DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEVELOPMENT OF A GIS BASED DECISION SUPPORT SYSTEM FOR INTEGRATED COASTAL ZONE MANAGEMENT OF GÖKOVA BAY

by
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June, 2011
İZMİR

DEVELOPMENT OF A GIS BASED DECISION SUPPORT SYSTEM FOR INTEGRATED COASTAL ZONE MANAGEMENT OF GÖKOVA BAY

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by
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İZMİR

PH.D. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"DEVELOPMENT OF A GIS BASED DECISION SUPPORT SYSTEM FOR INTEGRATED COASTAL ZONE MANAGEMENT OF GÖKOVA BAY"** completed by **ÖZEN ARLI KÜÇÜKOSMANOĞLU** under supervision of **PROF. DR. YALÇIN ARISOY** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy.

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Özen ARLI KÜÇÜKOSMANOĞLU

DEVELOPMENT OF A GIS BASED DECISION SUPPORT SYSTEM FOR INTEGRATED COASTAL ZONE MANAGEMENT OF GÖKOVA BAY

ABSTRACT

Coastal Zone is one of the vital regions in terms of both generosity of resources and intensity of land use as well as the range of business fields ensuring the financial continuance of these regions. This grift structure causes conflicts in uses. With the developments in information technologies, this structure in Coastal Zones can be managed more effectively. Within this scope, Gökova Bay is also a major coastal zone. In this study, land use and land cover of the study area were gathered and digitized from raster data into Geographic Information System (GIS). Elevations were digitized from topographical maps and a Digital Elevation Model of land and sea was generated. Biodiversity and anthropogenic stress data were included into GIS by using Marine Biological Diversity Assessment of Gökova Specially Protected Area Project Report of Environmental Protection Agency for Special Areas. GIS data was analyzed and new data was generated using GIS tools. A 500m x 500m grid mesh was set by using all GIS data. Grid data on the GIS was used on the Principal Component Analysis (PCA) in order to determine important parameters to be used in the Decision Support System (DSS) Model. The selected variables were used in the development of the reliable Adaptive Neuro-Fuzzy Inference System (ANFIS) model. The training and testing processes of the ANFIS model were carried out for different input and output groups. The relations were determined by the ANFIS model and the output values were forecasted using these relations between input data. After the forecast of output change, the visualized thematic map was prepared on GIS. In this study, the purpose is to develop a methodology to be used in major coastal zones, like Gökova Bay, and to provide information flow to the decision makers.

Keywords: Integrated Coastal Zone Management, Decision Support System, Geographic Information System, Adaptive Neuro-Fuzzy Inference System

GÖKOVA KÖRFEZİ BÜTÜNLEŞİK KIYI BÖLGESİ YÖNETİMİ (BKBY) İÇİN CBS TABANLI KARAR DESTEK SİSTEMİ GELİŞTİRİLMESİ

ÖZ

Kıyı bölgesi gerek kaynakların bolluğu, gerek arazi kullanımlarındaki yoğunluk ve gerekse bu bölgelerin ekonomik olarak varlığını sürdürebilmesini sağlayan sektörlerin çeşitliliği açısından önemli alanlardır. Bu karmaşık yapı kullanımlarda çakışmalara yol açmaktadır. Bilişim Teknolojilerinin gelişimiyle birlikte Kıyı bölgelerindeki bu karmaşık yapı daha etkin bir şekilde yönetilebilmektedir. Bu kapsamda Gökova Körfezi de önemli bir kıyı bölgesidir. Çalışmada, Gökova bölgesinin arazi kullanımı, orman alanları ve sosyal yapısına yönelik çeşitli veriler sayısallaştırılarak Coğrafi Bilgi Sistemi (CBS) ortamına aktarılmıştır. Topoğrafik haritalardan eş yükselti eğrileri sayısallaştırılarak çalışma alanının Sayısal Yükseklik Modeli hazırlanmıştır. Gökova Özel Çevre Koruma Bölgesi'nde yürütülmüş çalışmalardan elde edilen biyolojik çeşitlilik verileri derlenmiştir. CBS ana veri katmanları kullanılarak çeşitli metodlarla yeni veriler üretilmiştir. Tüm bu CBS katmanları verileri 500 m x 500 m ağ sisteminde her hücre için hazırlanmıştır. CBS'den alınan veriler Temel Bileşenler Analizine tabi tutularak bu çalışmada geliştirilen modelde kullanılacak önemli parametreler belirlenmiştir. Belirlenmiş önemli parametreler kullanılarak Yapay Sinir Ağları ve Bulanık Mantık araçlarını kullanan Adaptif Ağ Tabanlı Bulanık Mantık Çıkarım Sistemi (ANFIS) ile Karar Destek Sistemi modeli geliştirilmiştir. ANFIS'in eğitim ve test aşamalarında farklı girdi ve çıktı grupları kullanılmıştır. Girdi ve çıktı arasındaki ilişkiler belirlenmiştir. Geliştirilen model ile arazi kullanımlarının etkisi incelenmiş ve model çıktılarından yararlanarak öngörülen değişim tematik olarak haritalanmıştır. Bu çalışmada Gökova körfezi gibi önemli kıyı bölgeleri için de kullanılabilecek, karar vericilere bilgi akışı sağlayacak bir yöntem geliştirilmeye çalışılmıştır.

Anahtar sözcükler : Bütünleşik Kıyı Bölgesi Yönetimi, Karar Destek Sistemi, Coğrafi Bilgi Sistemi, Adaptif Ağ Tabanlı Bulanık Mantık Çıkarım Sistemi

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CHAPTER ONE
INTRODUCTION

The world's coasts have always been subjected to serious anthropogenic pressure in history due to its natural wealth. There exist various definitions to describe a coastal zone and given its high priority, it is within the interest of people, commerce, and a multitude of industries. Carter (1988) says:

"Coastal Zone is that space in which terrestrial environments influence marine (or lacustrine) environments and vice versa. The coastal zone is of variable width and may also change in time. Delimitation of boundaries is not normally possible; more often such limits are marked by an environmental gradient or transition. At any one locality the coastal zone may be characterized according to physical, biological or cultural criteria. These need not, and in fact rarely do, coincide".

The coastal zone may have a width of a few hundred meters to kilometers depending on your study objectives. This transitional field of land and sea mostly includes ecologically sensitive and valuable habitats (Clark, 1992; Canessa, 1998). For centuries, human beings mistakenly have believed that it will infinitely serve them. Time proved that it was finite; indeed it has been drastically degraded since the beginning of the 20th century.

In the coastal zones with vast sea area, such as Gökova Bay, both land and coast resources are used in various ways. It is vital to consider the effects of land usage on the sea and the affects of the sea activities on the land and also the interactions among these. It is important that the integrated management activities to be carried out considering this interaction in the coastal zones are applicable and understandable by the decision makers. This study aims to develop a method employing information technologies in order to effectively manage the vast gulf areas with profound land/sea usage such as Gökova Bay. The necessity of such studies is noted in the projects and activities carried out in the field of Coastal Zone

Management. Besides, this need is highlighted in the review articles with compiled coastal zone management activities.

The following literature review cites relevant studies and discusses the Integrated Coastal Zone Management (ICZM) and its historical evolution; Decision Support Systems (DSS) and importance for decision makers; and the statistical and mathematical tools, Principal Component Analysis (PCA), and Adaptive Neuro-Fuzzy Inference System (ANFIS), used for the methodology of this study.

It is important to emphasize that coastal zones are inhabited by more than half of the world's population, and hosting two-thirds of the world's largest cities (Sorensen & Mccreary, 1990; UNCED, 1992; Cincin-Sain, 1993; WCC, 1994; Cincin-Sain and Knecht, 1998). Due to intense stress, especially water and other resources have become scarce. The patterns of uses are leading to a steady process of degradation, and eventually to the exhaustion of the resources in some regions (WCC, 1994; Cincin-Sain and Knecht, 1998; Creel L., 2003).

All these extensive demands cause conflicts between sectors and stakeholders have begun to raise governments and public concern (Cincin-Sain, 1993; Canessa, 1998; WWF & IUCN, 1998; Westmacott, 2002; Cao & Wong, 2007). Besides the deficient management efforts like ineffective control over coastal uses and not directly solving conflicts, inadequate legislations and regulations increase the need for proactive environmental management efforts, instead of solving coastal problems (Canessa, 1998). The realization of ICZM needs was also influenced by international consensus.

ICZM is an internationally accepted approach to ensure sustainable development and managing resources. It is based on the Coastal Zone Management Act of 1972 in the United States, which allows policymakers and planners to take population issues into account when examining pressures, threats, and opportunities regarding coastal areas. ICZM has been mentioned repeatedly in major international conferences, including the UN Conference on Environment and Development in Rio de Janeiro, Brazil, in 1992 and the World Summit on Sustainable Development in Johannesburg, South Africa, in 2002.

There are several similar definitions for ICZM. ICZM is defined mainly as a continuous and dynamic, iterative, adaptive and participatory process by which decisions are made for the sustainable use of these resources without undervaluing the development and protection of coastal and marine areas and resources (Sorensen & McCreary, 1990; Clark 1992; Cicin-Sain and Knecht, 1998).

Since World Coast Conference, in many countries environmental managers started to adopt integrated multidisciplinary approaches to resource management including all stakeholders, governments, public and private sectors, nongovernmental organizations (NGOs), and individuals. Following 1972, the interest to ICZM started in developed nations, most of which on USA, but after 90's trend moved to developing countries (Sorensen, 1993).

Sorensen reviews 142 ICZM efforts that had been finalized/initiated by the year 1993. Among those, the scope was mainly preferred as small scale projects such as special area management plans and pilot projects, because these studies can be applied to other similar regions or national level. Because ICZM efforts always need much time and resources, it is important to convince the administrative and funding bodies (Sorensen, 1993).

Therefore the implementation of ICZM is often constrained by political systems in practice, especially after 90's. Study of Lau (2005) gives a political science perspective based on approaches inherent in neo-institutional and administrative theories. He said that a successful local ICZM working approach cannot be applicable to other regions without modifications to the organization structures of decision making and implementation besides geographic, biological and demographic studies.

There are many outputs of ICZM efforts such as management plans, laws, regulations, inventories, and Geographic Information Systems (GIS). Nonetheless, the achievements of those ICZM efforts are still not well known for most of projects because they usually not readily available to those who could benefit from its findings, conclusions and recommendations. Furthermore, it is very difficult to gain information from implemented ICZM projects about their success against unexpected developments and disasters. As a consequence, there is a great need to evaluate ICZM efforts to produce measurable outcomes and a need for extended research with case studies to assess the effectiveness of management actions in order to apply to other coastal regions (Sorensen, 1993; Lau, 2005).

Since defined previously as continuous, dynamic, iterative etc. ICZM is a long pursuit. There are many such examples from world. Two of them which lasted more than 20 years covering many legislative and regulative applications during the project are presented in detail to stress the broadness and duration. First one is from China which is the biggest growing economy of the world. There is broad range of problems in coastal zones of China: mainly point and nonpoint pollution rose with increasing population; generation of vast amount of wastes from coastal cities which are preferred by industries; high riverine pollutant fluxes. Ecosystem was also degraded by destruction of natural habitat by changing hydrodynamic system of the coasts and coastal reclamation which are resulted in extra habitat loss and coastal erosion. Combined with other stresses, introduction of invasive species intentionally and unintentionally resulted in biodiversity loss in coastal fauna and flora. Cao & Wong states that economic growth and industrialization exacerbate the ecosystem degradation and environmental deterioration in China (2007). From 1980s to 2006, many projects were carried out and hundreds of legislation were formulated with involvement of more than 20 ministries. In order to solve adverse consequences of conflicting resource uses, interagency conflicts and overlapping jurisdictions need to be solved in the country. As a result of costal management plans and regulations for corresponding level the responsibility of agencies was reorganized and for better decision making procedures, China established an interagency Executive Committee and uses marine expert groups to maintain public participation, to obtain capacity building in implementing bodies (especially to raise the local intelligence) which is crucial. As a result of all projects, inventory and monitoring studies were carried out nationwide to meet the data requirements. In China, more than 3600 coastal marine sub zones were defined according to their functionality and the need for coherent management requirements (Cao & Wong, 2007).

The other example is from the largest archipelago country of the world. Indonesia faced overfishing and overexploitation problems because of population growth in coastal zones. ICZM efforts need funding, regulations and responsible authorities that implement coastal management programs. According to Farhan & Lim (2010), in Indonesia, four main factors that prevent the sustainable implementation of the ICZM programs are extra responsibility, national policy, lack of information exchange and bureaucracy. Common problems of Indonesian coastal zones are: rapidly raising settlements; worsening environmental quality and biodiversity; overfishing and increasing vulnerability to natural hazards which are shared with many coastal regions. In addition to these problems, developing countries faced with excess problems such as no state laws for ICZM implementation, funding, not considering users needs, and lack of capacity to evaluate ICZM programs that were performed by developed countries. In 1999, Indonesia established the Ministry of Marine Affairs and Fisheries to enhance coastal community welfare besides maintaining coastal sustainable development. Between 1987 and 2009, there were many ICZM projects carried out mainly by international funds. In 2005 INA-GOOS, a national GOOS program, was launched to support operational oceanography while integrating research agencies and local governments. Farhan & Lim (2010) stated that, for better and sustainable management, DSS need to be developed to facilitate and assist decision makers in implementing and evaluating ICZM.

In this respect, many of the major problems faced by decision makers involve multidimensional and spatial complex structures often with conflicting needs and concerns. In order to effectively manage the degradation on a sustainable basis, decision-makers can use DSS in order to have a more structured analysis of the problem and define possible options of intervention to solve the problem. DSS also improve our understanding of the inter-relationships between the natural and socio-economic variables and therefore result in improved decision-making (Westmacott S., 2001).

Nature is continuously changing and trying to find a balance that has been altered by mankind. Understanding and measuring the anthropogenic effects on nature is critical for effective management. Scientific communities struggle hard initially to slow down, hold back and lastly remediate deterioration of nature. They try to provide a sustainable world, to meet the needs of the present without compromising the ability of future generations to meet their own needs (UN, 1987; Smith C. & Reed G., 1998). DSS are an important tool that uses information technologies to achieve sustainability.

DSS studies have been built and developed since the 1960s and after 1980s, they have been implemented in many technical areas widely from finance to space and to environmental field such as resource and environmental management, environmental quality and their spatial applications. DSS are used from operation systems of manufacturing processes to environmental management issues (Groot J.C.J., Rossing W.A.H., Jellema A., Stobbelaar D.J., Renting H. & Van Ittersum M.K., 2007; Oliveira C. & Antunes C.H., 2004; Pallottino S., Sechi G.M. & Zuddas P., 2005; Rao M., Fan G., Thomas J., Cherian G., Chudiwale V. & Awawdeh M., 2007; Vallega A., 2001; Young W.J., Lam D.C.L., Ressel V. & Wong I.W., 2000; Rodrigues S.M., Pereira M.E., Ferreira da Silva E., Hursthouse A.S. & Duarte A.C., 2009). There has been a rapid expansion in the development and description of both quantitative and software system methods that can be applied to decision-making processes and many of these have application in the spatial domain (Hill M.J., Braaten R., Veitch S.M., Lees B.G. & Sharma S., 2005). New methods can assist with correlation of input data layers, subjective weightings, and mixing of qualitative and quantitative data by means of GIS. GIS based DSS have many usages under sustainable development concept such as resource management and assessment of environmental quality (Bunch M.J. & Dudycha D.J., 2004; Chang N.B., Wei Y. L., Tseng C. C. & Kao C.-Y. J., 1997; Claassen T.H.L., 2007; Groot J.C.J. et al., 2007; Hill M.J., Braaten R., Veitch S.M., Lees B.G. & Sharma S., 2005; Matthews K. B., Sibbald A. R. & Craw S., 1999; Rao M., Fan G., Thomas J., Cherian G., Chudiwale V. & Awawdeh M., 2007; Simon U., Bruggemann R. & Pudenz S., 2004; Vallega A., 2005). Integration of mapping components enhances effectiveness and adoption of end user of developed DSS software and recent technical focus is placed on integrating relevant spatial data with useful multi-scale models under a user-friendly interface in a GIS environment (Chang N.B. et al., 1997; Matthews K. B., Sibbald A. R. & Craw S., 1999; Pallottino S. et al., 2005; Vallega A., 2005). The design of the DSS software is evolving and it uses many models in combination like spatial interfaces (Olson D.L., Shipley M., Johnson M. & Yankov N., 2007; Simon U. et al., 2004). Many decision-making models and methods like cost–benefit analysis, Multi Criteria Analysis (MCA) and fuzzy method have been developed in the world for solving problems (Guangtao Fu, 2008; Heinrich G., Howells M., Basson L. & Petrie J., 2007; Jimenez F., Cadenas J.M., Sanchez G., Gomez-Skarmeta A.F. & Verdegay J.L., 2006;Zavadskas E.K. & Antucheviciene J., 2005; Zavadskas E.K. & Antucheviciene J., 2007; Joerin, F., Theriault, M. & Musy, A., 2001). These methods and optimizations are used by many researchers together with programmers.

Coastal zone managers endeavor to base their studies on mathematics by using analytical tools, techniques and methodologies (such as GIS, PCA, ANFIS and MCA…). In this way, they can produce knowledge from data related to the interface of legislation and science policy. Therefore, developing a reproducible and controllable system that can give feedback and measure deterioration/remediation gains importance in this very scientific era. Below some of those closely related studies using these technical tools are given in detail.

One of the most important study areas that coastal zone managers dealt with is the sea level rise. In the study of El-Raey (1997), GIS, RS and modeling techniques were used to assess potential impacts on sectors and socioeconomy. The results of the study show that, 2 million people have to be displaced with a job and value loss for more than 200000 people. El-Raey (1997) states that coastal zone and resources are vulnerable to impacts of climate change and intense uses, and adds that ICZM approach is necessary for long term sustainable management. This vulnerability assessment shows that a GIS based DSS is necessary for future development and planning in Egypt.

Coastal ecosystems are increasingly threatened by lack of long run environmental policies and decisions, especially in tourism areas. Multi dimensional analysis with ranking method with GIS is used by Kitsiou et al (2002) for assessment of importance of zones in terms of coastal management. The study area, a coastal region in Rhodes Island, was zoned in this study. Population, number of shops, hotel beds, and agricultural area and water quality parameters indicating eutrophication used as criteria for Regime multiple criteria choice method which is an important tool for policy analysis. The used methods gives the priority to the criteria and sub regions, therefore gives a tool for decision makers for evaluating the potentials of the coastal regions comparatively (Kitsiou et al., 2002).

The third study aims to develop a DSS for Catalonia coasts of Spain. Sarda, Avila and Mora (2005) developed decision support tools as a methodological approach for coastal management. The study gives the outcomes of a 5 year coastal zone management project. The main sector in the region is tourism. Data was mainly composed of administrative, cartographic and socioeconomic data. All information was compiled in GIS. Sarda et al. used PCA to reduce the number of indicators. The indicators cover territorial, economical and social ones. After the indicator selection, the future planning scenarios are developed by using tools of GIS and visual interpretation.

River and marine water quality and its management are significant issues among environmental problems. There exist many technical DSS research efforts in the scientific era about the concept (Chen & Mynett, 2006; Kattaa, Fares & Al Charideh, 2010; Baxter & Shortis, 2002; Bunch & Dudycha, 2004). Bunch & Dudycha (2004) states that it is required to have an approach that can deal with complexity and uncertainty. For this reason implementing “adaptive management” and “soft system methodology” methods and techniques with system thinking is compulsory. In this research two workshops held for the management of Cooum River in India. In the first workshop, stakeholders and researchers developed a water quality model and DSS. In the second one, the DSS was used to derive the management scenarios and impact of interventions. Bunch & Dudycha (2004) used GRASSLANDS GIS software and DESERT water quality simulation module and an interface to data transport and found that distribution of income is a key factor to improve the water quality. It is also emphasized that integrated and interjurisdictional management is important for long run successive management efforts with the involvement of government agencies and NGOs.

There are further DSS studies which are developed to integrate economical pattern and sectoral dynamics of coastal zone (Olson, Shipley, Johnson &Yankov, 2007); integrating social concerns and expert knowledge about politics and law by using Multi Criteria Decision Analysis tools (Hill, Braaten, Veitch, Lees & Sharma, 2005; Siakavara & Eleftheriou, 2010); and enhanced by integrating remote sensing or updated data to analyze consequences of the management efforts as feedback (Kainuma et al., 1991; Rao et al., 2007). Multi Criteria (Decision) Analysis is widely used in DSS for ICZM, especially in studies carried out for technical purposes such as site selection and suitability analysis. Some of these tools integrated in GIS software are easy to use but the determination of relationships between criteria (indicators) and their weighs for calculations need to be set (Joerin, F., Theriault, M. & Musy, A., 2001; Salem, B.B., 2003; Hansen, H.S., 2007).

ANFIS has been used recently in DSS studies, especially in late 2000. ANFIS, developed by Jang in 1992, has the ability to solve complex nature dynamics and problems by human-like reasoning, to enhance decisions. These methods are used in many areas, mainly in engineering, economics, remote sensing, emergency response, medicine, ecological studies, flood risk, water quality and basin management, climate change studies, planning, agriculture, etc. (Zhang, Wang, Xue & Yuan, 2009; Olson, Shipley, Johnson &Yankov, 2007; Verdonschot, 2000; Urbanski & Szymelfening, 2003; Arkhipov, Krueger & Kurtener, 2008; Cui et al., 2010; Filippi & Jensen J.R., 2006; Astel, 2007; Baxter & Shortis, 2002; Retzlaff, 2008; Chen &

Mynett, 2006; Thumerer, Jones & Brown, 2000; Kattaa, Fares & Al Charideh, 2010; Jesus, Panagopoulos & Neves, 2008). These continuously developing mathematical tools are even effectively used in DSS of emergency response plans which necessitate precise and immediate solutions (Chang, Wei, Tseng, & Kao, 1997).

In Gökova Bay, determined as case study, many large and small scale researches have been carried out until now. Three of them are directly related to Coastal Zone Management. The first of these studies was carried out between 2005-2006 by Istanbul University Institute of Marine Sciences and Management namely Marine Biological Diversity Assessment of Gökova Specially Protected Area Project (OCEANOS). OCEANOS Project covered many field work including diving and water quality studies. The valuable outcomes of the study were used in this thesis by the permission of project owner, Agency for Specially Protected Areas (EPASA, 2006).

