6	3,8	0,07	1,6	49,13	12,64	38,2	L	20,5	9	19,8
16	44	0,032	7,7	1,6	17,8	5,8	0,084	1,4	71,33	8,59	20,1	SL	17,2	8,1	16
17	77	0,043	6,6	0	1,3	25,3	0,112	2,1	38,95	24,76	36,3	L	37	20,3	
18	58	0,051	6,6	0	1,6	41,9	0,154	2,2	50,55	22,81	26,6	SCL(SL)	34,6	21	18,4
19	44	E	7,2	0	1	10,9	0,126	1,5	70,96	4,58	24,5	SL	14,6	7	19,8
20	44	E	6,9	0	2,3	20,2	0,14	1,6	64,9	12,62	22,5	SL	18,4	9,8	20,4

3.4.3.1 Soil Analysis

The soil analysis sheet consist of three parts. The physical properties of soil are; texture (%sand, %silt, %clay), field capacity and wilting point. The chemical properties of soil are; moisture saturation, salinity, pH, lime content, total phosphorus, nitrate-nitrogen, total nitrogen and organic matter. Specific parameters of the soil are; moisture content, soil temperature, planted crops and natural plant cover.

The physical properties of soils are important because they control plant growth through influence on soil temperature (darker=warmer), soil aeration (sandy soils well aerated) and soil moisture content (clayey soils stay wet), (The University of Arizona, http://ag.arizona.edu/pubs/garden/mg/soils/principal.html#principal).

Texture

Soil texture is the percent of sand, silt and clay in a soil (The University of Arizona, http://ag.arizona.edu/pubs/garden/mg/soils/principal.html#principal).

Sand: is mainly small rock fragments and hard minerals such as quartz (silicon dioxide). It contains few plant nutrients. Of the three types of soil particles, sand is the largest in size (0.06 - 2 mm). If a sand grain were enlarged 1000 times, it would be about as big around as a man is tall. Moderate amounts of sand in the soil improve drainage, aeration, and tilth.

Silt: Silt consists of ground up sand (quartz) and rock minerals. Silt contains few nutrients by itself, but it can have nutrients clinging to its surface. Silt is between sand and clay in terms of size (0.002 - 0.06 mm). If a silt particle were enlarged 1000 times, it would be about the size of a basketball.

Clay: Unlike sand and silt, clays are aluminum-silicate minerals that also have varying amounts of plant nutrients such as potassium, calcium, magnesium, iron and etc. A good part of a soil's native fertility can come from its clay portion. Clay particles are the smallest of the three (<0.002 mm) . If you enlarged a clay particle 1000 times, it would be about the size of a marble. Clays have a negative charge (-) that makes them act like tiny magnets to attract and hold plant nutrients that contain a positive charge (+) like potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), and the ammonium form of nitrogen (NH_4^+). This helps to keep nutrients from being carried downward beyond the root zone by rainfall or irrigation. High clay content usually makes for harder plowing, more compaction, and poorer drainage, but it assures good water holding capacity.

Soils with specific ratios of these three particle types are usually represented on a soil textural triangle, as shown in Figure 3.21. An ideal soil texture would be 40% sand, 40% silt and 20% clay.

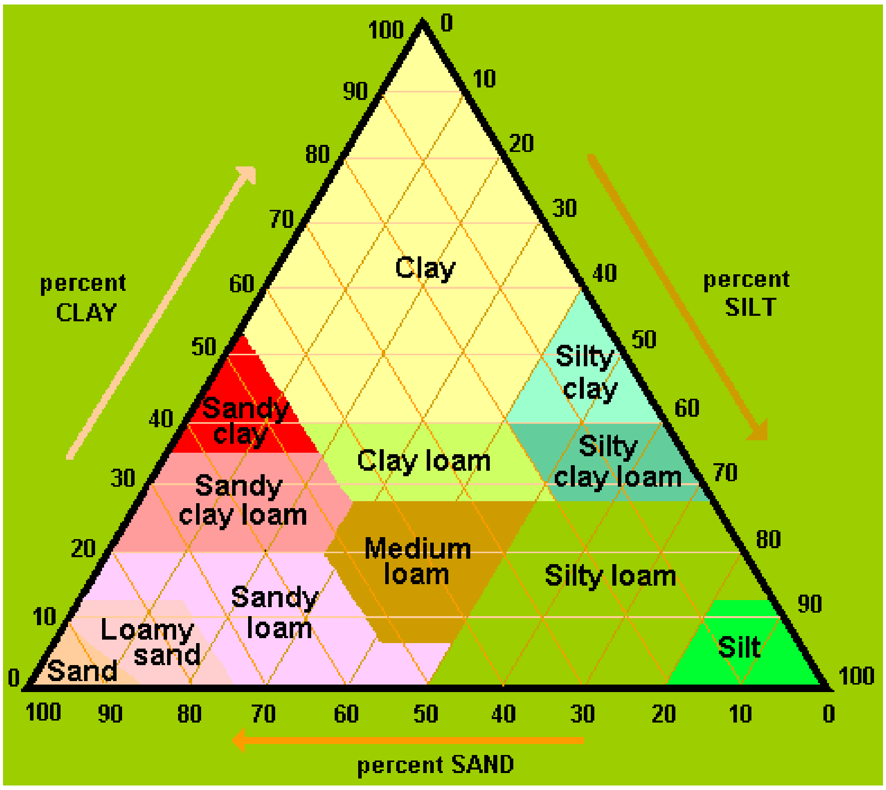

Figure 3.21 Soil texture triangle (HELPR, 2002)

Soil texture effects;

Water retention: Sandy soils have the coarsest texture and therefore the largest pore sizes. These large pore sizes are too large to hold water through its cohesive property. Clay soils have the finest texture, therefore the smallest pore sizes. Clay soils are able to hold much more water because of their smaller pore size.

Aeration: Sandy soils have the coarsest texture and therefore the largest pore sizes. These large pore sizes drain rapidly, and the sand particles do not compact, therefore these soils have the highest aeration volumes, and clay soils the lowest aeration volumes.

Specific heat capacity: Because sandy soils hold very little water, they warm up faster in the spring and cool down sooner in the fall. In contrast, clay soils with higher water content, have high specific heat capacities. They warm up slower in the spring and cool down slower in the fall.

Fertility: Clay soils have a greater surface area per volume and a higher cation exchange capacity and therefore are able to hold more ionized minerals or nutrients. Sandy soils have a lower cation exchange capacity and are able to hold fewer nutrients.

Tillage: Because clay soils have the finest texture, they are harder to till and more likely to become compacted.

Field Capacity and Wilting Point

After the rainfall or irrigation in an area, the water which infiltrated into the soil continue moving downward by gravity, which is known as percolation. The percentage of water remaining in the soil after this drainage (takes 2-3 days) is called field capacity, which gives the maximum moisture content of the soil. Plants can extract capillary water from the soil but not hygroscopic water since it stays there with very strong adhesive force between hygroscopic film and the soil particles (Rogers D. H, 1996). The lower limit of water content in the soil at which plants can not extract water any more is called wilting point. The equilibrium points in the soil are shown in Figure 3.22 (Rogers D. H, 1996).

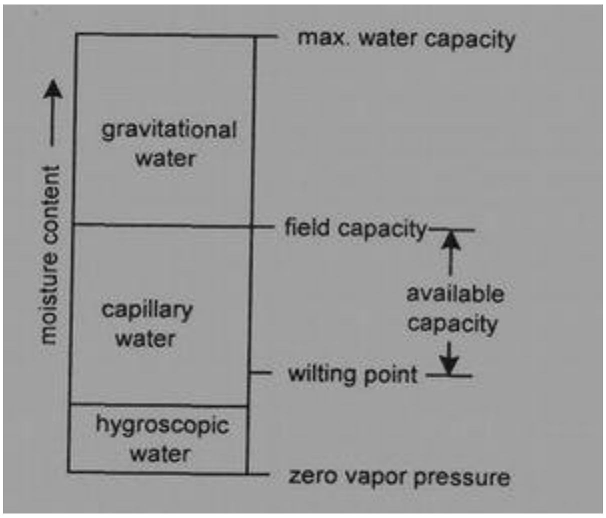

Figure 3.22 Equilibrium points in the soil (Rogers D. H, 1996)

Soil's water holding characteristics are important for irrigation system selection, irrigation scheduling, crop selection, and groundwater quality. Soil water content in the crops active root zone and available water capacity are the key indicators for applying the right amount of irrigation at the right time.