The second and biggest project is Preparation and implementation of the Integrated Management Action Plan in collaboration with stakeholders for the Inner Gökova Bay and the Sedir Island within Gökova Specially Protected Area Project funded by Euro-Mediterranean Partnership MEDA Program, SMAP III (Short and Medium-Term Priority Environmental Action Programme). Project was conducted by Muğla University and had partner institutions from all levels of government such as Agency for Specially Protected Areas, Governorate of Muğla Province including the Sub-Governor of the Ula County; the Provincial Administration Office; the Provincial Board for Protection of Cultural and Natural Assets, the Provincial Directorates for Tourism and Culture, Environment and Forestry, Agriculture and Rural Affairs, and Reconstruction and Settlements; the Regional Directorate for Forestry; Akyaka Municipality and Mayor’s Office, National Committee for Coastal Zone Management; Muğla University; and Middle East Technical University. The budget of the project was 1.3 million Euros. The objective of the project was to demonstrate the real process of integrated coastal management by utilizing the existing institutions (administrative bodies), laws and regulations, and by bringing together all actors and stakeholders by implementing ICZM principles accepted by the European Parliament and Council. Project outcomes covered studies on enhancement and protection of family scale subsistence fisheries, agricultural area s and management, coastal erosion and coastal water quality studies, public awareness and education efforts, protection of historical sites, and legislative studies on these issues where conflicts exist.

The last important project is Gökova Special Environmental Protected Area Integrated Coastal and Marine Management Planning Project which was conducted between 2009-2010 by Underwater Research Society-Mediterranean Monk Seal Research Group and Rubicon Foundation. Project covered field research and literature studies on ecological, socio-ecological aspects, threats and pressures. The project aimed to prepare a socio-economically sustainable and integrated management plan for coastal and marine area. Regulative and legislative studies also carried out with relevant state organizations. Project nominated additional protection areas for Mediterranean monk seal (Monachus monachus), sand bar shark (Carcharinus plumbeus), and sea birds; and advise places for recreational and eco-tourism uses in the Gökova Bay. Also restrictions for fisheries sites and limitation for land uses proposed due to outcomes (SAD, 2011; Kıraç et al., 2010).

In this study, a DSS was developed to estimate the response of complex and vague nature to human effects. This methodology allows the preparation of thematic maps of the estimated change and consists of GIS, PCA and ANFIS. The land use data is interpreted by GIS. Important parameters for the ANFIS model are selected by use of PCA and the relations of the parameters are determined by the ANFIS model. ANFIS, an adaptive intelligent system, is a combination of Artificial Neural Network (ANN) and Fuzzy Inference System (FIS). ANN learns by adjusting the weights of interconnections between layers and FIS uses fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. ANFIS has the ability to solve complex nature dynamics and problems by human-like reasoning to enhance the decisions.

Following this introduction, the dissertation is divided into seven main parts. First in Chapter Two, methods of the study and technical details of PCA and ANFIS are presented precisely. In this study, Gökova Special Environmental Protection Area was chosen as a case to apply DSS developed. Gökova Bay is in between two peninsulas, Datça and Bodrum. Two important mass tourism centers, Bodrum and Marmaris, are present in this region, but Gökova Bay and its settlements enjoy its geographical advantage with its natural wealth which is introduced in Chapter Three. Chapter Four lays out the research design and also notes the GIS representation, list of data and grid system. Chapter Five is devoted to explain application steps of methods given in chapter two. Data analysis stages are given in detail systematically by using one of the five data sets. Chapter Six interprets analysis results of five data sets with their thematic representation. In Chapter Seven, conclusion of the dissertation is provided. Recommendations for further research are made in the last chapter, Chapter Eight. More information about definitions, data analysis stages of all data sets and their results are introduced in Appendix A and Appendix B.

CHAPTER TWO
MATERIALS AND METHODS

2.1 General

In this study, a DSS Model for ICZM was developed by combining GIS, PCA and ANFIS. The data was gathered into GIS and converted into a grid system. The grid data was statistically analyzed with PCA method for refining the relationship in between. Thus, input and output variables were selected for further mathematical analysis called ANFIS which is a combination of Artificial Neural Networks and Fuzzy Logic. In this thesis, software of DEU computer facilities were used. MapInfo®, Statistica® and MATLAB® software were used for GIS, statistical and ANFIS applications respectively. Details of the study area and data are given in the following chapters.

In this chapter, ICZM, DSS and GIS are described briefly. PCA and ANFIS are presented more precisely for follow up on.

2.2 Integrated Coastal Zone Management (ICZM)

There is deterioration in coastal zones in terms of natural, environmental, economic, social and cultural resources, and ICZM (or Integrated Coastal Management, ICM) will be the comprehensive approach in promoting sustainable development in these areas. Sustainable development which is usually defined as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." as defined in the Brundtland Commission (UN, 1987). It aims at improving the situation in coastal zones through a continuous, proactive and adaptive process of resource planning and management. It is a process of achieving goals of sustainability in consideration of a large number of sectors, such as species and habitat protection, resource management, fisheries, agriculture, transport, energy, industry, employment, tourism and recreation, education, culture, and regional development. ICZM requires conservation of ecosystems as well as management of land and marine-based human activities. There is a need for systematic, coherent and active system towards the sustainable development of coastal zones which was aimed in this study. More literature review and information about ICZM is provided in Appendix A.

2.3 Decision Support System (DSS)

Coastal areas are the most populated areas with increasing stress and environmental degradation. Decision-making for ICZM involves multiple decision-makers and multiple sectors often with conflicting needs and concerns. DSS can be developed to improve our understanding of inter-relationships between natural and socio-economic variables and therefore result in improved decision-making (Westmacott S., 2001).

The DSS studies have been made and developed since the 1960s by the Information Systems researchers and technologists, and in the 1980s, it started to be implemented widely in financial planning systems. With the development of information technologies, it evolved model-driven systems from data intended systems.

DSS Developers design in namely four ways: Multi-Criteria Decision Analysis, Multidimensional Analysis, Optimization and Simulation. A Multi-Criteria Decision Model helps to evaluate a set of discrete actions, i.e., alternatives, projects, or proposals. A variety of approaches are available in this model. Multi-dimensional Analysis handles data hierarchically in each dimension to extract useful information and develop conclusions. Decisions arise from questions that require multiple perspectives on the data, such as time, regions and usages. Each of these perspectives is called dimensions. In this study, dimensions were selected from available data, gathered in GIS, by the help of statistical methods. After mathematical representation of multiple interrelationships, DSS results of selected dimensions were visualized by GIS. More literature review and information about DSS is provided in Appendix A.

2.4 Geographic Information System (GIS)

GIS is a computer-based information system that integrates stores, edits, analyzes, shares, and displays geographic information and geographic features on the Earth. GIS is a valuable tool that allows users to create interactive searches, analyze spatial information, edit data, produce maps, and present the results of all these operations digitally (GIS Development, 2010; GIS Lounge, 2010; The Encyclopedia of Earth, 2010; USGS, 2010).

The history of geographic information may be taken as the history of cartography, which goes back as long as the history of man. As information technology developed, the use of geographic methods improved (The Encyclopedia of Earth, 2010). In the 1980's, the use of GIS started to become widespread due to the improvement in software applications, which enabled working on maps in the same way as databases did.

GIS technology can be used for scientific investigations, resource management, environmental studies and planning. A GIS makes it possible to link different information that is difficult to associate (GIS Development, 2010; USGS, 2010).

Data can be observed in the form of a raster, vector or attribute format, and can be two or three dimensional. Data restructuring can be performed by a GIS in converting data from different formats, and it can quickly generate new maps. Furthermore, a GIS can recognize and analyze the spatial relationships among mapped objects such as figuring out the adjacency, containment, proximity etc. Thus, a GIS can use combinations of mapped variables to produce new variables and information for decision makers.

2.5 Principal Component Analysis (PCA)

PCA, as a statistical method, reduces a complex data set to a lower dimension and offers a clear vision to detect relationships between variables. In other words, PCA strives to explain the structure of a data set using a new set of coordinate systems that is less in dimension than the number of original variables.

For example, given a set of M variables (dependent to X), a principal component model aims to transform these variables into a new set lesser in dimension, i.e. C < M. Each coordinate in the new transformed system is known as a Principal Component (PC) and named as PC1, PC2; PC3… Figure 2.1 shows the transformation of a three-dimensional data to a two-dimensional Principal Component Model.

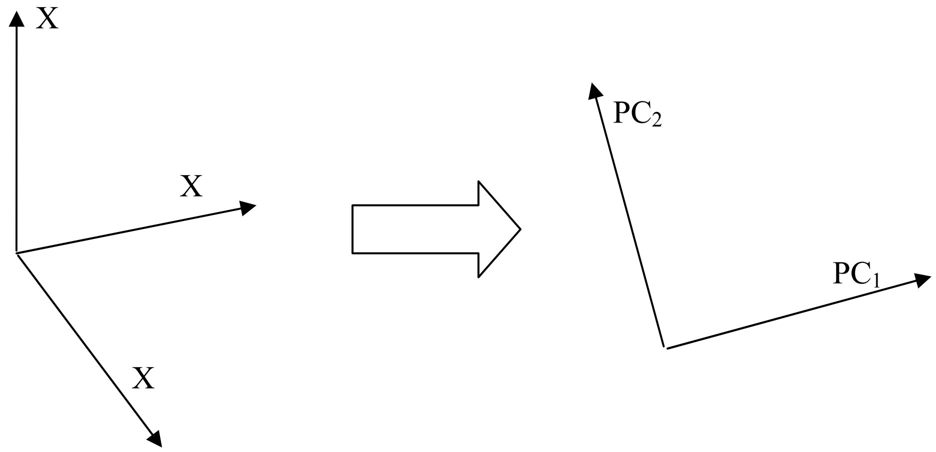


Figure 2.1 A schematic transform of three-dimensional data (left) to two-dimensional principal component (right)

In problems with a large number of variables and outcomes, PCA is a useful technique to attain an effective number of variables in the PC model. The first few principal components are interpreted in terms of the original variables and thereby a greater understanding of the data is estimated. However, just like many other methods of statistical inference, a preprocessing stage is required to transform the original data for the analysis.

2.5.1 Preprocess

Variables have substantially different ranges such as wide or narrow variances due to units of measurements or nature of variables themselves. However, numeric range of a variable can not indicate how important that variable is. Therefore, in order to determine a more important variable amongst all data, a process can be applied to facilitate the detection of the important variable.

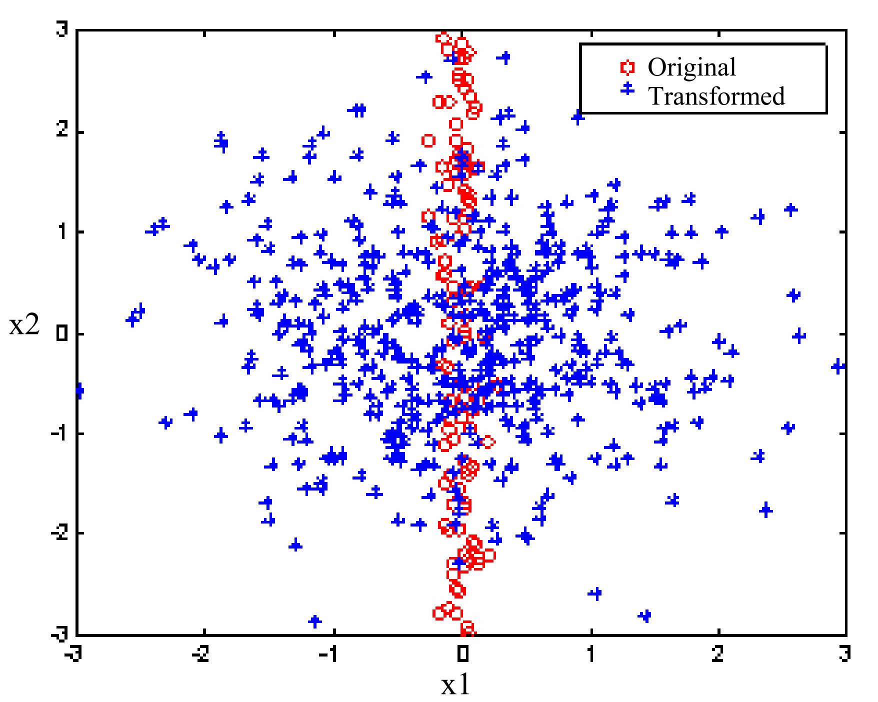


Figure 2.2 A schematic view between original and transformed variable

The variable represented with red circles in Figure 2.2, demonstrates a little variability on X_1, as compared to variability on X_2. However, after data scaling is applied to the original data, the picture changes and the variability on both axes shows comparable contributions.

Due to natures of the variables themselves, an immediate visual inspection of the original data provides with the false impression that most of the variability comes from the second dimension X_2. After scaling the variables, the first dimension X_1 adds as much variability to the data set as X_2. If no scaling is used, this superficial influence leads to faulty models. Therefore, a scaling process is used and data is transformed to the scaled data.

2.5.2 Mean Centering and Unit Variance

Unit variance scaling and mean centering preprocess are used to transform the data set. Unit variance preprocess converts every variable in the data set to a new variable with unit variance. Mean centering preprocess defines a new point of origin for the data set (Figure 2.3).

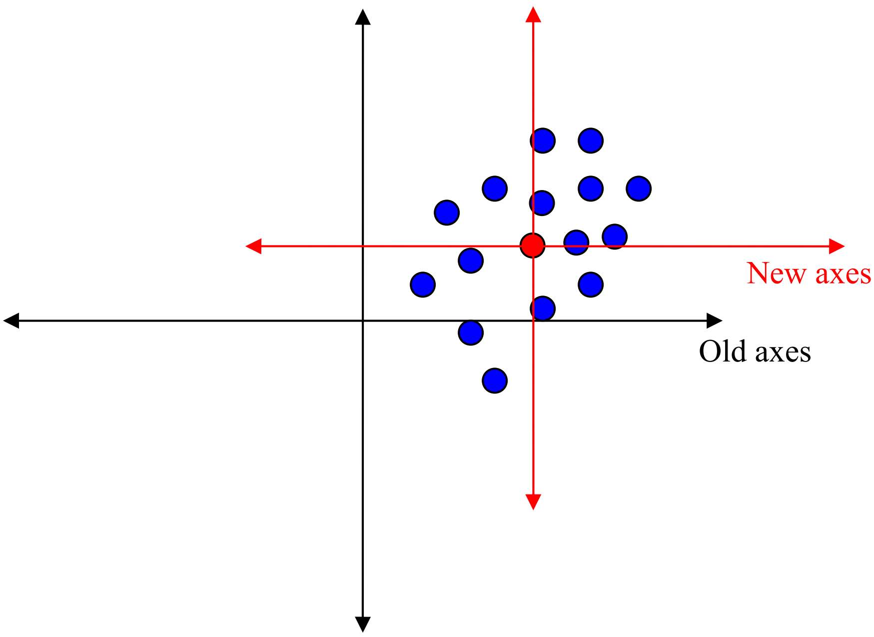


Figure 2.3 Mean centering in two dimensions

Mean centering and unit variance scaling are applied to the original data set with the formula defined below:

$$z_i^m = \frac{x_i^m - \mu}{\sigma} \quad (1)$$

$$\mu^m = \frac{1}{N}\sum_{i=1}^{N} x_i^m \quad (2)$$

$$\sigma_m^{\ 2} = \frac{1}{N-1}\sum_{i=1}^{N}\left(x_i^m - \mu^m\right)^2 \quad (3)$$

Where z_i: transformed variable, x_i: original variable, for i=1,…,N (observations of the variable), μ: mean of the data set, σ: standard deviation of the data set, σ^2: variance of the data set, m: variable number.

Transformation of the original variables becomes comparable in values. Thus impression of larger values to smaller values can be eliminated and the model can be interpreted on the basis of equally importance. In other words, scaling helps to treat all variables equally.

Mean centering and unit variance scaling assume central limit theorem that states if a variable size goes to infinity, the distribution of the independent random variables (each with finite mean and variance) will be approximately normally distributed (Rice John A., 1995).

2.5.3 PCA in One Dimension

If we assume a data z as bivariate, i.e. contains only two variables as shown in Figure 2.4. Such a data can be represented using a single PC and can be denoted by PC1, where the PC1 is passing through the mean of the multivariate variable.

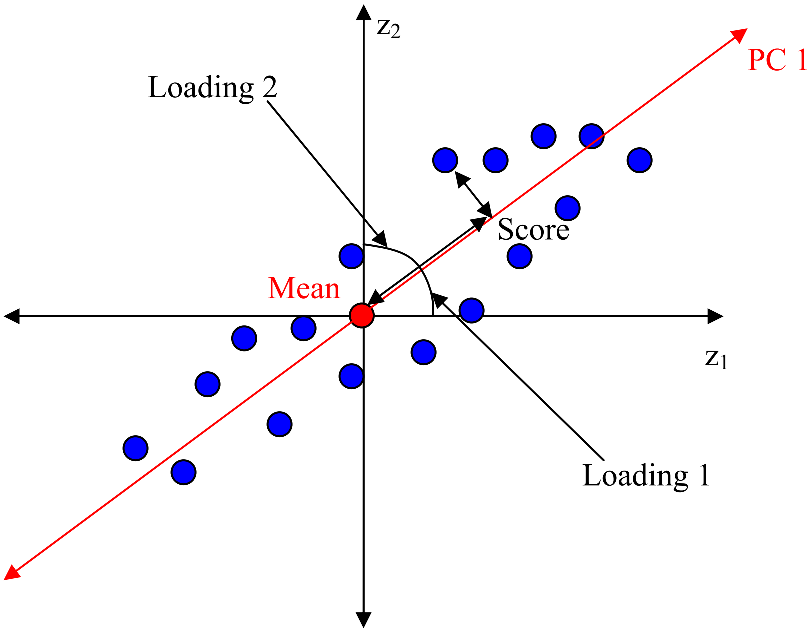


Figure 2.4 A schematic consisting of a 2-dimensional data represented by 1-dimensional PC model

The orientation of the PC1 is chosen such a way that it captures the maximum variability in data. The projected data on the PC1 represents each observation in the original data set z_i. The projection of z_i along the direction of PC1 is named as score (t_i). In other words, t_i is the new value of the original data set in the new coordinate system PC1. Besides, the cosines of the angles between PC1 and z_1, and PC1 and z_2 are the loading factors of z_1 and z_2, respectively.

2.5.4 PCA in Multiple Dimensions

Depending on the dimensionality of X, more than one PC is needed to adequately capture the variability. The first PC captures the most variability and second PC becomes lesser variability according to preceding PC. The PCs are orthogonal, i.e., the angles between PCs are 90^o. Thus, the PCs form an orthogonal system whose origin is the mean of the original data and orientation is defined by the loading factors.

2.5.5 Description of the Mathematical Model

The predictions $\hat{X}$ of the PC model can be calculated as:

$$\hat{X} = T \times P^T \tag{4}$$

If the matrix P defines the orientation of the principal components with respect to old coordinate system:

$$P^T = \begin{pmatrix} P_1 \\ P_2 \\ \cdot \\ \cdot \\ \cdot \\ P_C \end{pmatrix} = \begin{pmatrix} P_{11}....P_{M1} \\ P_{12}...P_{M2} \\ \cdot \\ \cdot \\ \cdot \\ P_{1C}...P_{MC} \end{pmatrix} \tag{5}$$

where *C* is the number of PCs in the model and *M* is the number of variables in X. Then in the t-scores matrix, T defines the representation of the original observations in the new coordinate system:

$$T = \begin{pmatrix} t_1 \\ t_2 \\ . \\ . \\ . \\ t_N \end{pmatrix} = \begin{pmatrix} t_{11}...t_{1C} \\ t_{21}...t_{2C} \\ . \\ . \\ . \\ t_{N1}...t_{NC} \end{pmatrix} \qquad (6)$$

The representation of the original data set X with the aid of an arbitrary number of C (up to M) principal components can be written as:

$$z = \hat{X} + E \qquad (7)$$

where z is the preprocessed data and $\hat{X}$ are the predictions of the PC model for z. However the residuals, i.e., differences between z and $\hat{X}$ gives the noise matrix E:

$$E = z - \hat{X} \qquad (8)$$

The matrix T x P^T can also be written as its vector components:

$$T \times P^T = t_1 p_1^T + t_2 p_2^T + ... + t_C p_C^T \qquad (9)$$

$$T = (t_1,...,t_C) \qquad (10)$$

$$P = (p_1,..., p_C) \qquad (11)$$

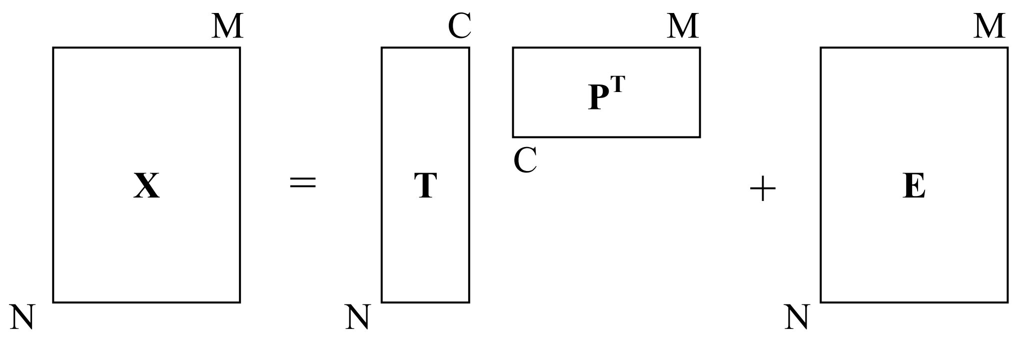


Figure 2.5 An algebraic representation of PC model

The N x C matrix T contains the scores of the principal components. In other words the projection of z_i along the direction of PC forms the N x C matrix T, where C is the principal components and N is the cases (Figure 2.5).

The loading factors of the principal components that geometrically determine the orientation of the principal components with respect to the original coordinate system form the C x M matrix P, where C is the principal components and M is the variables. Besides, P algebraically determines how well a variable will contribute to forming the scores (Figure 2.5).

The loading factors are arranged in the order of the largest eigenvalues of the covariance matrix XX^T. In other words, the rank of the eigenvalues forms the rank of the principal components. Adding more components gives closer prediction $\hat{X}$ to z, and the smaller sum of square error (i.e. the sum of square of the elements of E) as shown in Figure 2.6.

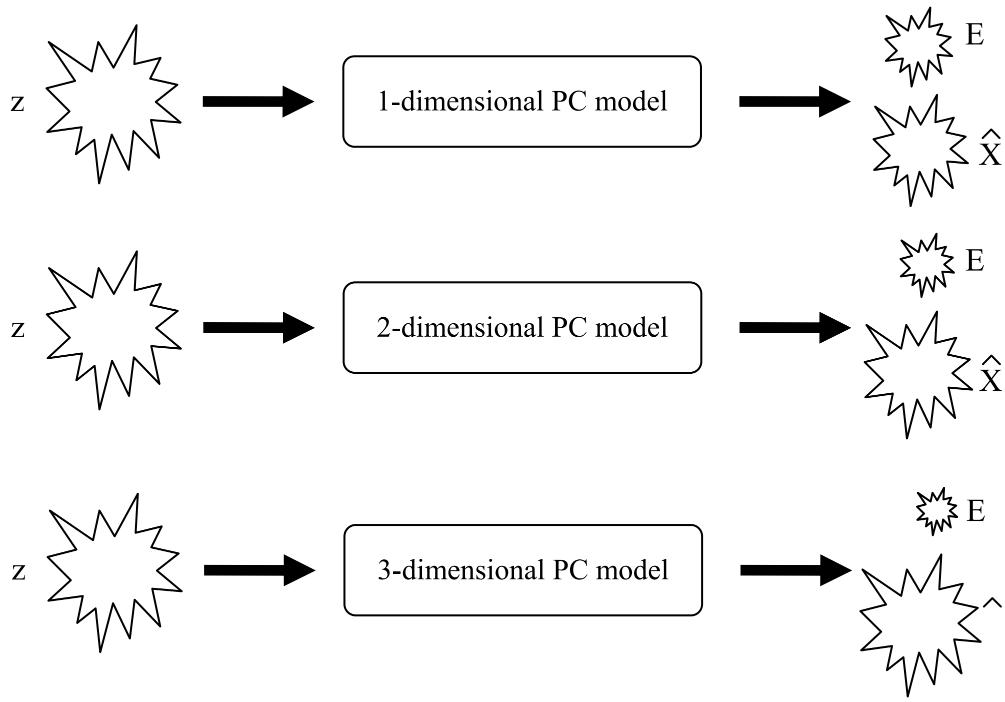


Figure 2.6 A progressive PC model with 1, 2 and 3 principal components

2.5.6 Data Diagnostic with the PCA

It is possible to see the importance of the original variable and their correlations by considering the loading factors and the scores. Another tool in PCA is the residuals. Residuals are the parts of the preprocessed data that are not captured by the principal components.

PCA has the ability to diagnose data on observation and variable levels. Diagnostics on the variable level helps to decide how well the variables are represented. Alternatively, diagnostics on an observation level helps to detect and identify outliers. Outliers are observations that do not fit the normal trend in the data set. Furthermore, strong outliers pull the model toward themselves. One way to visualize strong outliers is the Hotelling T^2, given by:

$$T_i^2 = \sum_{k=1}^{C} \frac{t_{ik}^2}{s_{ik}^2} \tag{12}$$

where t_{ik} is the score of the i^{th} observation for the k^{th} variable, s_{ik}^2 is the estimated variance of t_k. Note that s_{ik}^2 ensures that each PC has equal chance in calculating T^2.

The Hotelling T^2 is not sufficient for predicting outliers; observations that are not present in the data set were used to build the PC model. A better quantity is the Square of the Predictions Error SPE (Q). For the i^{th} observation SPE (Q) is defined as:

$$SPE(Q) = \sum_{i=1}^{M} \left(z_{ij} - \widehat{X}_{ij}\right)^2 \tag{13}$$

where z_{ij} and $\widehat{X}_{ij}$ are the elements of z and $\widehat{X}$, respectively.

Moderate outliers do not have the power to pull the model toward themselves and cannot be easily detected with the Hotelling T^2. An alternative approach is offered by the residuals (i.e., elements of matrix E). The residuals are used to detect the so-called distance-to-model (D-To-Model). A data case is labeled as an outlier if the corresponding value of its distance-to-model is found to exceed a given threshold value. For a typical observation i, the distance-to-model is calculated as:

$$D - To - Model_i = \sqrt{\frac{\sum_{j=1}^{M} \left(z_{ij} - \widehat{X}_{ij}\right)^2}{DF}} \tag{14}$$

where degree of freedom DF is defined as the difference between the number of variables and the number of principal components:

$$\text{DF} = \text{M} - \text{C} \tag{15}$$

The elements of the residual matrix E can also be used for data diagnostics on a variable level. For example, the importance of a variable is based on how well it is represented by the PC model. This is measured by the modeling power:

$$Power = 1 - \frac{SV_j}{SV_j^o} \tag{16}$$

where SV_j is the residual standard variation of the j^{th} variable and SV_j^o is its initial standard deviation. SV_j^o is equal to unity for all variables in z because of the scaled data. A variable is completely relevant if its modeling power is equal to 1. So variables with low modeling power have little relevance.

For example, Variables v1, v3 and v4 are positioned on the same side of the plot and positively correlated among themselves. However, they are negatively correlated with respect to v2 because of the relative location of these variables (Figure 2.7).

The variables v3 and v4 are close, which means that they have similar effect in the PCA model and they are also positively correlated. Variable v1 affects the PC model in the same way as v3 and v4. Variable v2 has less effect as compared to v1, v3 and v4 because it is located near the origin. As it gets further from the origin, the influence will increase.

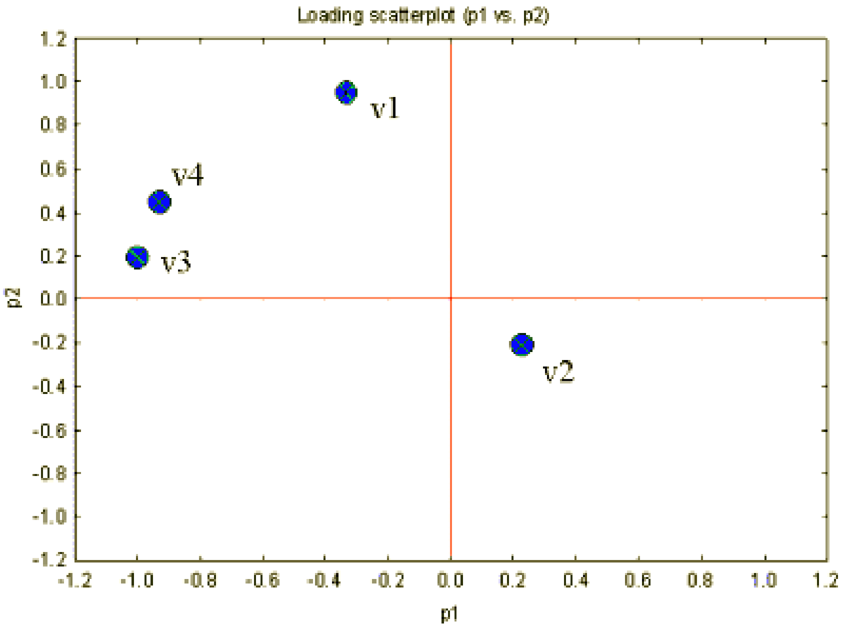


Figure 2.7 The scatter plot of the loading factors for the PC1 and PC2

Other quantities useful for PC model diagnostics are the *fraction of the explained variation R^2X* and the *fraction of predicted variation Q^2X*. R^2X is measured on the entire training sample using the formula:

$$R^2X = 1 - \frac{residual \;\; sum \;\; of \;\; squares}{sum \;\; of \;\; squares} \tag{17}$$

The cumulative $R_A^2X(cum)$ is given by:

$$R_A^2X(cum) = 1 - \frac{\sum_{i,j}\left(x_{i,j} - \widehat{X}_{i,j}^A\right)^2}{\sum_{i,j} x_{i,j}^2} \tag{18}$$

where $\widehat{X}_{i,j}^A$ is the prediction of the PC model (with A components) for the ith observation of the jth variable. Thus R_{A+1}^2X, due to adding the next principal component, can be written as:

$$R_{A+1}^2 X = R_{A+1}^2(cum) - R_A^2(cum) \tag{19}$$

The predictive variation of Q^2 is mathematically identical to R^2X:

$$Q^2 = 1 - \frac{predictive\ \ residuals\ \ sum\ \ of\ \ squares}{residual\ \ sum\ \ of\ \ squares\ \ for\ \ the\ \ previous\ \ component} \tag{20}$$

Given a PC model with a principal component Q^2 *(cum)* is defined as:

$$Q^2(cum) = 1 - \prod_{k=1}^{A} \left(\frac{predictive\ residuals\ sum\ of\ \ squares}{residual\ sum\ of\ \ squares\ for\ the\ previous\ component} \right)_k \tag{21}$$

If more components are added to the PC model, Q^2 and $Q^2(cum)$ increases to a certain point. This point provides an estimate to the numbers of the principal components. It is also possible to define $Q^2(cum)$ for a single variable j:

$$Q^2V(cum) = 1 - \prod_{k} \left(\frac{predictive\ residuals\ sum\ of\ \ squares}{residual\ sum\ of\ \ squares\ for\ the\ previous\ component} \right)_{jk} \tag{22}$$

Q^2V can explain how well a variable is represented by the principal components.

2.5.7 Limit and Significance of a Principal Component

To declare a PC as significant, a limit is determined. The limit of the k^th^ PC is defined as the ratio of the degree of freedom DF_k to the total degree of freedom DF_k^{total}:

$$Limit_k = \frac{DF_k}{DF_k^{total}} \tag{23}$$

A PC is regarded as significant if one of the following rules is satisfied:

1. Q^2>Limit
2. At least $\sqrt{M}$ variables has Q^2V>Limit.

2.5.8 Determination of Optimal Principal Component

PCA is a useful tool for the representation of the original variables in lesser dimension. However to determine the number of principal components C, a suitable method should be used. A model with an insufficient number of components cannot predict the data accurately enough. Moreover, a model with too many components has more components than it needs in predicting the data.

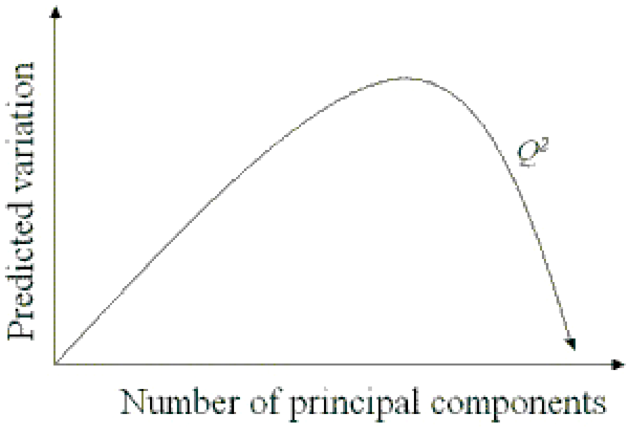


Figure 2.8 The variation of Q^2 with increasing principal components

The peak of the variation fixes the optimal number of components. As more components are added to the PC model, Q^2 increases. However, this trend will change after a certain number of PC and will decrease. The peak point of the variation of Q^2 provides an estimate for C (Figure 2.8).

2.5.9 The Method of Cross Validation

By calculating Q^2 for PC models with increasing principal components, the optimal number of principal components can be found. Either the v-fold or Krzanowski cross-validation method can be used.

In *v-fold* cross validation, the data is divided into *v* segments, *v-1* of which is used to build the model, and the rest is used for testing. This process is then repeated for all possible permutations of the training and testing segments, and the overall Q^2 and Q^2V are calculated for the newly added principal component using the test samples. The significance of a principal component is determined by using the limit criteria and rules in the section “Limit and Significance of a Principal Component”.

In contrast to *v-fold* cross-validation, *Krzanowski* (Eastman & Krzanowski, 1982) does not partition the data into folds, but rather removes an entry for all entries one at a time. This missing entry is treated by the *NIPALS* algorithm as missing data, and then the model is used to predict its value. The value is then used for calculating Q^2 and Q^2V, and for the significance of the PC as well.

Whether using *Krzanowski* or the standard *v-fold* cross-validation method, the above steps are repeated by increasing the number of principal components, starting from 0. For each added component, the test of significance is applied. This process is repeated until an insignificant PC is found.

2.5.10 The NIPALS Algorithm for PCA

The *NIPALS* algorithm is an iterative procedure used for constructing PC models. The algorithm extracts one PC at a time. A better loading factor *P* is searched at each iteration. After finding the value of *P*, it is then used to improve the estimate of *t*:

1. To start the iterative procedure for extracting a component, a value of t_k is assumed as the starting point. This initial value may be selected from a column of z (preprocessed data) with the highest remaining residuals.
2. Next the estimate of the loading vector P_k is improved by projecting the z_{k-1} on the scores t_k.

$$P_k = \frac{t_k^T z_{k-1}}{t_k^T t_k} \quad \text{and normalizing its length using} \quad P_k = \frac{P_k}{\left\| P_k^T P_k \right\|} \qquad (24)$$

3. Similarly, the t_k is improved by projecting the matrix z_{k-1} on the loading vector P_k.

$$t_k = \frac{X_{k-1} P_k}{P_k^T P_k} \tag{25}$$

4. Using the k^{th} scores, the eigenvalues are re-estimated from:

$$\lambda_k = t_k^T t_k \tag{26}$$

5. If the difference between the estimates of λ_k from two successive cycles is below a certain threshold, the algorithm converges. If not, steps 2 through 4 will be repeated.

2.5.11 Categorical Variables

Categorical variables are in discrete forms such as, *male* and *female* or *red*, *green*, and *yellow*. Such variables can be represented using a *1-of-N* coding scheme. For example, if a variable consists of three categories; *A, B*, and *C* then a natural representation of the variable would be (*1, 0, 0*), (*0, 1, 0*) and (*0, 0, 1*), depending on whether the outcome is *A, B, or C*, respectively. Categorical variables should be determined to create a suitable PC model.

2.6 Neuro-Fuzzy Model

Neuro-fuzzy proposed by Jang (1992) is the combination of artificial neural networks and fuzzy logic. The human-like reasoning style of fuzzy systems is combined with the learning and connectionist structure of neural networks. Thus, advantages of these two techniques can also be used.

2.6.1 Artificial Neural Networks (ANN)

ANN, also called Neural Networks (NN) are models based on the working mechanism of the biological neural networks. The fundamental element of biological neural networks is neuron. There are approximately 10^{11} neurons in the human brain cortex and each neuron has 1000 to 10000 connections with other neurons. The neuron consists of axon, dendrites and cell body (Figure 2.9). Signals from a neuron coming to the cell body by dendrites are transmitted by axon. The coming signal changes the stability of the cell body and stimulations of the cell body cause chemical reactions. Transmission of signal to other neurons synapse and synaptic gap is located between axon and dendrites. The new synaptic connections or change of the synaptic connections cause the learning process.

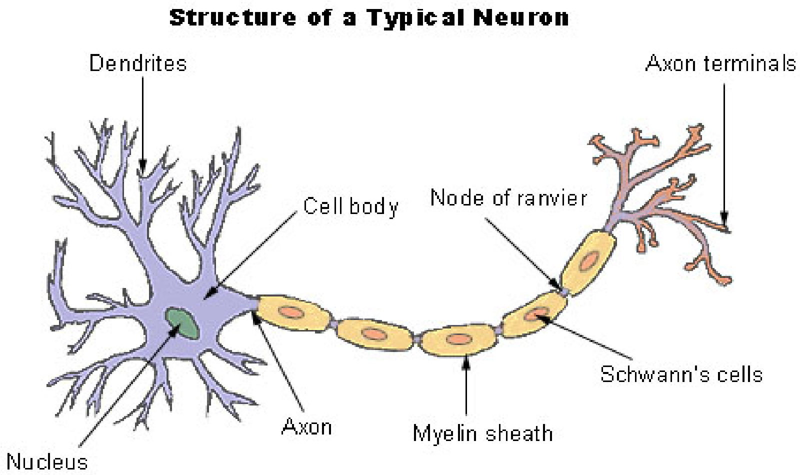


Figure 2.9 Structure of a typical neuron (E-Library, Medicine, 2010)

ANN are based on the simplified mathematical model of biological neurons:

- Axon and dendrites ➔ connections (signals from/to cells)
- Synapse ➔ weight factor
- Chemical reactions ➔ limit values

Coming signals to the cell, which depend on the weight factor, are transformed to the output signals with the help of a nonlinear function considering the body cell balance and limit values. The change of the weight factor is equivalent to the learning process of the biological neuron (Figure 2.10).

The origin of the NN began in the 1940s with the work of McCulloch and Pitts (1943), who proved that ANN could compute any arithmetic or logical function. They also showed that any arbitrary logical function could be configured by a NN. The first practical application of ANN was presented by Rosenblatt in the late 1950s. He published a book called "Principles of Neurodynamics" in 1962. He introduced a learning algorithm by which the weights can be changed, and demonstrated the ability to perform pattern recognition in a perceptron network.

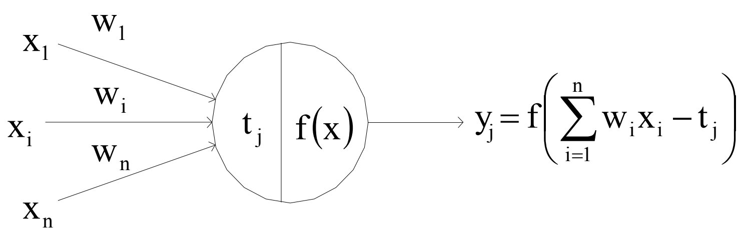


Figure 2.10 Structure of an artificial neuron

In 1960, Widrow and Hoff introduced a new learning algorithm and used it to train adaptive linear Neural Networks, which were similar in structure and capability to Rosenblatt's perceptron. Unfortunately, both Rosenblatt's and Widrow's networks suffered from the same inherent limitations. The single-layer systems were limited and expressed deficiency over multilayer systems.

Neural networks became popular again in the early 1980s, when the method of training a multilayer neural network, known as the backpropagation algorithm was developed by Parker (1985) and McClelland & Rumelhart (1988).

Backpropagation, known as back error propagation, is an effective supervised learning method for training multilayer perceptrons (Rumelhart, Hinton & Williams, 1986). The process consists of two steps: a forward propagating step and a backward propagating step.

In the forward step, the input data of training is used in the input layer. The data propagates on through the hidden layers, until it reaches the output layer, where it displays the output pattern.

In the backward step, the error term is calculated and it propagates back to change the assigned weight factors of the inputs. The magnitude of the error value indicates the adjustment size, and the sign of the error value determines the direction of the change.

Figure 2.10 shows a node of a Backpropagation Multilayer Perceptrons given in Figure 2.11. Usually, the node is a composite of the weighted sum and a differentiable nonlinear activation function. The function is often assumed as:

$$f(x) = \frac{1}{1+e^{-x}} \tag{27}$$

Figure 2.11 shows a multilayer backpropagation with *k* inputs and *n* outputs. There may be several hidden layers with different numbers of neurons between input and output layers.

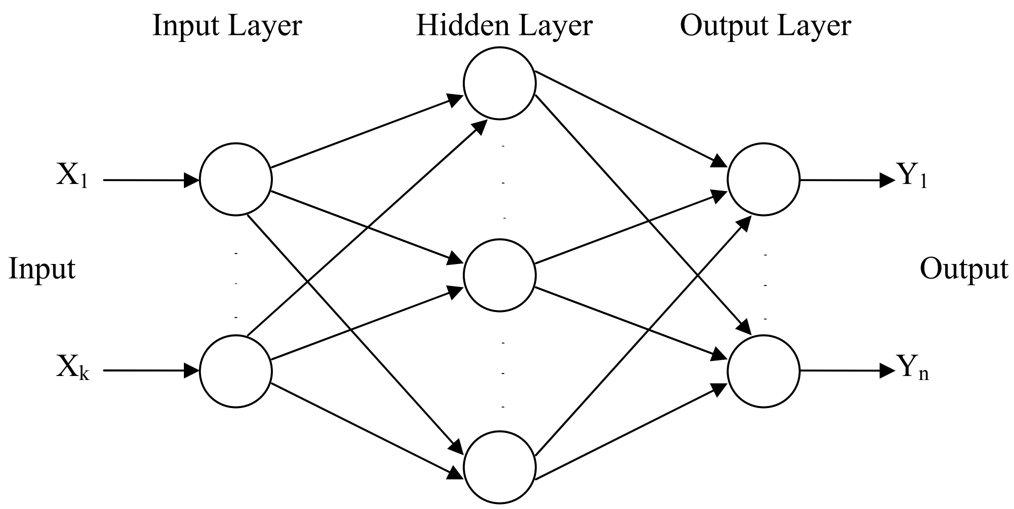


Figure 2.11 A multilayer backpropagation perceptron

Backpropagation algorithm is an iterative algorithm designed to minimize the mean square error between the actual output and the desired output (Lippmann, 1987). The error is defined as:

$$E = \sum_p E_p \tag{28}$$

where E_p is the error for one input pattern, and described as:

$$E_p = \frac{1}{2}\sum_i (T_i - O_i)^2 \tag{29}$$

where T_i is the desired output while O_i is the actual output.

From the backpropagation rule of Rumelhart et al.(1986):

$$W(t+1) = W(t) - \eta \frac{\partial E}{\partial W} \quad (30)$$

The weight change according to the gradient of the error is:

$$\Delta W_{ji} = \eta \delta_j X_i \quad (31)$$

where η is learning rate affecting the convergence speed and stability of the weights; W_{ji} is the weight of the connection from node i to j; δLj is error term of node j and X_i is the input of the node j.

A recursive method is used to adjust weights starting from the output nodes to the first hidden layer with the formula:

$$W_{ji}(t+1) = W_{ji}(t) - \eta \delta_j X_i(t) \quad (32)$$

The success in application of NN provides choices in solving a wide range of problems such as image processing, signal processing, pattern recognition, speech recognition, industrial control, aerospace, manufacturing, medicine, business, finance, …etc. The NN are mostly used because of their applicability to complex nonlinear systems and multivariable systems.