The chemical properties of soil are;

Moisture Saturation

The saturation moisture content of the soil matrix such that the entire soil porosity is water filled, (%v), and dependant only on the soil texture. It is not effected by salinity or gravel.

Salinity

Salinity is a measure of soluble salts in the soil at saturation. It effects the suitability of a soil for crop production, the stability of soil, if used as construction material, and the potential of the soil to corrode metal and concrete.

pH

pH is a measure of soil acidity and soil alkalinity on a scale of 0 (extremely acidic) to 14 (extremely alkaline), with a pH of 7 being neutral (The University of Arizona, http://ag.arizona.edu/pubs/garden/mg/soils/pH.html#pH).

The pH classification table is shown in Table 3.7. It is used to identify very alkaline, sodic and acid sulphate soils; nutrient deficiencies and toxicities.

The plant roots will not function optimally in soils outside a specific pH range unique to that organism. If the pH of the soil is extreme either alkaline or acidic, the plant will die.

pH also gives an indication of the availability of plant nutrients and relates to the growth requirements of particular crops. Acidic soils are usually deficient in necessary nutrients eg. calcium and magnesium.

pH decreases (increase acidity) with the increasing organic matter. Lime can be added to increase pH (increase alkalinity).

Table 3.7 pH Classification Table

(The University of Arizona, http://ag.arizona.edu/pubs/garden/mg/soils/pH.html#pH).

pH Classification			
> 8,5	strongly alkaline	**6,2 –6,7**	slightly acidic
7,9 – 8,5	moderately alkaline	**5,6 – 6,2**	moderately acidic
7,3 –7,9	slightly alkaline	**3,0 –5,6**	strongly acidic
6,7 –7,3	neutral		

Certain fertilizers are delivered as acidic or basic solutions. These will also alter soil pH. However, soils have a buffering capacity. This means that within their normal range of pH values, they can absorb lots of protons or lots of hydroxyl ions before the pH of the soil water changes. But once the buffering capacity of the soil is reached, then the pH of the soil water will change rapidly to toxic extremes. It will also take a lot of new buffering activity to repair the soil to its original pH

Lime Content

Lime is a naturally occurring calcareous material used to raise the pH of an acidic soil and/or supply calcium for plant growth. Large amounts of lime decreases nutrient retention and fertility, but soils with %60 CaCO3 can be successfully irrigated with a restricted choice of crops. The deposition of lime under saline conditions of fine grained material blocks pores and reduces permeability. Nevertheless, lime is an effective component for treating acidic soils.

Total Phosphorus

After N, P is the most generally limiting nutrient in terrestrial natural and agricultural ecosystems. In many cases, it may be the ultimately limiting nutrient, due to its constraining influence on the N cycle. Soil P occurs in many forms, which have complex interrelationships. Total soil P is one of the few robust measures. Full fractionation of soil P, into organic P, secondary P, extractable P and occluded P.

Nitrate

Nitrate nitrogen is the measure of readily available nitrogen in the soil and is used with percentage of organic matter to make a nitrogen fertilizer recommendation. Because nitrate-N is highly soluble, it is subject to leaching in all soils, especially in coarse to medium textured soils.

Total Nitrogen

Nitrogen is the element most generally limiting primary production in natural and agricultural ecosystems. Several important greenhouse gases (e.g., N2O and NOx and CH4) are tied to the soil N cycle. Total N analysis mostly measures organic N, which is not the form taken up by plants. However, inorganic N (NO3 and NH4) are very variable at short time scales and therefore not suitable for monitoring except at centres or in ground water and aquatic systems. The process of conversion of organic N to inorganic N (mineralization and nitrification) are suitable for measuring only at the centre level.

Organic Matter

Percentage of organic matter can be used to estimate nitrogen in the soil (The University of Arizona, http://ag.arizona.edu/pubs/garden/mg/soils/properties.html#physical).

This method alone is not always a dependable measure of available nitrogen, but is used with nitrate nitrogen to make nitrogen fertilizer recommendations on many crops. Organic matter in the soil, includes plant and animal residues at various stages of decomposition. Most cultivated topsoils contain about 2-4% organic matter by weight. Despite its small proportion, organic matter has a remarkable beneficial effect on soil behavior and crop yields. Organic matter in the soil is frequently in the form of humus, partially decomposed organic matter that has become dark and crumbly and continues decomposing at a slow rate. Humus benefits the soil in many ways;

- It can improve overall physical condition (tilth), especially in clayey soils.
- It can help reduce soil erosion by wind and water because it acts as a "glue" to bind soil particles together into aggregates, that improve water intake rates and lessen runoff. Aggregates are resistant to being moved by wind or flowing water.

- It stores and supplies nutrients, especially nitrogen, phosphorus, and sulfur. These are slowly released for use by plant roots as organic matter decomposes.
- It increases the water-holding capacity of sandy soils.
- Its high negative charge helps prevent positively-charged nutrients from leaching. Also the negative charge improves soil's buffering capacity.

Some of the specific parameters are;

Moisture Content

Soil moisture is the most important determinant of non-point pollution and vegetation structure, composition and density. It also is the integrator of surface and sub-surface water fluxes and is thus the key diagnostic variable for surface water budget.

Soil Temperature

Soil temperature is a combined product of changes in air temperature and precipitation, especially snowfall and snow cover on ground.

Once the appropriate set of land characteristics are determined, the next step in the land suitability assessment process must be economic and social analysis. Such a process would be subject to a collaborative work among experts and professionals from various disciplines such as landholders, personnel from related agencies, consultants, etc. It is important to note that this process should be an iterative one, involving refinement and feedback. Close contact should be maintained between the resource survey and the land-use. At the end of this process, the land suitability classification can be finalized and be brought to the attention of decision-makers.

3.4.3.2 Land Suitability Assessment

Once the appropriate set of land characteristic are determined, the next step in the land suitability assessment process will be the economic and social analysis. Such a process would be subject to a collaborative work among experts and professionals from various disciplines such as landholders, personnel from related agencies, consultants, etc. It is important to note that this process should be an iterative one, involving refinement and feedback. Close contact should be maintained between the resource survey and the land-use. At the end of this process, the land suitability classification can be finalized and be brought to the attention of decision-makers.

4. CONCLUSIONS AND RECOMMENDATIONS

The major output of this study is to show the guidelines of how land-based information can be gathered and integrated with GIS so as to give rise to land assessment. Besides, it also emphasizes the data that would be required for watershed modelling, planning and management studies. The GIS database actually acts as a basis for future model applications and is, as of today, known to be the most of efficient tool for modelling studies. This could also be justified with the trends of engineering software technology, which lead to penetrate into the GIS platform more and more widely in the recent years. The data gathering and modelling capabilities of GIS software packages are of very substantial potential value for integrated watershed management practices.

This study acts as a guide for land suitability assessment of the selected watershed, which can also be applied to other watersheds. It is important to note that land evaluation studies should be followed by validation of gathered data through field studies. In the future studies, land suitability assessment process will be the economic and social analysis. After the completion of all these analysis, attention of decision makers and related authorities will be drawn to the results attained.

Soil analysis form an essential part of such land suitability analysis even though it is a money and time consuming job. However, only by means of actual field tests, the verification of the assessment results can be realized.