2.6.2 Fuzzy Logic

Fuzzy logic was developed to represent uncertain and indefinite knowledge. It provides information about the behavior of systems that are too complex or not easily analyzed. “Inferencing” is a key of any fuzzy system. A typical fuzzy inference system consists of membership functions (MF), a rule base and an inference procedure.

2.6.2.1 Fuzzy Sets

A fuzzy set is a set with smooth boundary. Let X be a space of objects and x is an element of X. In classical set theory, a subset A of the universe X is defined by its binary (0 or 1) characteristic function $\mu_A(x)$: $X \rightarrow [0,1]$ such that $\mu_A(x) = 1$ if $x \in A$ and $\mu_A(x) = 0$ if $x \notin A$. However, the characteristic function of a fuzzy set allows to have values between 0 and 1, where A is called a fuzzy set and μA is called the membership function of A (Zadeh, 1965). The fuzzy sets can either be discrete or continuous.

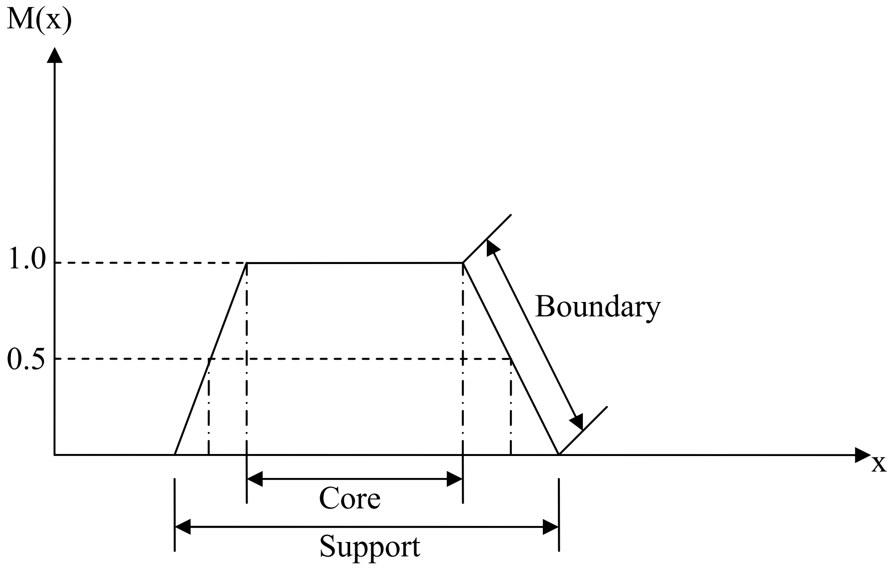


Figure 2.12 A membership function

A fuzzy set is uniquely characterized by its membership function. The basic features about membership functions are graphically shown in Figure 2.12. The basic concepts and terminology of membership functions are as follows (Deng, 2002):

- Support

The support of a fuzzy set A is the set of all points x in X such that $\mu_A(x) > 0$:
Support (A) = $\{x \mid \mu_A(x) > 0\}$

- Core

The core of a fuzzy set is the set of all points x in X such that $\mu_A(x) = 1$:

Core (A) = $\{x \mid \mu_A(x) = 1\}$

- Boundary

The boundary of a fuzzy set is the set of all points x in X such that $0<\mu_A(x)<1$:
Boundary (A) = $\{x \mid 0 < \mu_A(x) < 1\}$

- Normality

A fuzzy set is normal if there is a point $x \in X$ such that $\mu_A(x) = 1$

- Crossover point

A crossover point of a fuzzy set is a point $x \in X$ in which $\mu_A(x) = 0.5$:
Crossover (A) = $\{x \mid \mu_A(x) = 0.5\}$

Classical sets have three basic operations: union, intersection, and complement. Fuzzy sets operations were defined in Zadeh's seminal paper (Zadeh, 1965). Assume A and B are fuzzy sets of the universe, X with membership functions μ_A and μ_B. The union $A \cup B$, intersection $A \cap B$ and complement $\overline{A}$ are defined as:

- Union $\mu_{A\cup B}(x) = \max(\mu_A(x), \mu_B(x)) = \mu_A(x) \vee \mu_B(x)$
- Intersection $\mu_{A\cap B}(x) = \min(\mu_A(x), \mu_B(x)) = \mu_A(x) \wedge \mu_B(x)$
- Complement $\mu_{\overline{A}}(x) = 1 - \mu_A(x)$

Furthermore, other operators have been introduced to extend the classical set operations (Fodor & Roubens, 1994). These operators are referred to as T-norm (Dubois & Prade, 1980) for the intersection, T-conorm or S-norm (Dubois & Prade, 1980) for the union, and negation for the complement.

2.6.2.2 Membership Functions

A fuzzy set can be defined mathematically by membership function if it is continuous. Although there exists many types of membership functions, the most commonly used membership functions in practice are trianglar, trapezoidal, Gaussian, and bell curves shaped.

- Triangular Membership Function

A triangular membership function is specified by three parameters (a, b, c) as:

$$\text{Triangle}(x;a,b,c)=\begin{cases} 0 & x \le a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ \dfrac{c-x}{c-b} & b \le x \le c \\ 0 & c \le x \end{cases}$$

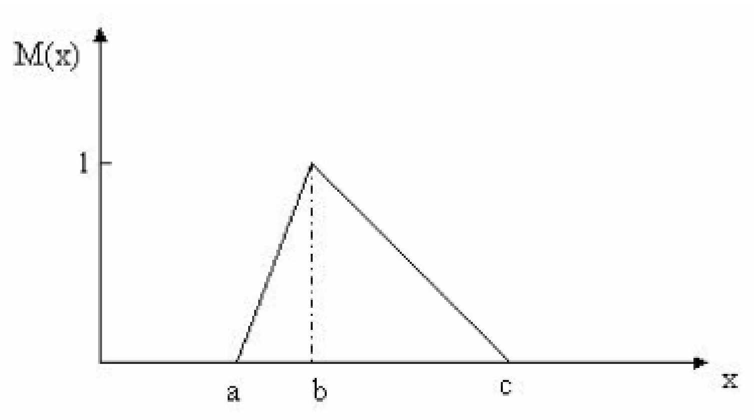


Figure 2.13 Triangular membership function (Deng, 2002)

- Trapezoidal Membership Function

A trapezoidal membership function is specified by four parameters (a, b, c, d) as:

$$\text{Trapezoid }(x;a,b,c,d) = \begin{cases} 0 & x \le a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \dfrac{d-x}{d-c} & c \le x \le d \\ 0 & d \le x \end{cases}$$

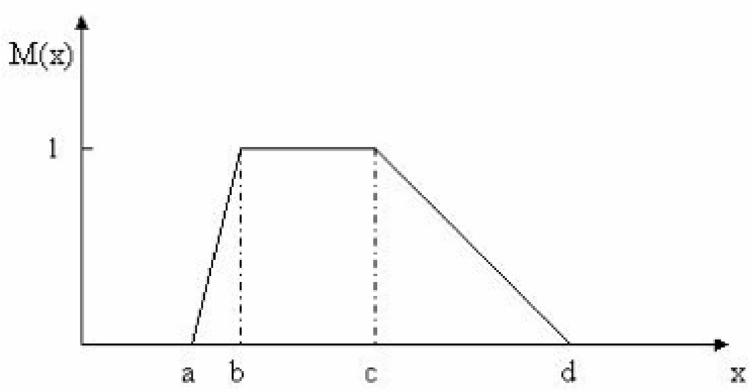


Figure 2.14 Trapezoidal membership function (Deng, 2002)

- Gaussian Membership Function

A Gaussian membership function is specified by two parameters (c, σ) as:

Gaussian (x; c, σ)=$e^{\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2}$

where c is the membership functions center and σ is the membership functions width.

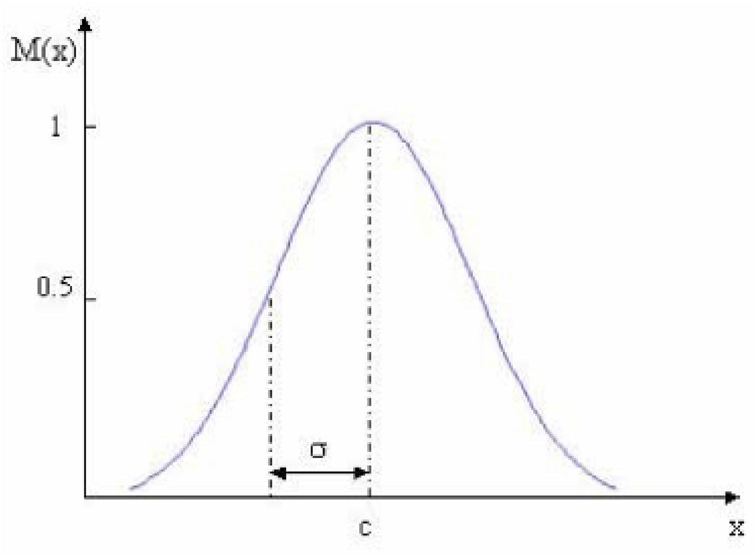


Figure 2.15 Gaussian membership function (Deng, 2002)

- Generalized Bell Membership Function

A generalized bell membership function is specified by three parameters (a, b, c) as:

$$\text{Bell}(x; a, b, c) = \frac{1}{1 + \left| \frac{x-c}{a} \right|^{2b}}$$

where a is the membership functions width, b is the slopes at the crossover points and c is the membership functions center.

Triangular membership functions and trapezoidal membership functions have been widely used due to their simplicity and computational efficiency (Yen & Langari, 1999).

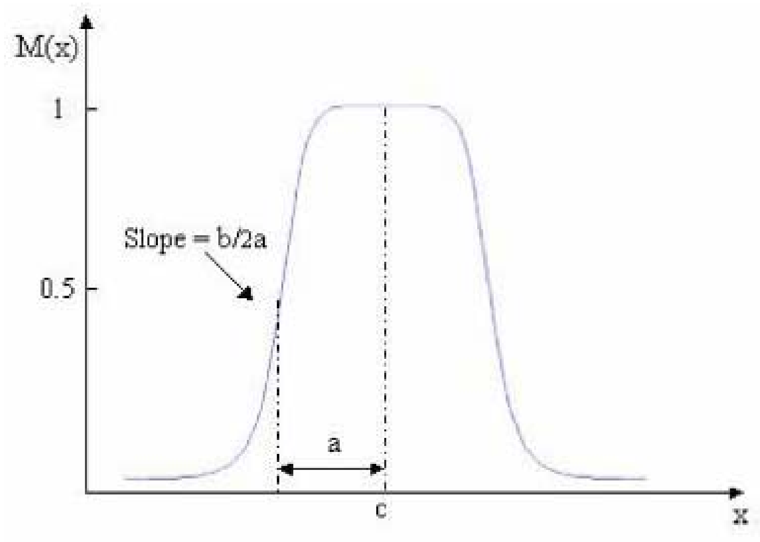


Figure 2.16 Generalized bell membership function (Deng, 2002)

2.6.2.3 If-Then Rules

If-then rules are the rule base of the system. It is a knowledge representation scheme for capturing knowledge. Generally, this scheme is achieved by using linguistic variables (Zadeh, 1973; Zadeh, 1975).

A fuzzy if-then rule takes a form as:

IF x is A_n THEN y is B_n (x)

where A_n and B_n are linguistic values defined by fuzzy sets on universes X and Y, respectively.

Often, the "if part" is called the antecedent or premise, and the "then part" is called consequence or conclusion. The fuzzy sets in a rule's antecedent define a fuzzy region of the input space. The consequent of fuzzy rules can be classified into three categories (Yen & Langari, 1999):

a. Crisp Consequent: IF… THEN y = a.
where a is a nonfuzzy numeric value or a symbolic value.
b. Fuzzy Consequent: IF… THEN y is A.
where A is a fuzzy set.

c. Functional Consequent: IF x_1 is A_1, x_2 is A_2, … and x_k is A_k THEN $y = a_0 + \sum_{i=1}^{k} a_i * x_i$.

where a_0, a_1 … a_k are constants.

2.6.2.4 Fuzzy Reasoning

Fuzzy reasoning, also called approximate reasoning, is an inference procedure that derives conclusions from a set of fuzzy if-then rules and known facts.

The process of fuzzy reasoning can be divided into four steps (Jang, Sun & Mizutani, 1997):

1. Degrees of compatibility: Compare the known facts with the antecedents of fuzzy rules to find the degrees of compatibility with respect to each antecedent membership function.
2. Firing strength: Combine degrees of compatibility with respect to antecedent membership functions in a rule using fuzzy AND or OR operators to form a firing strength that indicates the degree to which the antecedent part of the rule is satisfied.
3. Qualified (induced) consequent membership functions: Apply the firing strength to the consequent membership function of a rule to generate a qualified consequent membership function.
4. Overall output membership function: Aggregate all the qualified consequent membership functions to obtain an overall output membership function.

2.6.2.5 Fuzzy Inference System

The basic structure of a fuzzy inference system consists of three conceptual components:

- a rule base, which contains a selection of fuzzy rules,
- a database, which defines the membership functions used in the fuzzy rules,

- a reasoning mechanism, which performs the inference procedure upon the rules and given facts to derive a reasonable output or conclusion.

Depending on the types of fuzzy reasoning and fuzzy if-then rules employed, most fuzzy inference systems can be classified into three types, as: Mamdani fuzzy model, Sugeno fuzzy model and Tsukamoto fuzzy model.

- Mamdani Fuzzy Model

Mamdani fuzzy model was proposed to control a steam engine and boiler combination by a set of linguistic control rules (Mamdani & Assillian, 1975). The fuzzy rule in this model is in the form of:

IF x_1 is A_{i1}…and x_n is A_{in} THEN y is C_i.
where x_j (j=1, 2… n) are the input variables, y is the output variable, A_{ij} and C_i are fuzzy sets for x_j and y, respectively.

- Sugeno Fuzzy Model

Sugeno fuzzy model (also known as TSK model) was proposed to develop a systemic approach to generate fuzzy rules from a given input-output data set (Takagi & Sugeno, 1985; Sugeno & Kang, 1988). For a two-input system, the fuzzy rule in this model is in the form of:

IF x_1 is A and x_2 is B THEN $y = f(x_1, x_2)$, where A and B are fuzzy sets in the antecedent, $y = f(x_1, x_2)$ is a polynomial function in the consequent. Yet, it can be any function that can suitably describe the output of the model within the fuzzy region specified by the preceding of the rule. When $f(x_1, x_2)$ is a first-order polynomial function, the resulting fuzzy inference system is called a first-order Sugeno fuzzy model. When $f(x_1, x_2)$ is a constant, the system is referred as a zero-order Sugeno fuzzy model.

- Tsukamoto fuzzy model

Tsukamoto fuzzy model (Tsukamoto, 1979) was proposed as another approach to the fuzzy reasoning method. The fuzzy rule in this model is in the form of:

IF x is A_i THEN y is C_i.

where x is the input variable, y is the output variable, A_i is a fuzzy set with a monotonical membership function, C_i is a crisp value induced by the rule's firing strength.

2.6.2.6 Fuzzy Modeling

In general, the process to construct a fuzzy inference system is called fuzzy modeling. Theoretically, fuzzy modeling can be accomplished in two stages. The first stage is the identification of surface structure, which includes the following tasks (Jang, Sun & Mizutani, 1997):

1. Select relevant input and output variables.
2. Choose a specific type of fuzzy inference system.
3. Determine the number of linguistic terms associated with each input and output variable. For Sugeno model, determine the order of consequent equations.
4. Design a collection of fuzzy rules.

The second stage is the identification of deep structure, which means:

1. Choose appropriate parameters of membership functions.
2. Refine the parameters of the membership functions using regression and optimization techniques.

2.6.3 General Neuro-Fuzzy Architecture

The general Neuro-Fuzzy hybrid system is basically a multi-layered fuzzy rule-based NN, which integrates the basic elements and functions of a traditional fuzzy logic inference into a NN structure (Li, Ang & Gray, 1999). With the input and output membership functions, the system indicates that neural nets could have more crisp and meaningful inputs and thus improve the overall output quality when compared with the standard NN, where the output values are ranging between 0 and 1 by nonlinear transform functions.

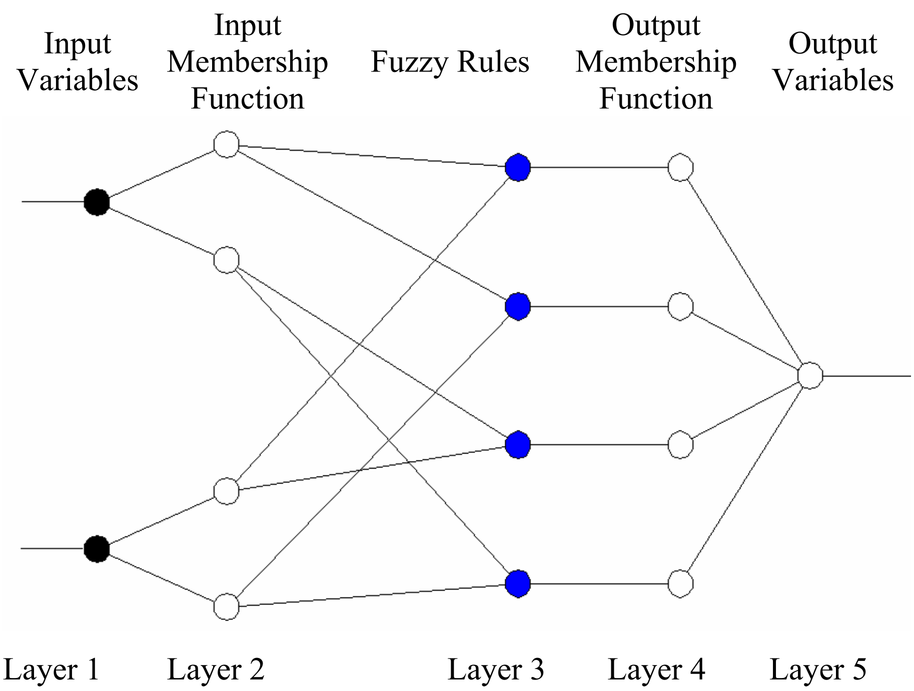


Figure 2.17 General Neuro-Fuzzy architecture

As shown in Figure 2.17, the general neuro-fuzzy structure is a five-layer fuzzy rule-based neural network consisting of nodes in each layer. Input variables are assigned to layer 1, from where the input values transmit to layer 2 directly. Layer 2 works as a fuzzifier, where the outputs represent the membership grade of the corresponding inputs. The nodes in layer 3 performs fuzzy AND operations on their inputs, and the output indicates whether the rule "fires or not", which consequently determines the activation level of layer 4, the output membership functions layer. Finally, layer 5 performs defuzzification of the overall output.

However, the calculation for the defuzzification operation is a time-consuming and intractable task. Further, most of the defuzzification operations being used are based on experimental results, hence are not easily subject to rigorous mathematical analysis. This leads to the consideration of systems that do not need defuzzification operations.

2.6.4 Adaptive Neuro-Fuzzy Inference System (ANFIS) Architecture

ANFIS is an efficient and transparent Neuro-Fuzzy paradigm first proposed by Jang (1992, 1993, and 1996). Sugeno fuzzy model is a suitable choice for the requirement of not using defuzzification operation, and it is widely used in sample-based fuzzy modeling. Assume that the fuzzy inference system under consideration has two inputs x1 and x2 and one output y. For a first-order Sugeno model, a common rule set with two fuzzy if-then rules is the following:

Rule 1: If x_1 is A_1 and x_2 is B_1, then $f_1 = a_1\, x_1 + b_1\, x_2 + c_1$.
Rule 2: If x_1 is A_2 and x_2 is B_2, then $f_2 = a_2\, x_1 + b_2\, x_2 + c_2$.

where A_1, B_1, A_2, B_2 are fuzzy sets, a_i, b_i and c_i ($i = 1, 2$) are the coefficients of the first-order polynomial linear functions. It is also possible to assign a different weight to each rule based on the structure of the system. Figure 2.18 shows the structure of a two-input first-order Sugeno fuzzy model with two rules, where weights w_1 and w_2 are assigned to rules 1 and 2, respectively.

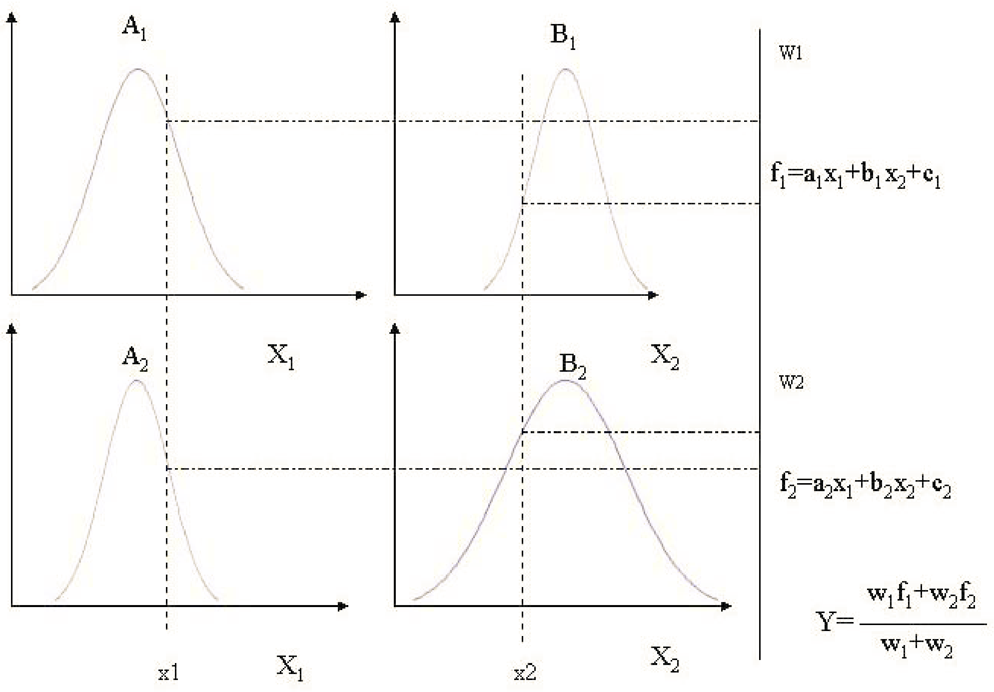


Figure 2.18 A two-input first order Sugeno fuzzy model (Deng, 2002)

Figure 2.19 shows the equivalent ANFIS architecture, where nodes of the same layer have similar functions. Note that Oj,i is the output of the ith node in layer j.

Layer 1: Each node output in this layer is membership grade of a fuzzy set corresponding to each input. The membership function for this fuzzy set can be any appropriate parameterized membership function, such as triangular or trapezoidal function. The parameters of the membership function are the premise parameters of the system.

$$O_{1,i} = \mu_{Ai}(x_1) \qquad i = 1, 2 \text{ or} \tag{33}$$

$$O_{1,i} = \mu_{Bi-2}(x_2) \qquad i = 3, 4 \tag{34}$$

where x_1 and x_2 is the input of node i (i = 1, 2 for x_1 and i = 3, 4 for x_2).

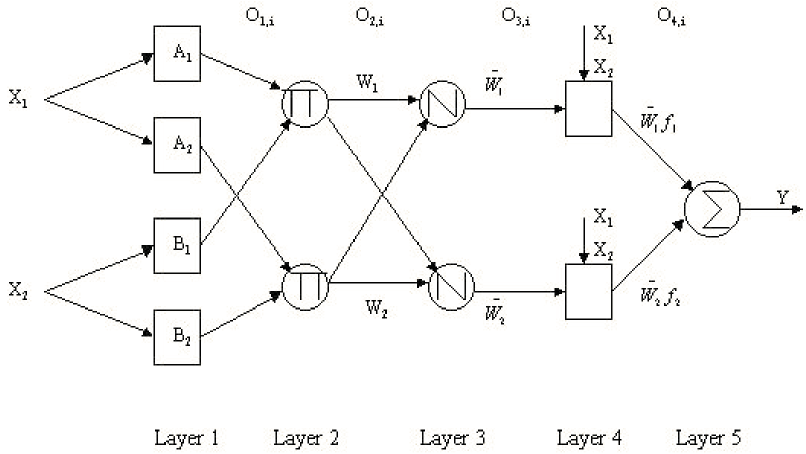


Figure 2.19 Equivalent ANFIS architecture (Deng, 2002)

Layer 2: Each node output in this layer represents the firing strength of a rule, which performs fuzzy AND operations. The output could be the product of all coming signals or the minimum value of all coming signals or other T-norm operation.

$$O_{2,i} = W_i = \mu_{Ai}(x_1)\,\mu_{Bi}(x_2) \qquad i = 1, 2 \tag{35}$$

Layer 3: Each node output in this layer is the normalized value of layer 2, i.e., the normalized firing strengths.

$$O_{3,i} = \overline{W_i} = \frac{W_i}{W_1 + W_2} \qquad i = 1, 2 \tag{36}$$

Layer 4: Each node output in this layer is the normalized value of each fuzzy rule. The coefficients of the polynomial linear equation of each rule are the consequent parameters in the system.

$$O_{4,i} = \overline{W_i} f_i = \overline{W_i}\left(a_i x_1 + b_i x_2 + c_i\right) \qquad i=1, 2 \qquad (37)$$

Layer 5: The node output in this layer is the overall output of the system, which is the summation of all coming signals.

$$Y = \sum_{i=1}^{2} \overline{W_i} f_i = \frac{\sum_{i=1}^{2} W_i f_i}{\sum_{i=1}^{2} W_i} \qquad (38)$$

Where, W_i is weight factor of the i[th] incoming signal, f_i is the function of the i[th] incoming signal, $\sum_{i=1}^{2} W_i f_i$ weighted sum of the incoming signal for 2 layers, $Y=\sum_{i=1}^{2} \overline{W_i} f_i$ is normalized response function for 2 layers.

CHAPTER THREE
GÖKOVA BAY

Muğla is the province with the longest shoreline in Turkey and Gökova Bay (Figure 3.1) is one of the biggest bays in the region. It is located between two important peninsulas: Bodrum and Datça. The population of Muğla province was 715328 in 2000. The counties surrounding Gökova Bay are Muğla, Bodrum, Datça, Marmaris, Milas and Ula, and the 2000 Population Census was 83 500, 97 800, 14 000, 79 000, 113 000 and 22 000, respectively. 37 % of the population lives in the cities of the province and record an increase particularly in coastal counties Bodrum, Marmaris and Fethiye.

The shoreline length of Muğla is 1 124 km. Geographical places of the bay are suitable for tourism and particularly important for yacht tourism. Tourism is the major economic sector in Muğla. There are important natural and historical sites in the region having high numbers of visitors in Turkey. Agriculture is the other major sector of Muğla. Agricultural areas represent 16 % of the surface area in study region (Table 3.1), and other parts are mostly mountainous and forest regions. There exist aquaculture sites in Gökova Bay as well.

Table 3.1 Land Cover / Land Use of study area

LandCover /Land Use	Area km^2	% cover
Forest	760	72.7%
Agriculture	175	16.7%
Build Up	21	2.0%
Bare Land	31	3.0%
Burnt areas	59	5.6%

Figure 3.1 Inner part of the Gökova Bay

The land part of the region biome is characterized by shrubs, commonly called Mediterranean vegetation. There exists an important marine biodiversity study carried out in Gökova Bay by the Istanbul University for EPASA. Although the region is a Special Environmental Protection Area (SEPA), wildlife is under threat because of uncontrolled hunting and agricultural activities.

3.1 Study Area

The study area is in Muğla Province which is located in southwest Anatolia. The area consists of five counties (Figure 3.2). The coastal region covers 16 municipalities, which is one-fourth of the total municipality number of Muğla. These municipalities are Muğla, Bodrum, Datça, Marmaris, Milas, Ula, Ören, Akyaka, Armutalan, Gökova, Yerkesik Merkez, Mumcular, Yalı, Bitez, Konacık, and Ortakent. Despite its high spatial coverage area, population density of the region is lower than average as a result of fewer settlements due to topographic structure and special and natural protected areas. The most populated area nearby is Bodrum in the northern outer part of the Gulf. The available data of the study area only cover Special Environmental Protection Area and neighboring.

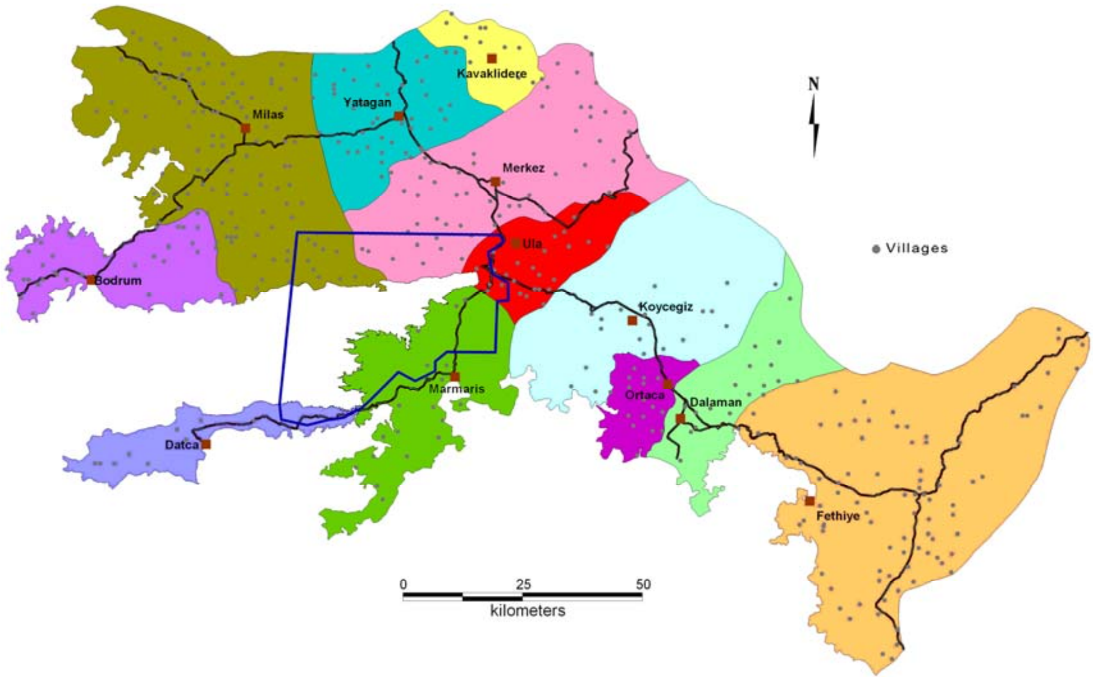


Figure 3.2 Study area and counties of Muğla province

3.2 Special Areas

There are two National Parks in Muğla, which are mainly Saklıkent and Marmaris National Park, but they are not located in the coastal zone under study. There are more natural parks in Fethiye, Ölüdeniz Kıdrak Natural Park, and indeed the province has particular natural wealth. First three of 14 SEPA are found in Muğla in 1988. In addition to all these, there are many forestry recreation and camping sites. Yet, only the two SEPAs and two camping sites are within the scope of the study area.

There are 14 SEPA in Turkey. The most important five are located in Muğla and two of them are in the specified coastal area of our study. 26 % of the surface area of Muğla is considered as SEPA, which make up 30 % of 14 SEPA of Turkey. The EPASA is the administrative body of SEPA.

3.2.1 Gökova Special Environmental Protection Area

The Gökova SEPA covering 576.9 km^2 area was determined and declared by the Decree of Cabinet of Ministers, with the Code Number 88/13019 and date 12.06.1988. Gökova SEPA is one of the first three SEPA in Turkey (Figure 3.3). The population of the area is 7615 according to the population census in 2000 and includes Akyaka, Gökova, Akçapınar, Gökçe, Çamlı, Karacaköy and Çetibeli settlements. Important elevations of the region are West Menteşe Mountains, stretching to Gökova Bay and East Menteşe Mountains forming Ula subsidence and Yaran Mountains, rising dominantly from Gökova Gulf. Agricultural land that is formed with the accumulation of alluviums in small valleys directly open to the sea and the interior subsidence are called Gökova and Kızılyaka Prairies.

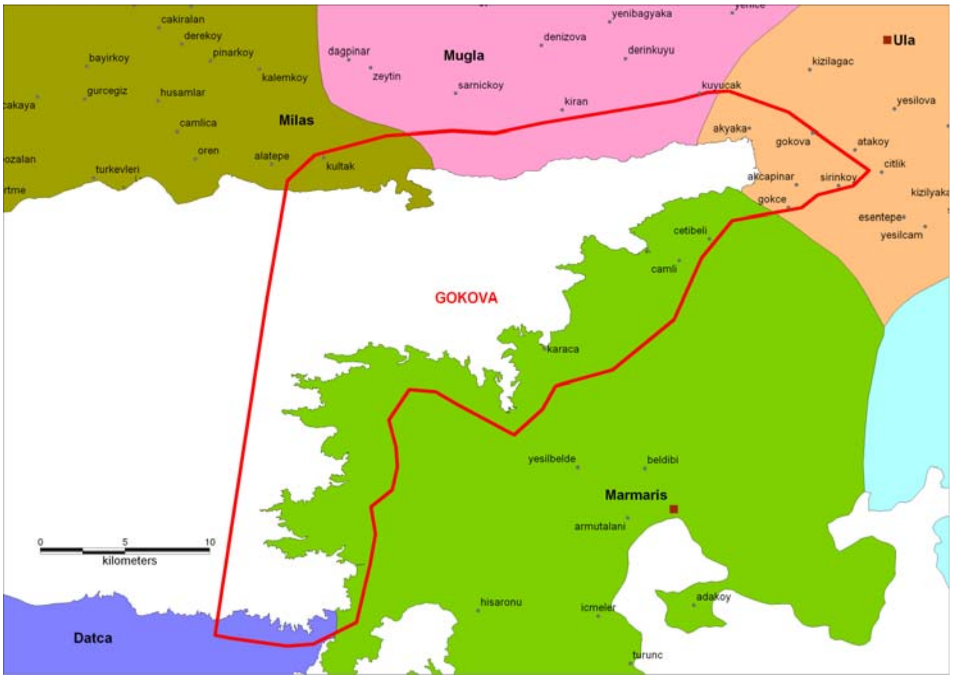


Figure 3.3 Gökova SEPA

Akyaka town, which is in the SEPA and regarded as an important settlement, is located in the Northeast of Gökova Gulf and 28 km away from Muğla. At the North of the Bay there is suddenly rising mountainous topography, covered with forests. At the eastern part of the Bay, there is an unequaled prairie and rush and swamp areas between Kadın and Akçapınar streams.

Another significant area in the region is Sedir Island, which is also known as Ketra, Setra, Sedir or Şehirlioğlu Island. The island is situated in the South of Gökova Gulf and it possesses tablets belonging to Hellenistic and Roman periods. Sedir Island is an important historical site in the region having the maximum visitor number in Muğla.

Gökova SEPA is of great value in terms of the rich fauna, flora and ecology; and its flora are dominated by both Aegean and Mediterranean types of flora features. In addition to shrubs, olive groves are also significant. Moreover, in the region red pine (*Pinus brutia*) and Oriental Sweet Gum forests (*Liquidambar orientalis*) are of great value. Following these, there are trees with needles such as Black Pine (*Pinus nigra*), Aleppo Pine *(Pinus halepensis)*, Seaside Pine *(Pinus maritime)*, Stone Pine *(Pinus pinea)*, Pistachio, Cedar *(Cedrus libani)*, Cypress (*Cupresus sempervirens)* and Juniper, and trees with leaves such as oak. Furthermore, there are sandal, heather, mock privet (*Phillyrea latifolia*), laurel, celtis and carob trees (EPASA, 2006).

Base lands are generally lands associated with 1st to 4th class in terms of the soil's abilities. Apart from base lands, the hillsides, hilly and mountainous areas consist of 6th and 7th class soil types. Scars and moors are defined as 8th class soils (EPASA, 2006).

The fauna of region is rich. There are winged animals seen in almost every part of the region. They are turtle doves, quails, crested wood partridges, pygmy cormorants, terns, swifts, swallows, woodpeckers, starlings, blackbirds, marsh sandpipers, crows, hawks, grey partridges, wild ducks, wild geese, rock sparrows, eagles, falcons, and owls. Marine fauna of the coastal part is also rich. Fish species of the region and other sea products (octopus, lobster and carabidae) are available in the waters of the region (EPASA, 2006).

Another important area that has been focused on since 2005 by researchers is Boncuk Bay, where Sandbar Sharks are breeding. This seldom phenomenon, parturition, occurs in shallow water habitats, providing a 'nursery' area for young sharks where they are protected from predation by larger sharks. Juvenile sandbar sharks remain in the shallows until late fall at which time they form schools and move southward and further offshore only to return for the summer months. There are ongoing research projects about their habits in Boncuk Bay (FLMNH, 2008).

3.2.2 Datça-Bozburun Special Environmental Protection Area

Datça-Bozburun SEPA has 1443.89 km^2 area was determined and declared by the Decree of Cabinet of Ministers, with the Code Number 90/1117 and date 22.10.1990. Our study area covers only a part of the northern coasts of Datça Peninsula (Figure 3.4).

The year 2000 population of the area is 28174 and consists of 2 municipalities and 17 villages in Datça and Marmaris counties in Muğla. Datça is located in the Southwest of Muğla, between Gökova Bay in the North and Hisarönü Bay in the South as a 70-km extension to the west to the Aegean and Mediterranean Seas. The total population of Datça is 13914 according to the population census in 2000. 8108 of the population live in the urban areas, whereas 5806 live in rural areas.

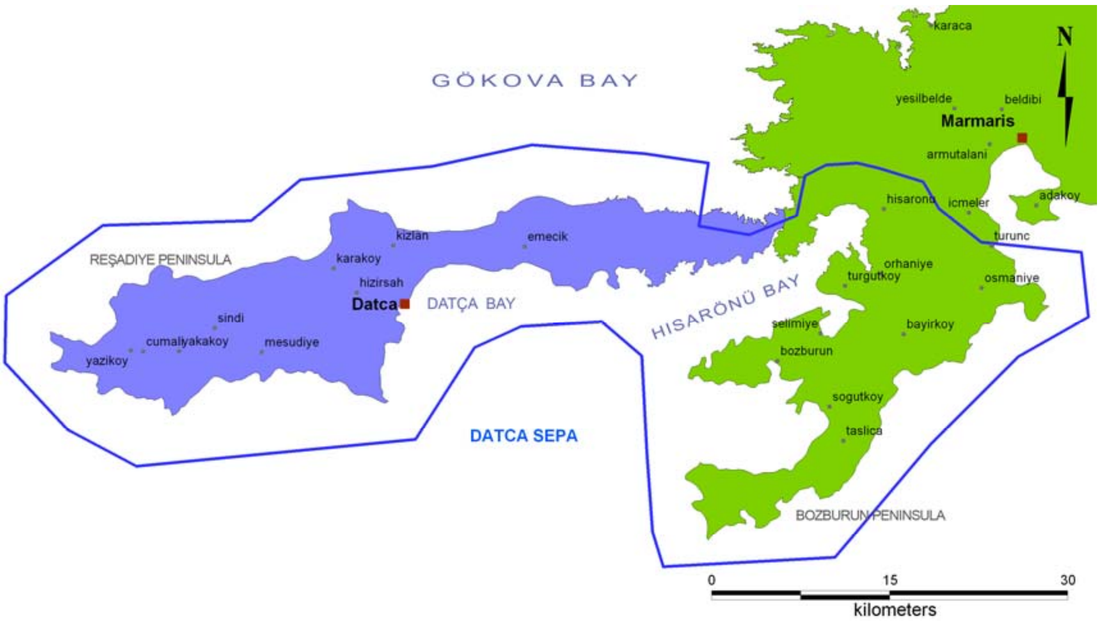


Figure 3.4 Datça SEPA

The peninsula is declared to be a site which needs to be protected in terms of archaeological, urban, natural, historical etc. aspects. These aspects reflect social, economic, and architectural features of their time and are the products of various civilizations from past to today. These areas are scattered all over the peninsula (EPASA, 2006).

In addition to its archeological value, the peninsula not only serves as a bridge between the Aegean and the Mediterranean Seas, but also presents a potential resource in terms of yacht tourism. The peninsula is a stopover place for yacht sailors with its convenient climate conditions and its coasts with numerous bays as a result of its special topographic structure.

Datça-Bozburun Peninsulas generally have rather steep topography and the land is stony, and under erosion risk. Datça-Bozburun Peninsulas have limited potential for agriculture due to their physical and natural characteristics. There exist few agricultural flats. The main crops are almond and olive groves. Furthermore, there is not enough water for agriculture. People in the rural areas make a living by fishing and beekeeping, by working in the forest, or by picking vegetation and forestry products such as laurel, thyme carob, mushroom and so on.

In terms of diversity, there are obvious differences between the northern and southern parts of Datça-Bozburun due to the characteristics in the peninsula. In this wealthy region, 167 terrestrial spineless species, 110 fish species, 27 reptile species, 123 bird species and 45 mammal species are identified.

In Datça-Bozburun, fortunately, the environment mainly preserves its natural conditions except for the rural and urban settlements, agricultural areas and the present transportation network including sea transportation but the anthropogenic stress rises every year. In the region, Palamut Bükü, Domuz Çukuru, Kargı Bay, Mesudiye and Körmen Bays are among well known places.

Both Gökova and Datça-Bozburun SEPA are declared to be 1st degree natural and archeological protected areas by the Protection of Cultural and Natural Heritage Board.

3.2.3 Gökova Recreational Camping Park

The park is located in the eastern part of Gökova Bay near Akyaka town in Ula County. The facility sits on a 31 ha area and was established in 1964. Daily capacity is 3000 person, and there are 150 tenting lots, 10 bungalows and 4 village houses, a coffee house, sport facilities such as basketball, volleyball, tennis court cubicles, showers and restrooms (GDEIA, 2008).

3.2.4 Bucak Recreational Camping Park

The park is located near Çamlık Village on Gelibolu Bay and sits on a 5 ha area. There is a small facility with a market stall and restroom. The small port serves as a bridge to Sedir Island, which is a historical and recreational site.

3.3 Socio-Economy of the Region

The main employment sectors are agriculture, tourism and services. The problem of unemployment exists in urban areas, and it is worse in counties relative to the unemployment ratio of the province. The unemployed population is mainly composed of the young population.

In the province, there are manufacturing sectors that stand out with their economic transactions. These sectors are the services sector, marine transportation vehicles manufacturing, wood, wooden accessories, forestry products and mushroom market, mining and quarrying industry and livestock production (SPO, 2008). The economic transaction in marine transportation vehicles manufacturing, wood, wooden accessories, forestry products and mushroom production enjoy leading roles in Turkey.

The services sector is more developed in Bodrum and Marmaris; however there are much more sustainable tourism opportunities that have not yet been sufficiently evaluated. Given its wealth of natural endowments, nearly all types of tourism can take place in the region. The most important ones are cultural, beach, yacht, scuba, thermal, plateau cave, agro, stream and nature tourism. In addition, there are paragliding, winter tourism and conger tourism opportunities (MCT, 2008; SPO, 2008). Most of these activities take place in the study area as well.

In addition, there are three thermal power plants that use lignite of the region in Yatağan, Yeniköy and Kemerköy. The air quality of the region has been affected severely, especially in Yatağan (Figure 3.5) (MENR, 2008).

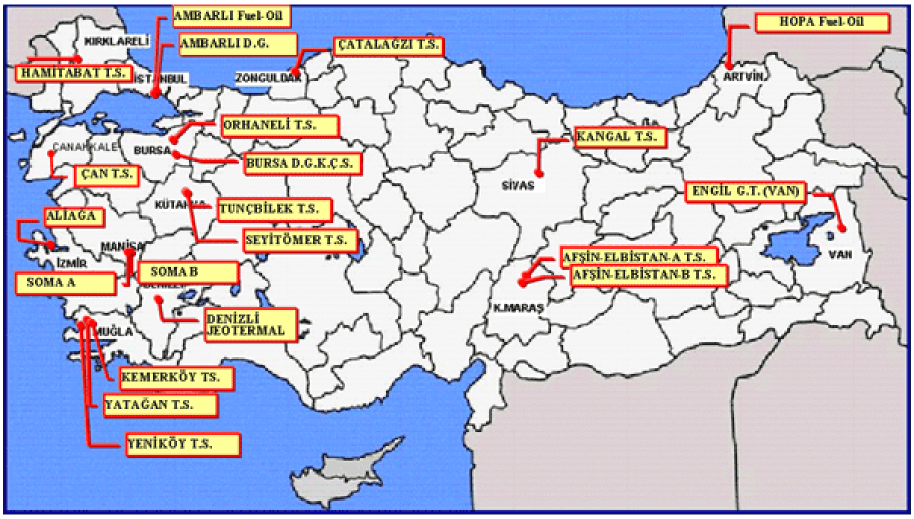


Figure 3.5 Thermal power plant distribution in Turkey (MENR, 2008).