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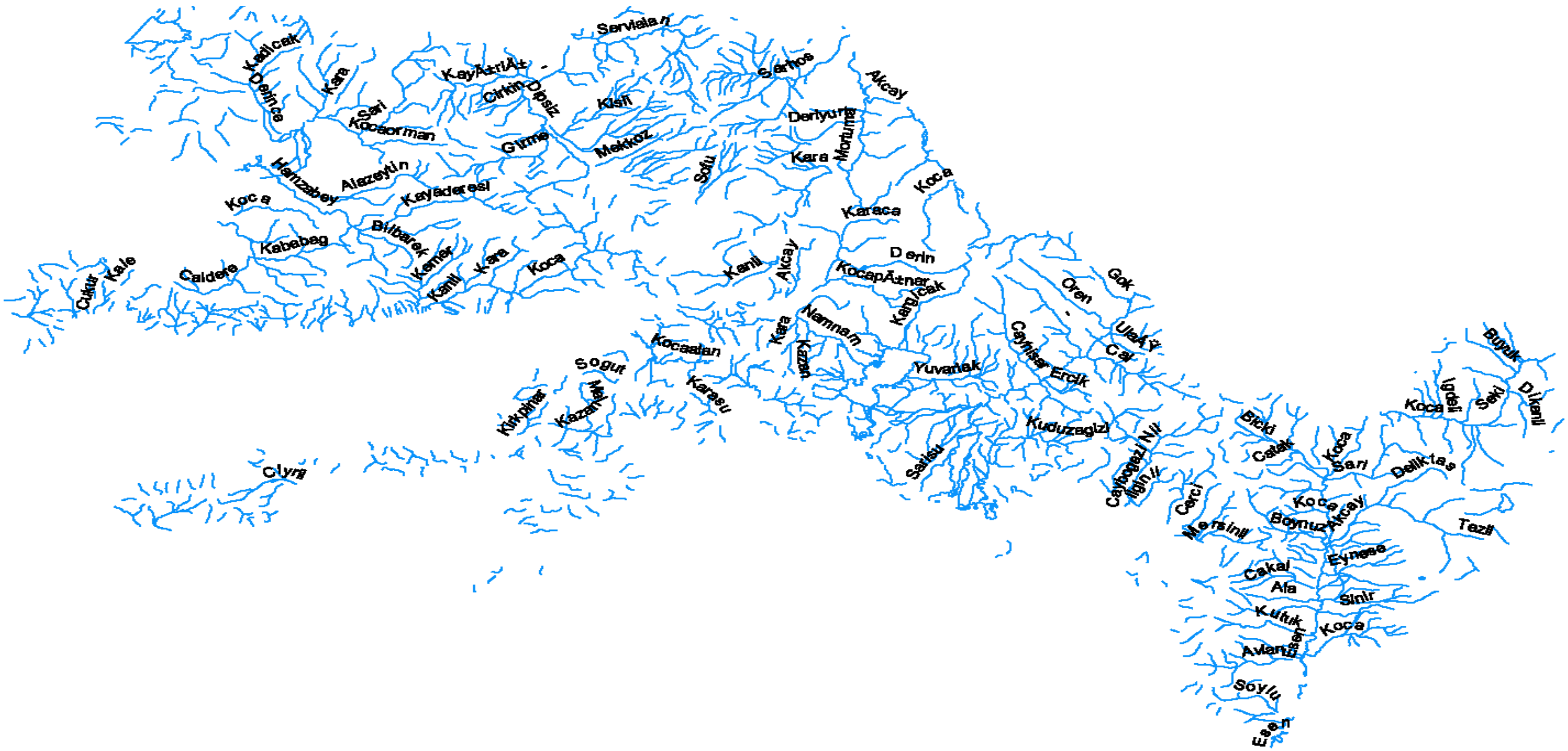
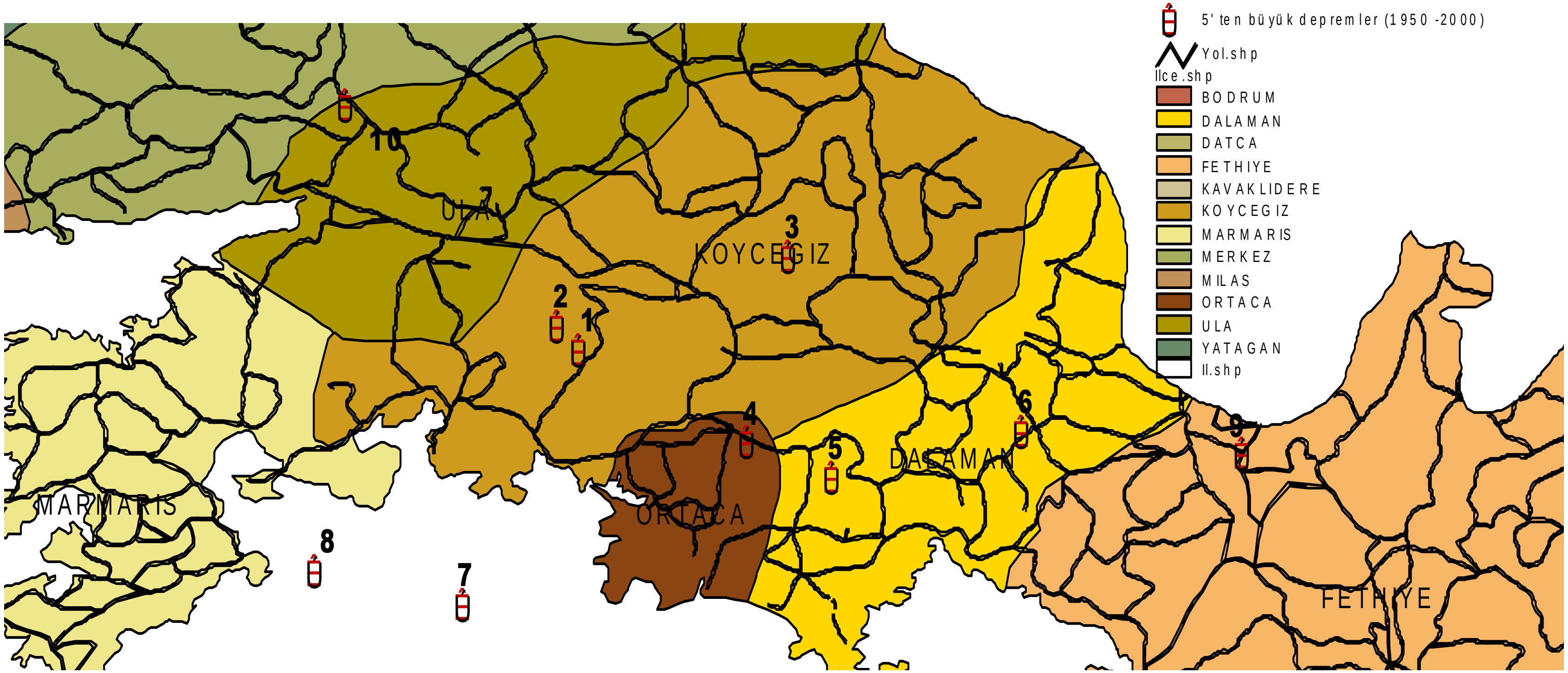
APPENDIX A