3.4 Meteorology of the Region

The region has the second highest precipitation rates following the Black Sea region in Turkey. The meteorological information is given in Table 3.2 and Figure 3.6 below (TSMS, 2008).

Table 3.2 Long-term meteorological data of counties of Muğla.

STATION NAME	YEAR	MONTH	DAY	VALUE
MAXIMUM TEMPRATURE (°C) 1975-2006				
Bodrum	1998	8	4	45.0
Dalaman	2000	7	6	44.5
Datça	2000	7	6	42.5
Fethiye	1988	7	7	44.3
Köyceğiz	2000	7	12	45.6
Marmaris	1988	7	7	45.2
Milas	2000	7	6	45.7
Muğla	2000	7	6	41.6
Yatağan	2000	7	6	43.5
MINIMUM TEMPRATURE (°C) 1975-2006				
Bodrum	1976	2	9	-4.5
Dalaman	1976	2	9	-5.3
Datça	2004	2	14	-1.7
Fethiye	1983	2	21	-4.4
Köyceğiz	2004	2	15	-6.2
Marmaris	2004	2	15	-3.4
Milas	1983	2	21	-6
Muğla	1976	2	9	-9.9
Yatağan	1991	2	4	-8.8
MAXIMUM WIND SPEED (m/s) 1975-2006				
Bodrum	1981	12	5	37
Dalaman	1996	12	1	34
Datça	1998	3	26	21
Fethiye	1984	3	22	25
Köyceğiz	1993	2	23	26
Marmaris	1983	12	23	32
Milas	1984	3	6	39
Muğla	1976	2	9	30
Yatağan	1991	2	16	24

Table 3.2 Long-term meteorological data of counties of Muğla. (cont.)

STATION NAME	YEAR	MONTH	DAY	VALUE
MAXIMUM PRECIPITATION (mm) 1975-2006				
Bodrum	1984	1	13	85
Dalaman	1990	12	2	148
Datça	1992	12	11	146
Fethiye	1990	12	2	125
Köyceğiz	1998	2	3	239
Marmaris	1992	12	11	466
Milas	1989	11	9	89
Muğla	1995	12	20	155
Yatağan	2001	12	18	89

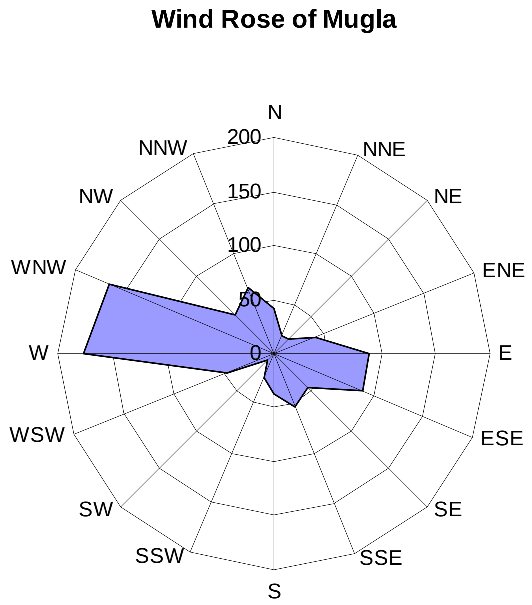


Figure 3.6 Wind Rose of Muğla (Muğla Station,17292)

3.5 Geography of the Region

The territory of Muğla Province is covered by the Büyük Menderes Basin and the Western Mediterranean Basin. Those two basins are the country's medium-sized basins. The Western Mediterranean Basin accounts for the region between Gökova Bay and Akdağlar Mountain. The water collection area of the basin is 21 000 km^2 and average yearly volume is 7 billion m^3. The irrigation area of the basin is 211 000 hectares and plain area of the basin is 322 000 hectares. The drainage water of the basin reaches the Mediterranean by Dalaman and Eşen Streams. These two streams also represent two major streams for Muğla Province. Between the two basins, the coastal catchment, Gökova Bay, lies which will be concerned in this study.

Gökova Bay is placed on the southern part of the coasts of the Aegean Region and is also known as Kerme Bay or İstanköy Bay. Gökova Bay is extending in an east-west direction as roughly in a triangular form between Bodrum on the northern and the Reşadiye (Datça) Peninsula on the southern part. The name of the bay, known as Kerameikos in antiquity, was later changed to İstanköy and then Kerme. The name Gökova used for the eastern plain of the region in the past is now being used for the entire bay.

3.6 Vegetation (Forest) Pattern of the Region

Muğla offers many different types of vegetation due to its topographic structure, weather and soil features. There are more than 40 economically valuable forest tree species that are naturally distributed to the forest ecosystem. Turkey is a distinctive country with its diversity in local forest tree species. Needle-leaved trees in the Muğla Province forests are red pines, black pines, pistachio pines, halab pines (95% of Turkey reserve is found in Milas and Gökova), junipers, cedars and cypresses. However, there are wide-leaved trees that grow naturally, such as oak, willow, sweet gum, chestnut, eucalyptus, acacia, alder and olives can also be found in the forests. The slopes of Kıran Mountains, which are located in the northern shore of the Gökova Bay, have high quality forest cover (GDEIA, 2008).

Sweetgum forests are of great importance in the flora. Sweetgum trees that grow only in the southwest coast of our country are located at the back parts of small bays of Gökova Bay and majorly used in medicine.

Gökova represents the vast part of the vegetation species of the Mediterranean and agricultural products. The region can serve as a laboratory as it includes all patterns of the Mediterranean natural vegetation.

The region is very rich in terms of the presence of fauna. It was identified that otters (*Lutra lutra*) in the region had relatively high population. The world's highest quality sponges also grow in the region (GDEIA, 2008).

Archeological areas represent the larger part of the Gökova region. Sedir Island (Kedrai) and Gelibolu are historically protected areas. A theater, a temple, ancient walls and castle ruins are present in the Sedir Island. Similarly, there are architectural ruins around Gelibolu and in the bay.

3.7 Forest Wealth of the Region

The region is mountainous and there are forests on the hills. Forest wealth of the region is given in Table 3.3 and Table 3.4 with respect to species types. Mushrooms, sweetgum, daphne, sage, thyme, cyclamen, mastic and carob are economically important forest products.

The forest heritage of Turkey is 20.2 million hectares, which accounts for 26 % of its surface area. The forest areas and its regional distribution in percentages are given in Table 3.5. The total surface area of Muğla is 1233316 ha. 68 % of the area is forest, which represents 25 % of the Aegean Region’s forest wealth. 72 % of study area is covered by forest (Table 3.1).

Table 3.3 Needle species and coverage area

Species	**Area (ha)**
Pinus brutia (Red pine)	404 405.9
Pinus nigra (Black pine)	41 910.0
Pinus pinea (Stone pine)	4 220.0
Pinus halepensis (Aleppo pine)	573.5
Pinus maritima (Seaside pine)	244.0
Cedrus libani (Cedar)	2 753.5
Juniperus (Juniper)	6 073.5
Cupresus sempervirens (Cypress)	60.0
Needle Total	**460 240.4**

Table 3.4 Leaved species and coverage area

Species	Area (ha)
Robinia pseudoacacia (Black locust)	539.5
Alnus glutinosa (European alder)	10.9
Quercus (Oak)	2.5
Eucalyptus	1 166.4
Liquidanber orientalis (Sweet gum)	(endemic) 1 164.8
Other leaved	664.5
Leaved Total	**3 548.6**

Table 3.5 Turkey's forest wealth regional distribution

Regions	Forest Area (ha)	Forest Area Ratio (%)
Black Sea	5 029 623	24.90
Mediterranean	4 884 187	24.18
Aegean	3 383 380	16.75
Marmara	2 277 429	12.76
Eastern Anatolia	2 187 583	10.83
Central Anatolia	1 523 026	7.54
Southeast Anatolia	614 068	3.04
Total	20 199 296	100.00

Mediterranean, Aegean and Marmara coastal regions, from Antakya to Istanbul, severely suffer from forest fires, which constitute 90 % of all fire disasters. The sensitivity map of Turkey is given in Figure 3.7. The 1st degree sensitive areas cover a 7182051 ha which includes all Muğla Province. The forest area under fire risk is 60 % of all areas. 5.6 % of study area is covered by burnt forest area (Table 3.1).

The three components of fire are oxygen, fuel and heat. Meteorological conditions affect these factors as well. Wind speed, atmospheric pressure, temperature and solar radiation have an impact on the oxygen state. Relative humidity, precipitation, temperature, and wind speed change the availability of fuel which is wood itself. Finally, temperature and solar radiation form the heat factor. Moreover, terrain features such as craggy and mountainous terrain, slope of the hills and density of vegetation cover are the other factors increasing fire risk. As soon as a forest fire starts, wind direction and speed become the most important agents in efforts to extinguish it. The study area is one of the highest risk areas in Turkey in terms of having all unfavorable factors. As seen in Figure 3.8, Muğla province has the highest count of forest fires caused by natural phenomenon, lightening, in 2000.

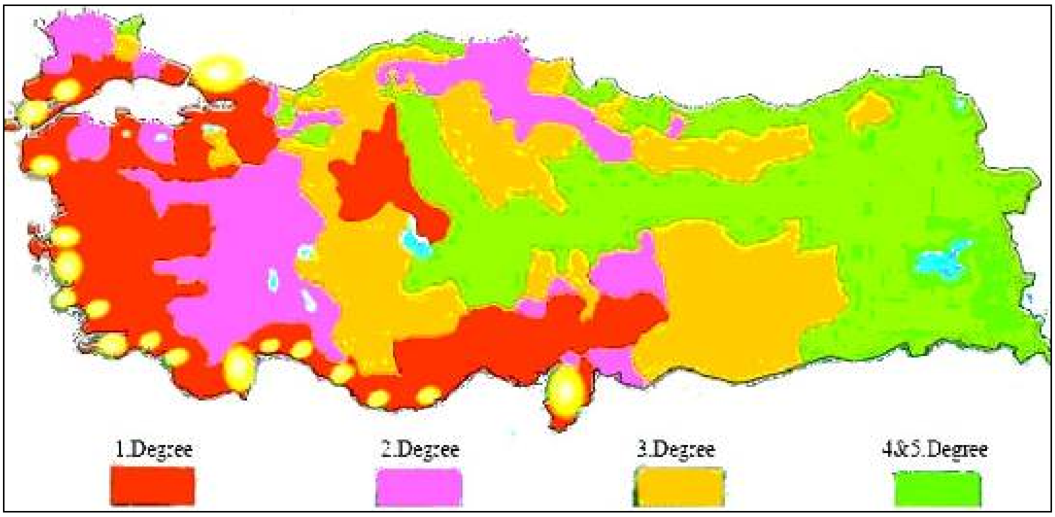


Figure 3.7 Forest Sensitivity Map and special protection forest areas (TSMS, 2008)

Some of the factors causing fire can be measured and monitored with many technologies. For instance, lightening (via special sensors) and drought (by remote sensing analyses) are widely measured all over the world.

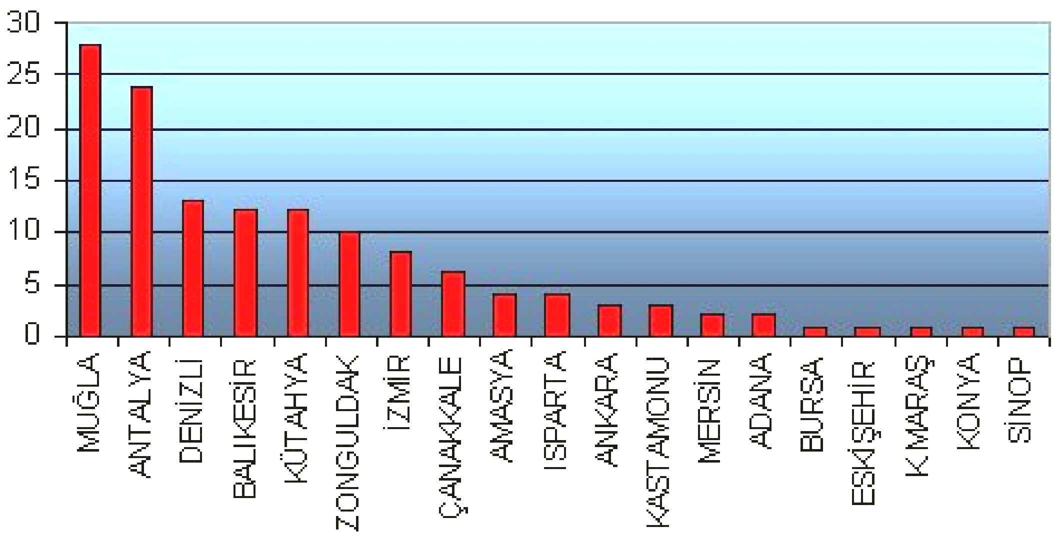


Figure 3.8 Forest fire counts as a consequence of lightening in 2000 (TSMS, 2008).

The causes and percents of forest fires for Turkey are as follows: 14 % deliberately, 35 % unintentionally (due to negligence), and 3 % lightening. 48 % of the causes are unknown. Forest fire disasters have an important role in forest degradation in Turkey. Muğla Province is one of the most sensitive regions. Anthropogenic stress, especially daily tourism activities, and sabotage are two main reasons of destructive forest fires in the region.

CHAPTER FOUR
DATA PREPARATION AND DEVELOPMENT

The study based on vector data collected mainly from four main sources: a) 1/25000 scaled military maps (land use maps) of General Command of Mapping; b) 1/25000 scaled forest management maps of General Directorate of Forestry; c) Biodiversity data gathered from Marine Biological Diversity assessment of Gökova Specially Protected Area Project (OCEANOS Project) report of EPASA; and d) population and villages data of Turkish Statistical Institute (TurkStat) archives. All maps in raster format were scanned, digitized and set to same coordinate system, Turkish Coordinate System (UTM 6 Degree k=0.9996 - ED50; UTM Central Meridian 27).

4.1 GIS Representation of the Data

GIS development is the first step of the DSS (Figure 5.1). The data prepared in GIS was used for the other technical stages after setting a grid system. In order to develop a GIS, all collected data was processed in a planned manner. During data collection and GIS work, metadata information was stored electronically for further use (Table 4.6 and Table 4.7). The flow chart representing the process of GIS is given in Figure 5.2(a).

Initially, digitization of the available maps was carried out for GIS development. The available General Command of Mapping - Turkey maps and General Directorate of Forestry maps were used as main data sources.

4.1.1 Digitized General Command of Mapping Maps

In order to develop a GIS, the available General Command of Mapping terrain maps were used. The list of the used maps is given in Table 4.1.

The digitization processes of General Command of Mapping maps include the following layers:

- Settlements
- Mountain peaks
- Water resources
- Roads Trail
- Roads Unimproved
- Highways
- River
- Intermittent Streams
- Cost line
- Villages
- Water bodies
- Swamp
- Rushes
- Elevation

Table 4.1 1:25000 raster maps and their production years

General Command of Mapping Maps	
Raster Layers	**Production Year**
N19-c3	1976
N19-c4	1976
N20-c3	1978
N20-c4	1995 and 1978
N20-d3	1995
N20-d4	1995
O19-b3	1977
O20-a1	1994
O20-a2	1994
O20-a3	1976
O20-a4	1976
O20-b1	1961
O20-b3	1994
O20-b4	1994

4.1.1.1 Settlements

Settlements and buildings of the civil services were digitized from N20-c4, N20-d3, N20-d4, O19-b3, O20-a1, O20-a2, O20-a3, O20-a4 and O20-b1 1:25000 maps. Detailed data in maps (Figure 4.1) is provided in Table 4.2.

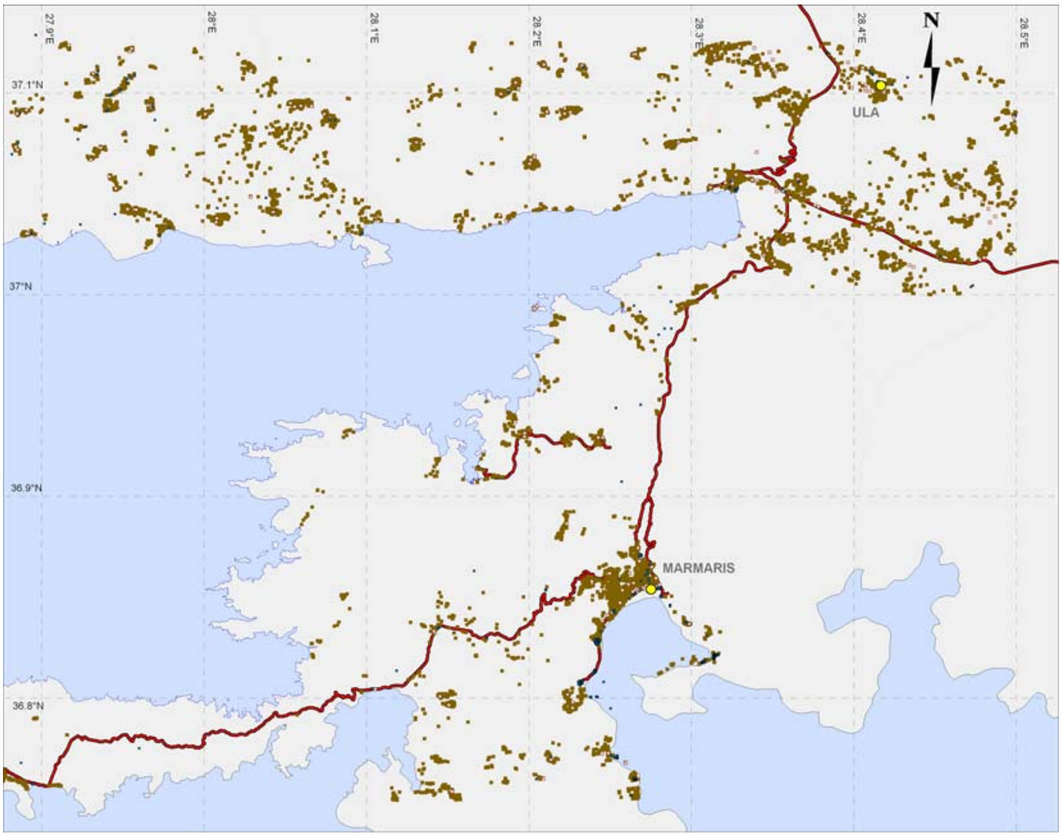


Figure 4.1 Settlement data

Table 4.2 Settlement symbols and explanation.

Personal	Commercial	Services	Other Symbols	Other uses
House-buildings	Factory Olive oil press Power plant Fuel station Beekeeping Stockbreeding	School Cooperative PTT Patrol Clinic Municipality Traffic control Forestry regional head Forestry houses Forest fire observatory Forestry warehouse	Mosque Livestock Mill Ruin Mine Moto pomp	Harbor Marina Water treatment plant Solid waste disposal Solid waste recycling Wharf Hotel DPT housing President summerhouse

Personal, commercial and service buildings have the same symbols. All these usages were entered in the attribute data. The results of the population census of 1945 - 2000 were included in the village information. The province, county, district and village administrative changes were figured out from the system. Settlement information is used as total counts in analysis.

4.1.1.2 Elevation contours and Coastline

The coastline and elevations (10, 20, 30, 40, 50, 100, 150, 200 …) were digitized with 340411 nodes and points from N20-c4, N20-d3, N20-d4, O19-b3, O20-a1, O20-a2, O20-a3, O20-a4 and O20-b1 1:25000 maps (Figure 4.2). Digital Elevation Model (DEM) of the region is produced from digitized elevation data and given in Figure 4.13. Slope and aspect information are used as percent slope and categorical data.

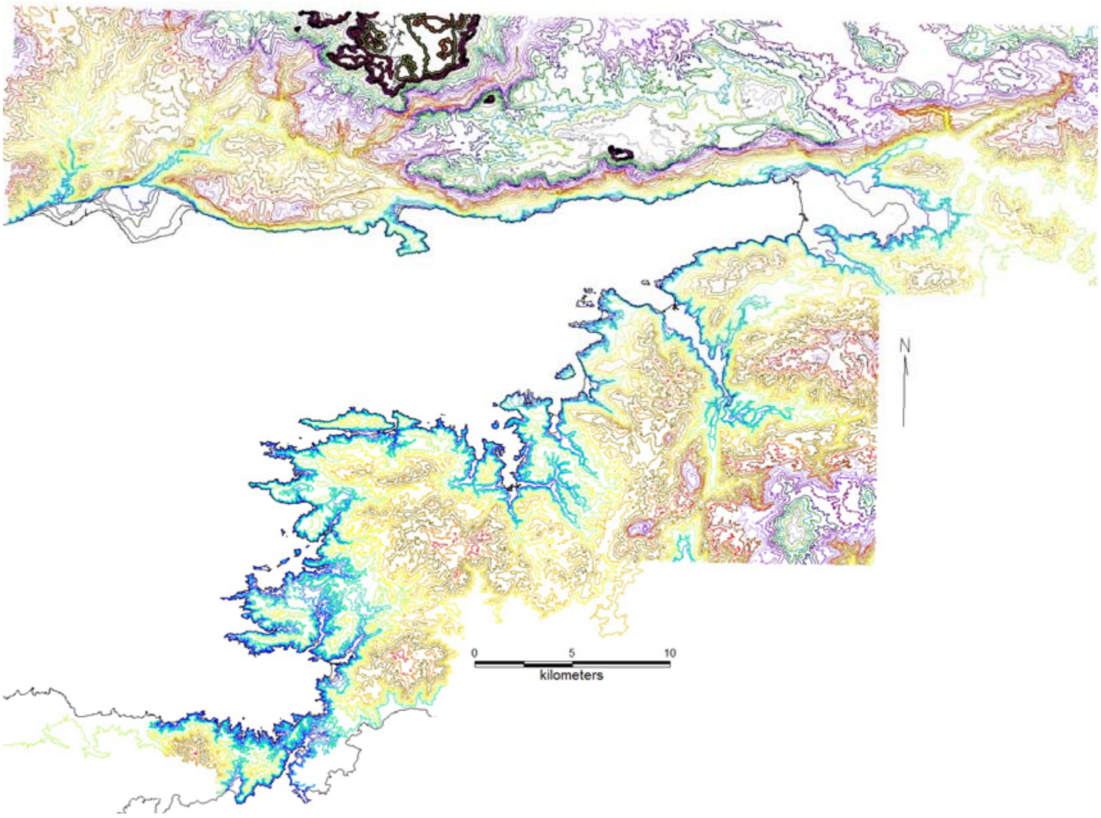


Figure 4.2 Elevation contours and coastline

4.1.1.3 Roads

Highways, loose surface highways and unimproved roads were digitized from 11 1:25000 military maps of General Command of Mapping (Figure 4.3). The types and lane width were entered for each item. The road type table is given below (Table 4.3). Recently developed roads were updated by the help of General Directorate of Forestry and road maps of year 2000. Information of road types are prepared both as length and surface area. Also road data used separately and as sum of all types in analysis.