THE RIVERS AND STREAMS IN THE WATERSHED


Servialan
Kadicak
Delince
Kara
Sari
Kocaorman
KayÄ±rlÄ±
Cirkin
Dipsiz
Kisli
Sarhos
Akcay
Deriyurt
Mortuma
Girme
Mekkoz
Kara
Sofu
Hamzabey
Alazeytin
Kayaderesi
Koca
Koca
Karaca
Bilbarek
Kababag
Kemer
Kara
Koca
Kanli
Akcay
Derin
Kale
Cukur
Caldere
Kanli
KocapÄ±nar
Gok
Oren
Karaicak
Namnam
Kara
Kocaalan
Sogut
Karasu
Kazan
Yuvanak
Cayhisar
Ercik
Cal
Kirkpinar
Kazan
Mal
Kuduzagizi
Sarisu
Ciyril
Buyuk
Igdeli
Seki
Dikenli
Koca
Bicki
Catak
Koca
Sari
Deliktas
Caybogazi
Ilginli
Cerci
Mersinli
Koca
Boynuz
Akcay
Tezli
Eynese
Cakal
Ala
Sinir
Kutuk
Koca
Avlan
Esen
Soylu
Esen

APPENDIX B

THE MAJOR EARTHQUAKE HISTORY OF THE WATERSHED



5' ten büyük depremler (1950 -2000)
Yol.shp
Ilce.shp
BODRUM
DALAMAN
DATCA
FETHIYE
KAVAKLIDERE
KOYCEGIZ
MARMARIS
MERKEZ
MILAS
ORTACA
ULA
YATAGAN
Il.shp
ULA
KOYCEGIZ
MARMARIS
ORTACA
FETHIYE
1
2
3
4
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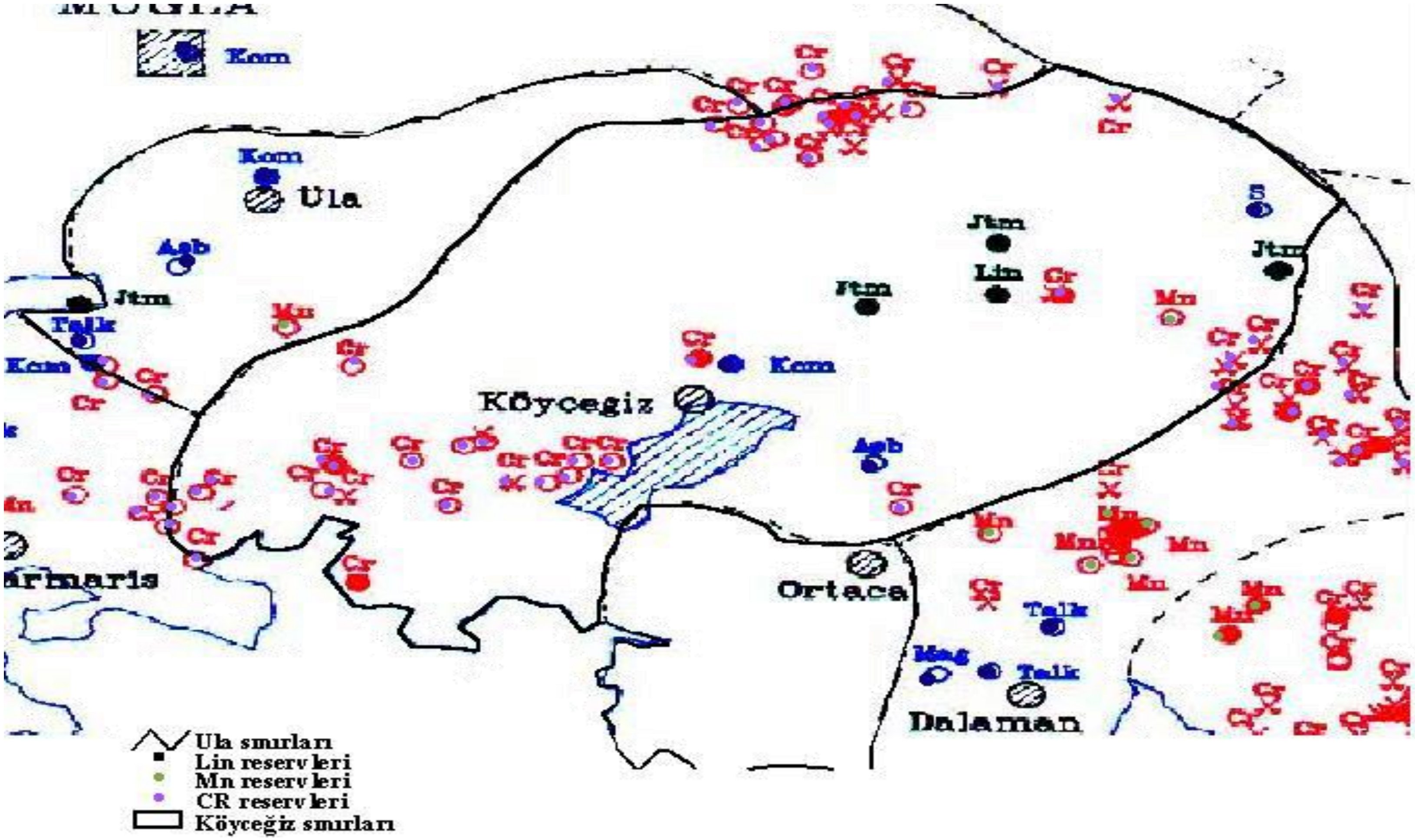
10

APPENDIX C

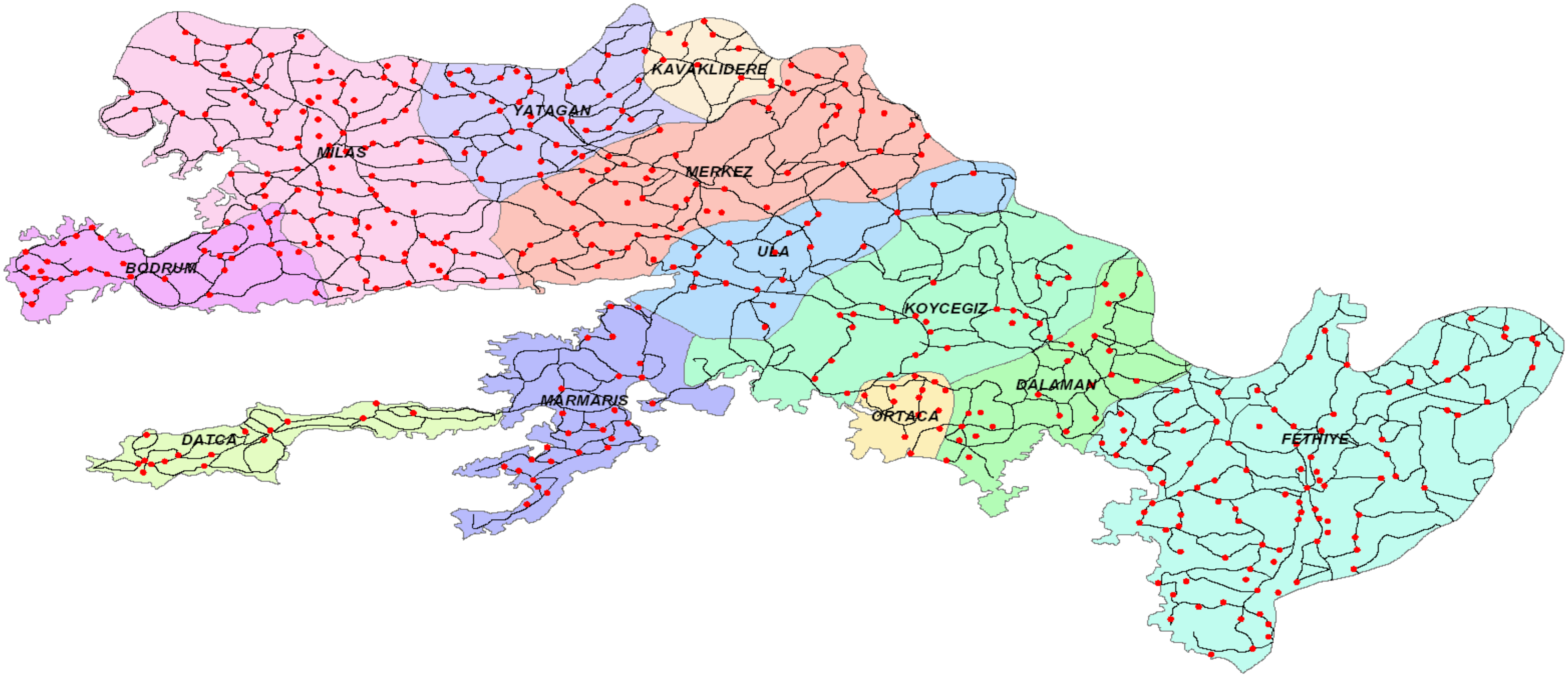
THE SIGNIFICANT MINING ZONES OF THE WATERSHED

(taken from Mine Study & Research Institute webpage)



APPENDIX D

THE ROAD MAP OF MUGLA


KAVAKLIDERE
YATAGAN
MILAS
MERKEZ
ULA
BODRUM
KOYCEGIZ
DALAMAN
MARMARIS
ORTACA
DATCA
FETHIYE

CURRICULUM VITAE

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