Table 4.3 Road types and attribute data

Roads		
Unimproved Roads	Pack Trail	1
	Cart Road (dry)	2
	Cart Road (all weather)	3
Loose Surface Highways	One lane wide	4
	Less than two lanes	5
	Two or more lane	6
Highways	One lane wide	7
	Less than two lanes	8
	Two or more lane	9
	Dual highway	10
	Street	11

4.1.1.4 Rivers and Intermittent Streams

Rivers and intermittent streams were digitized from N19-c3, N20-c4, N20-d3, N20-d4, O20-a1, O20-a2, O20-a3, O20-a4 and O20-b1 1:25000 maps with a count of 5677 and 66661 nodes respectively (Figure 4.4). The names of the streams were entered, where available. Information of rivers and intermittent streams are prepared as length, and data used separately and as sum of two types in analysis.

4.1.1.5 Water bodies, Swamp and Rushes

Water bodies, swamp and rushes were digitized from N19-c3, N20-c4, N20-d3, N20-d4, O19-b3, O20-a1, O20-a2, O20-a3, O20-a4, O20-b1, O20-b4 1:25000 maps (Figure 4.5). Data of water bodies are used as area in analysis.

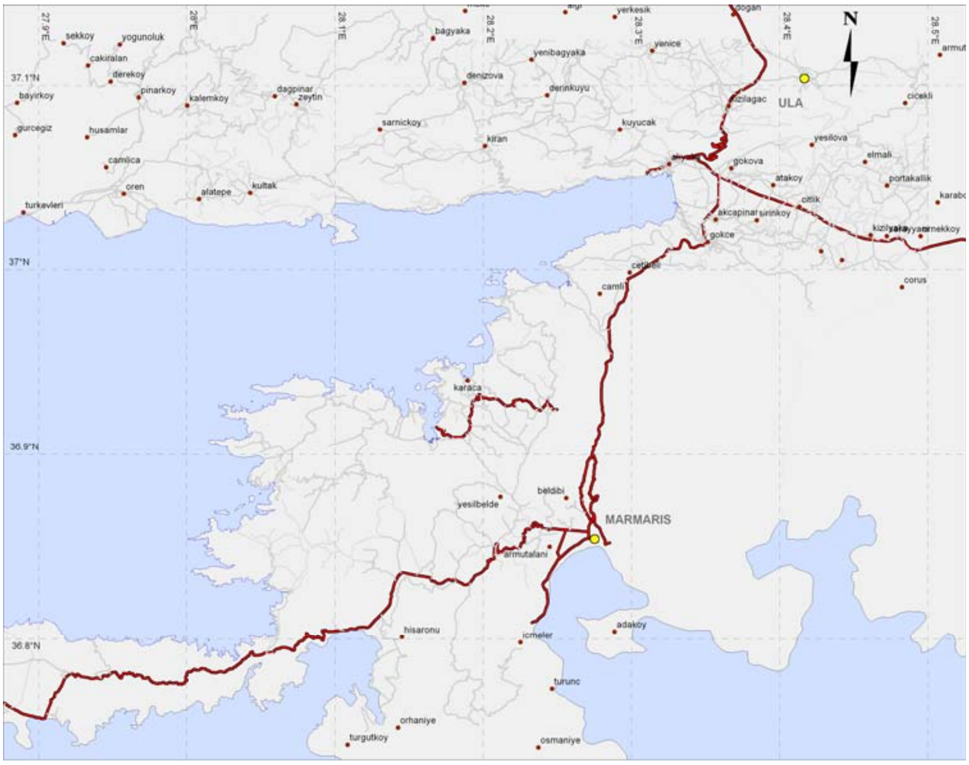


Figure 4.3 Roads

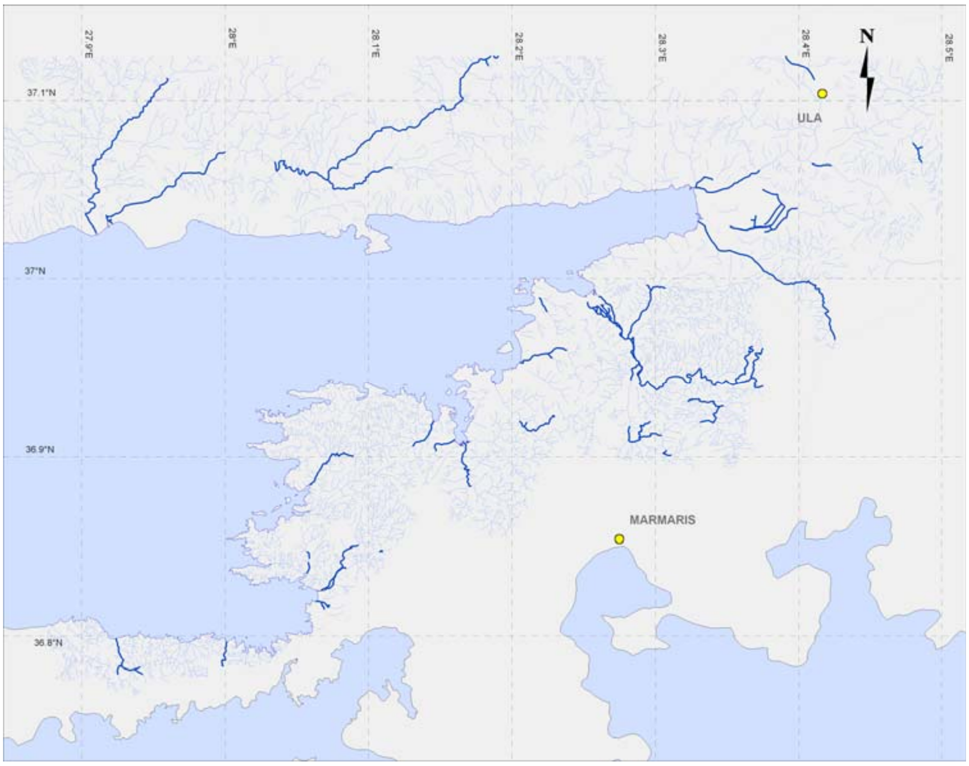


Figure 4.4 Rivers and intermittent rivers

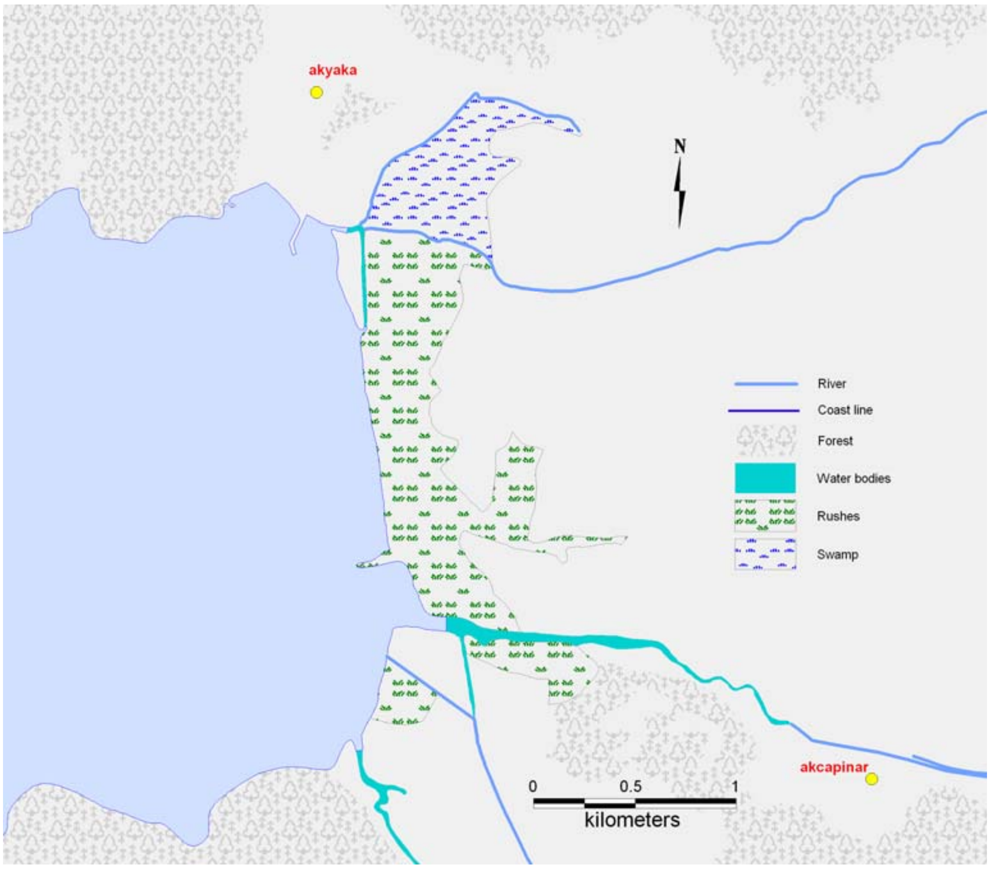


Figure 4.5 Water bodies, swamps and rushes

4.1.2 Digitized Management Maps of General Directorate of Forestry

The raster maps of General Directorate of Forestry were obtained and registered. The list of maps is given in Table 4.4. The digitization processes of the General Directorate of Forestry (GDF) maps which were done with 258654 nodes include layers:

- Forest
- Degraded forest
- Agriculture
- Urban

The attribute data set to CORINE Land Use / Land Cover classes as shown in Table 4.5 and Figure 4.6.

Table 4.4 1:25000 forestry maps and their production years

General Directorate of Forestry Maps	
Raster Layers	**Production Year**
Gökova	1999-2000
Yerkesik	1999-2000
Ören	1999-2000
Hisarönü	1999-2000
Denizova	1999-2000
Datça	1999-2000
Çetibeli	1999-2000

Table 4.5 CORINE Land Cover / Land Use classification

Classes / Sub Classes	**Description**
Class 1	Built up area
112	Discontinuous urban fabric
121	Industrial or commercial units
131	Mineral extraction sites
132	Dump sites
Class 2	Agricultural area
Class 2.4	Heterogeneous agricultural areas
Class 3	Forest and natural area
311	Broad-leaved forest
312	Coniferous forest
313	Mixed forest
324	Transitional woodland-shrub
331	Beaches dunes and sand plains
332	Bare rock
333	Sparsely vegetated areas
334	Burnt areas
Class 4	Wetland, salt
421	Salt marshes
Class 5	Water
521	Coastal lagoons

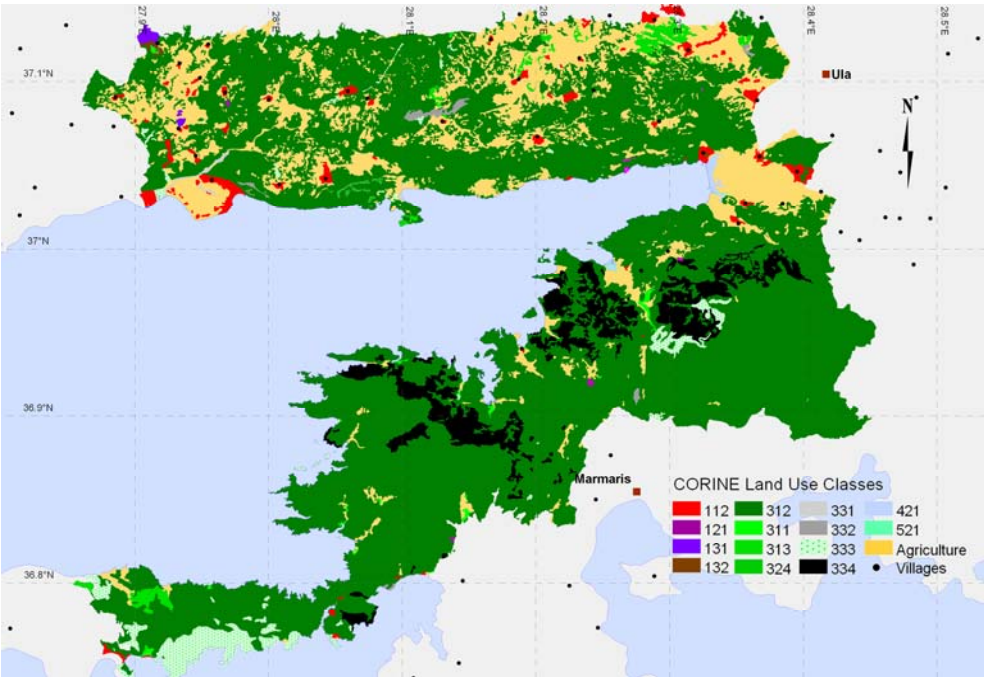


Figure 4.6 CORINE Land Cover / Land Use classes

4.1.2.1 Forest

The 1:25000 military maps' forest areas were digitized but not used in analysis because of the difference of their generation dates. The managerial forestry maps of GDF were obtained and used as forest data. Forest data is used as area in analysis.

The forestry data involves the following information:

- Tree species of regional coniferous and deciduous fauna such as pines and sweet gum (Figure 4.7)
- Land cover / Land use information such as forest, bare, agriculture, residential, wetland
- Terrain properties such as earth, rock, sand, water, etc.
- Maintenance properties and forest quality and age of the trees.
- Forest density percent of the regions under 4 groups (Figure 4.8):

  0, 0-10 % coverage

  1, 10-40 % coverage

  2, 40-70% coverage

  3, > 70% coverage

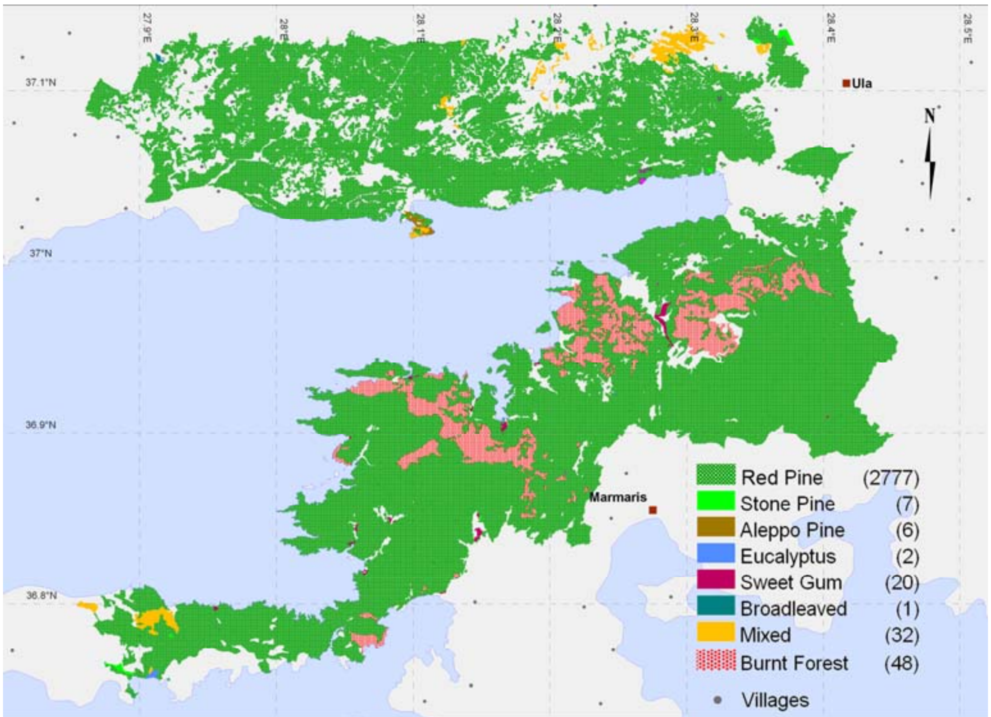


Figure 4.7 Tree species distribution of forest area

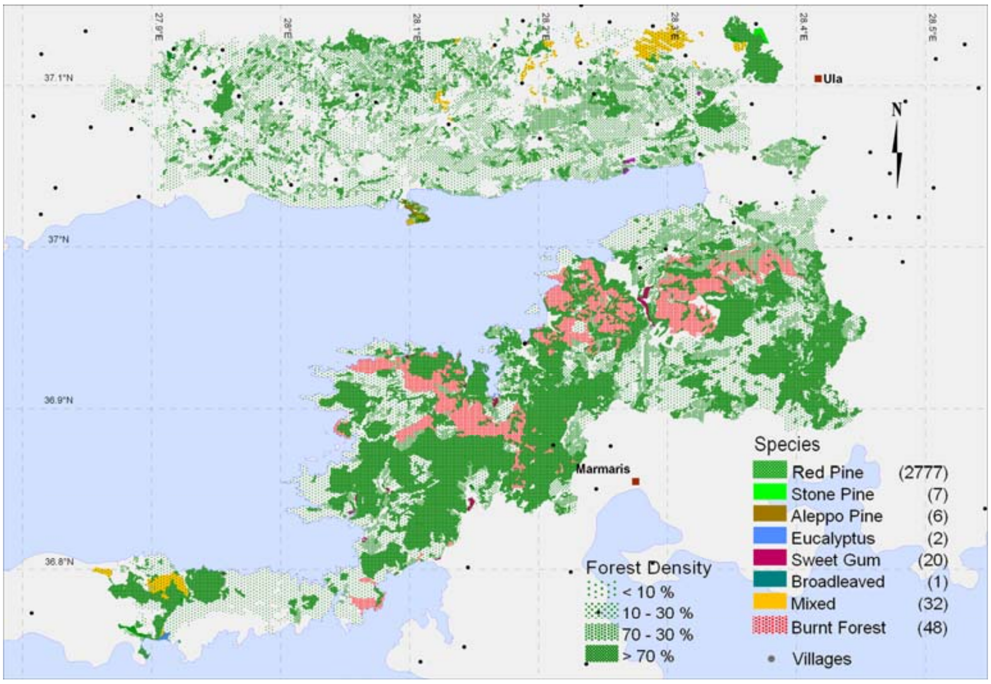


Figure 4.8 Species distribution of forest area and density as percent tree coverage

4.1.3 Digitized Maps of the Office of Navigation, Hydrography and Oceanography

To digitize the bathymetry of Gökova Bay, map number: 3112 of the Office of Navigation, Hydrography and Oceanography (SHOD) was used. The production year of the map is 1992 and the scale is 1:25000. The digitization process of SHOD map includes layer of sea depths. Sea DEM produced is given in Figure 4.9 and Figure 4.13.

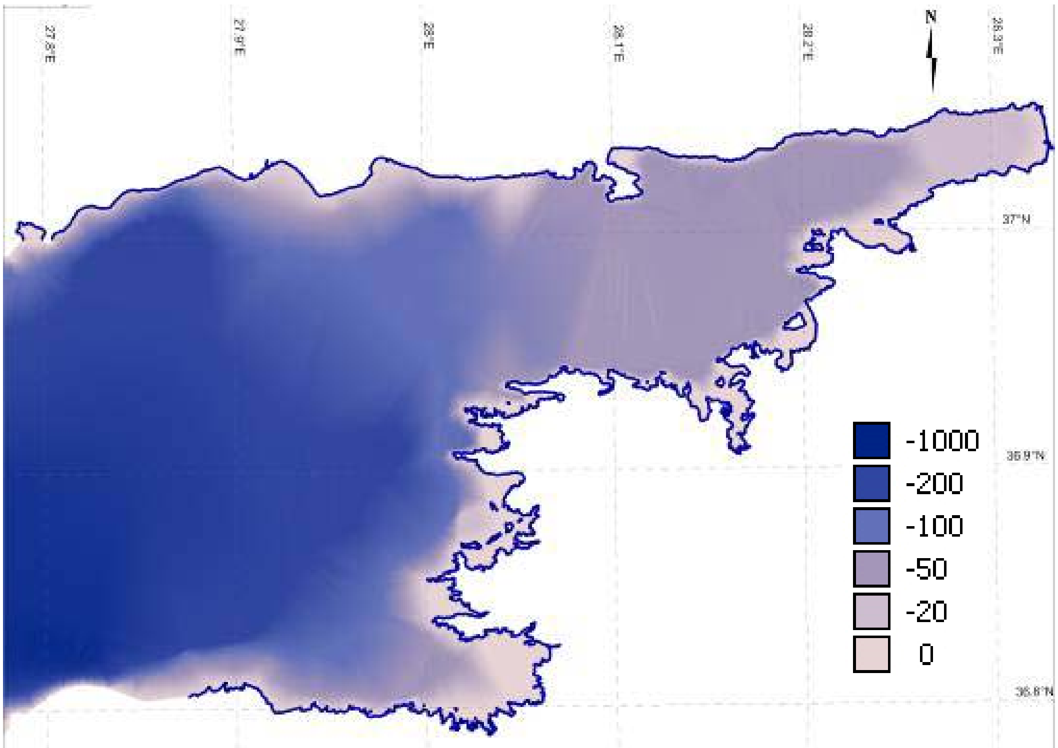


Figure 4.9 DEM of sea

4.1.4 Environmental Protection Agency For Special Areas (EPASA) Regions

The SEPA boundaries were entered with coordinates on the GIS based system. Figure 4.10 gives the location of the Gökova and Datça SEPA regions below.

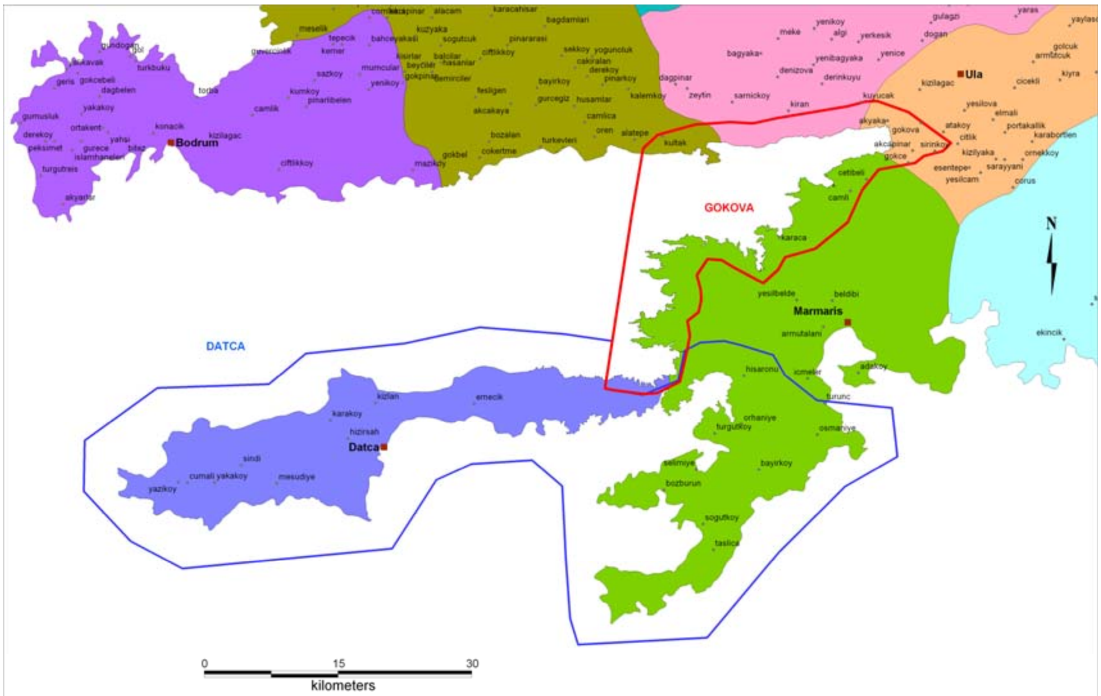


Figure 4.10 Gökova and Datça-Bozburun SEPA

4.1.5 Digitized Data of OCEANOS Project Report

The Istanbul University Institute of Marine Sciences and Management prepared a report for the OCEANOS Project of Gökova Special Environment Protection Area. The report involved information about the biological variety on coastal and marine environment. The digitization process of the report includes the following layers:

- Biodiversity
- Anthropogenic stresses on marine environment
- Water quality data

Figure 4.11 gives the location of diving places where biodiversity and anthropogenic stresses data collected. Data used as total counts.

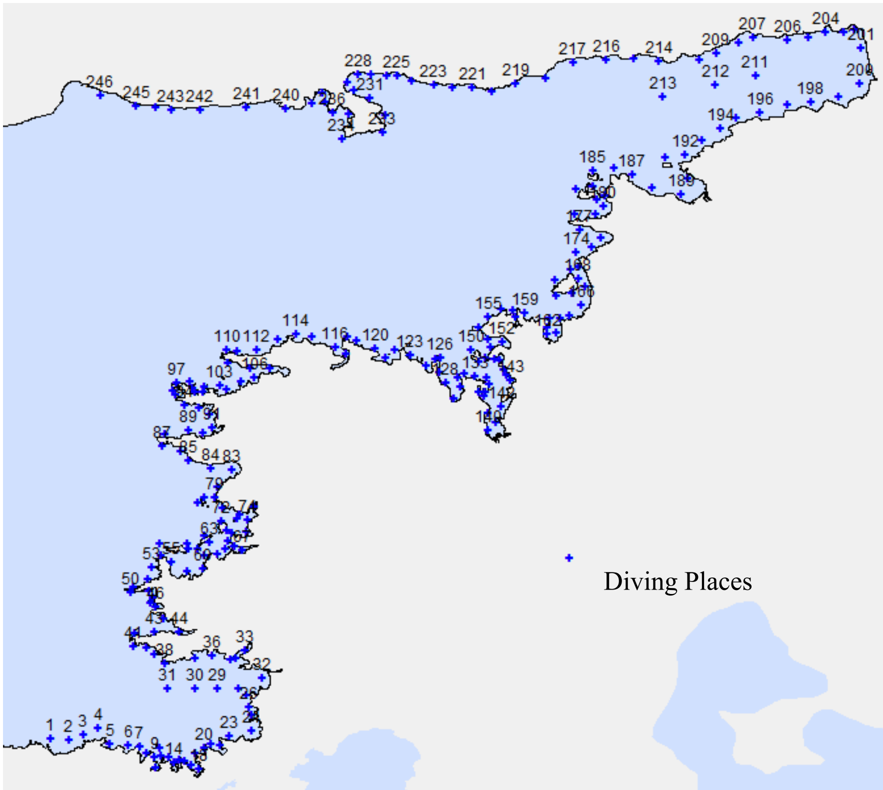


Figure 4.11 Diving places of OCEANOS project

4.1.6 Digitized Data of the Turkish Statistical Institute (TurkStat)

The population of the settlement according to years was gathered from the TurkStat archives. The digitization processes of TurkStat data include the following layers:

- Population
- Villages

The village area is defined by the voronoi method, which splits the neighboring villages with regard to their distances (Figure 4.12). After defining the boundaries, the population density layer is produced to be used in further analysis. Data is used as total capita and capita per kilometer as density.

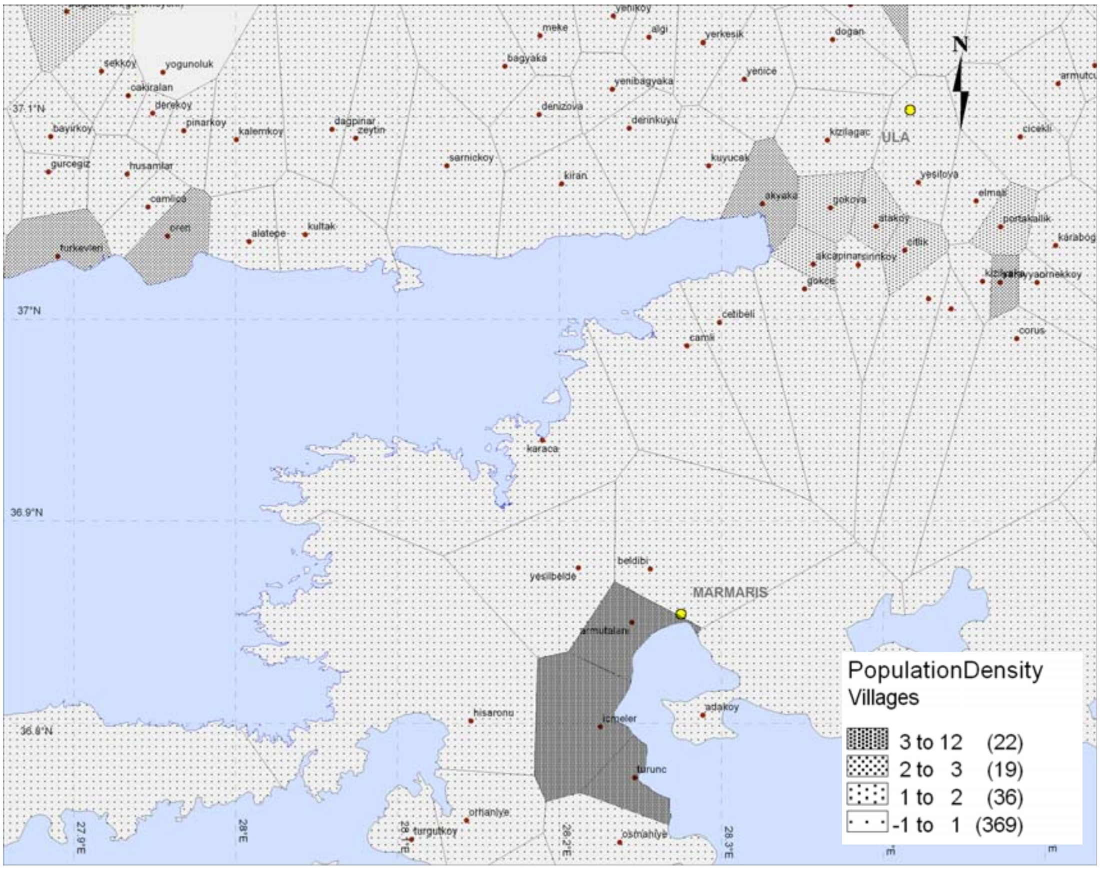


Figure 4.12 Population density of villages (people per km^2)

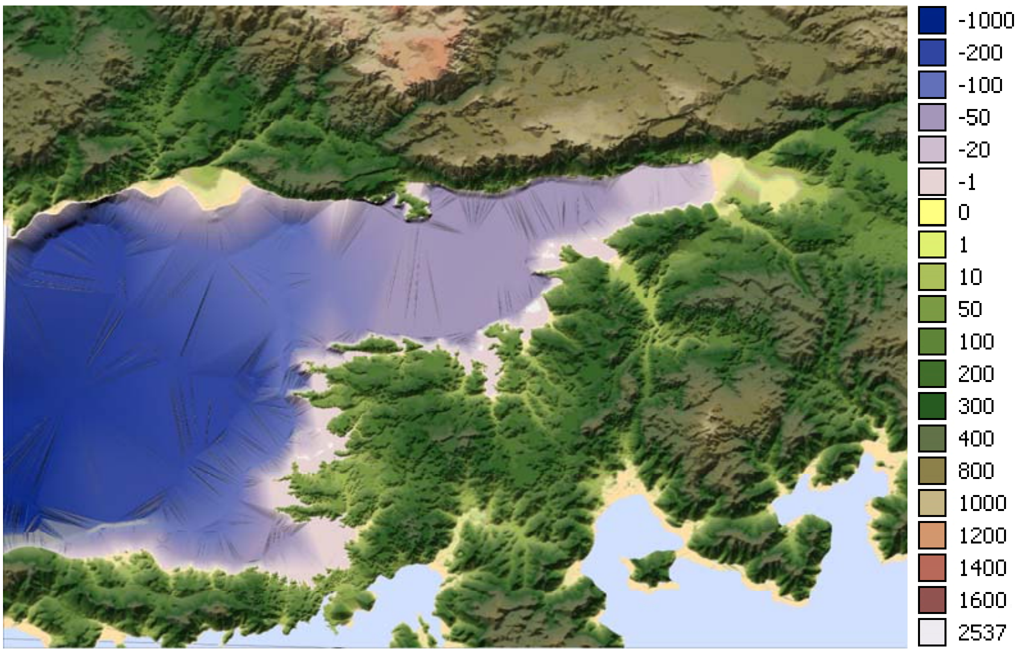


Figure 4.13 DEM of land and sea

4.2 Meta Data

Meta data is structured data, which describes the characteristics of the data. It is similar to inventory catalogs of libraries, archives and museums. A metadata record includes at least the number of elements and attributes of them, type and format of data, creator, publisher and layer type for GIS. The metadata of the GIS data is provided in Table 4.6 and Table 4.7.

Table 4.6 Metadata of digitized and integrated data layers of GIS

VECTOR LAYERS*	DATE	SOURCE /PUBLISHER	FORMAT	# FIELDS	# ROWS	LAYER TYPE
Settlements	1961-1995	GCM	tab	7	13457	Node
Piers	1961-1995	GCM	tab	7	47	Node
Elevation	1961-1995	GCM	tab	1	3806	Line
Sea depth	2002	SHOD	tab	1	35	Line
Peaks	1961-2000	GCM & DGF	tab	1	524	Node
Roads Trail	1961-1995	GCM & DGF	tab	13	511	Line
Roads Unimproved	1961-1995	GCM	tab	13	293	Line
Highways (joined)	1961-2008	GCM	tab	13	1891	Line
River	1961-2000	GCM & DGF	tab	3	95	Line
Intermittent Streams	1961-1995	GCM	tab	1	3646	Line
Waterresources	1961-1995	GCM	tab	4	1545	Node
Cost line (Muğla)	1961-2000	GCM & DGF	tab	1	47	Line
Water bodies	1961-1995	GCM	tab	2	14	polygon
Swamp	1961-1995	GCM	tab	2	2	polygon
Rushes	1961-1995	GCM	tab	2	4	Polygon
Forest Border	2000	DGF	tab	5	3953	Line
Counties	1945-1997	TurkStat	tab	27	12	Node
Villages	1945-1997	TurkStat & GCM	tab	29	458	Node
Province Information	-	web	tab	7	92	Polygon
Province Centers	-	web	tab	6	81	Node
Municipalities	...-2000	TurkStat	tab	9	76	Node
Mugla districts	...-2000	TurkStat & GCM	tab	6	12	Polygon
Gökova SEPA region		EPASA	tab	1	1	polygon
Datça SEPA region		EPASA	tab	1	1	polygon
Forest Fire Roads	1961-1995	GCM	tab	1	58	Line
DEM	-	web	ASCII			DEM
Diving Places	2006	EPASA	tab	3	246	Node
Biodiversity data	2006	EPASA	tab	47	246	Node
* All digital layers were created from hardcopy sources during this study.						

The data used in the PCA and ANFIS are given in Appendices C.

Table 4.7 Metadata of produced data layers of GIS

VECTOR LAYERS	DATE	FORMAT	# FIELDS	# ROWS	LAYER TYPE
Land DEM	1961-1995	grd			DEM
Sea DEM	2002	grd			DEM
Land Elevation	1961-1995	grd			Grid
Land Aspect	1961-1995	grd			Grid
Land Slope	1961-1995	grd			Grid
Land Aspect	1961-1995	tab			Polygon
Land Slope	1961-1995	tab			Polygon
Sea Depth	2002	tab			Polygon
Land Cover Land Use	1961-2000	tab	8	3973	Polygon
Land grid	1945-2000	tab	32	3679	Polygon
Sea grid	1945-2006	tab	57	2488	Polygon
Forest Regions	2000	tab	8	3927	polygon

4.3 Grid System

All data set given above were set to same coordinate system, Turkish Coordinate System (UTM 6 Degree k=0.9996 - ED50; UTM Central Meridian 27). A grid was placed on the pilot area, Gökova Bay, to study the relations of the data. Land and sea data were then grouped considering the grid mesh.

4.3.1 Land Data Grid System

Grid mesh of 500 m was placed on the land area as shown in Figure 4.14. Thus, the prepared data on GIS was grouped using the grid mesh. The specifications of the land data on each grid were described as a case for the models. Area of forest, agriculture, degraded forest, length of roads, rivers, number of houses, wells etc. were calculated for each grid to provide necessary data for further analysis. The land input data grids are given between Figure 4.16 and Figure 4.24 in organized data part.

4.3.2 Sea Data Grid System

A grid of 500m was placed on the sea area as shown in Figure 4.15. The specifications of the sea data on each grid were described as case for the models. Number of protected species, exotic species and value of water quality parameters were calculated on each grid to provide necessary data for further analysis. The sea input data grids are given between Figure 4.25 and Figure 4.30 in following heading.

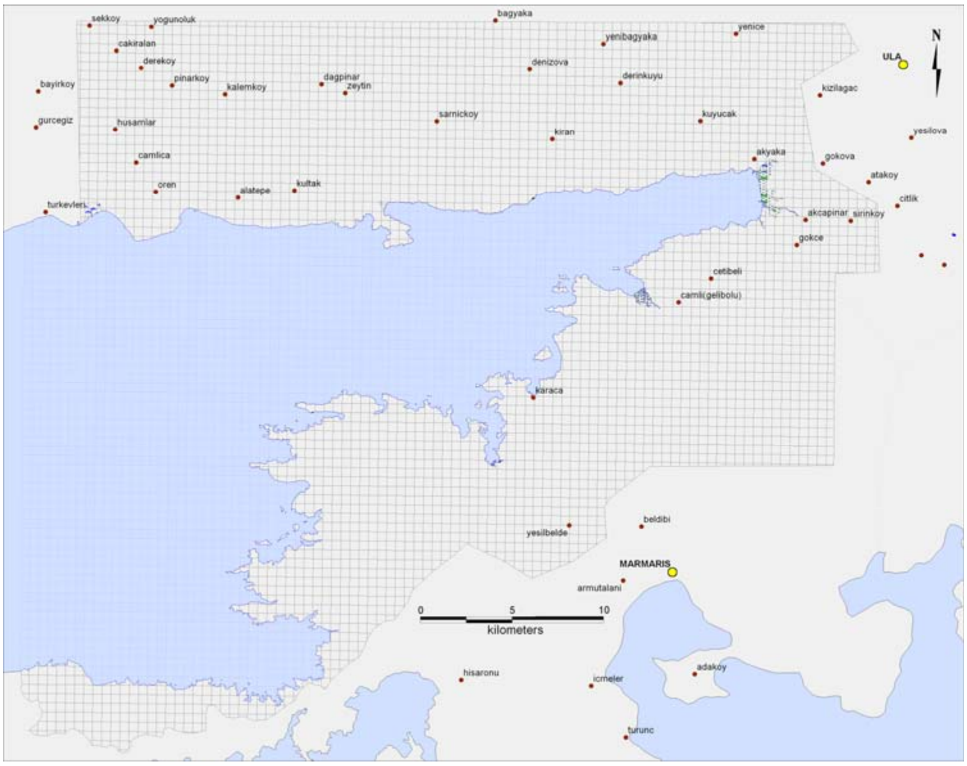


Figure 4.14 500 m grid of the land area

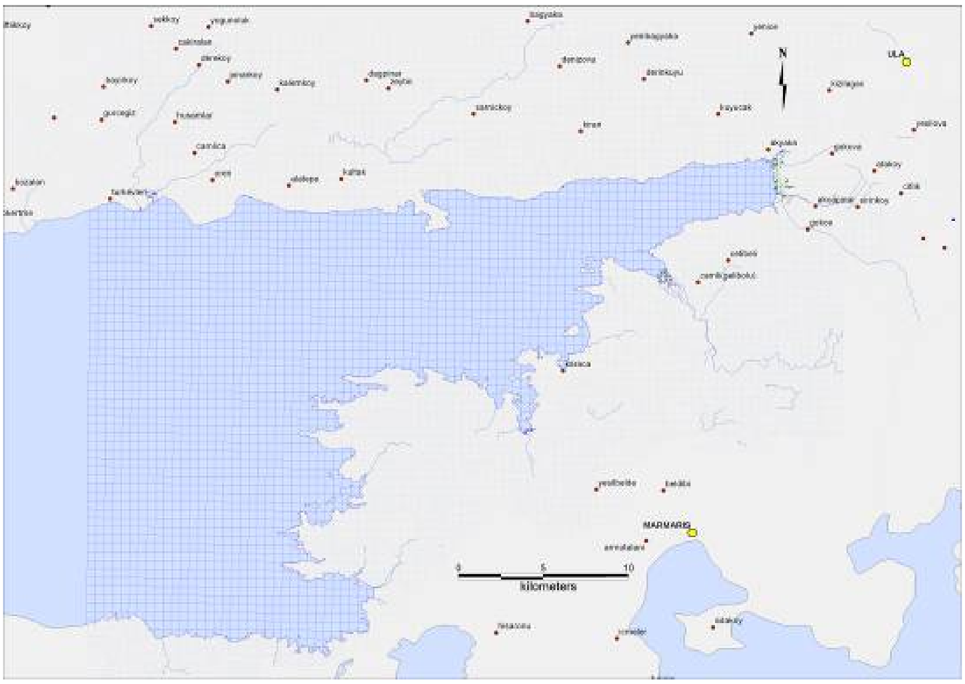


Figure 4.15 500 m grid of the sea area

4.4 Organized Land and Sea Data

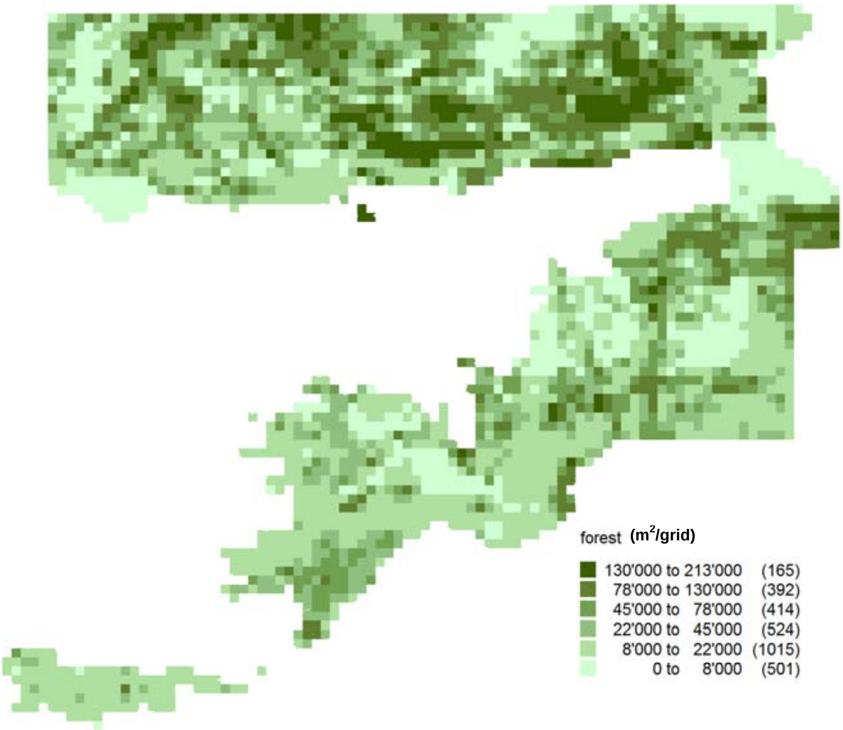


Figure 4.16 Forest data grids

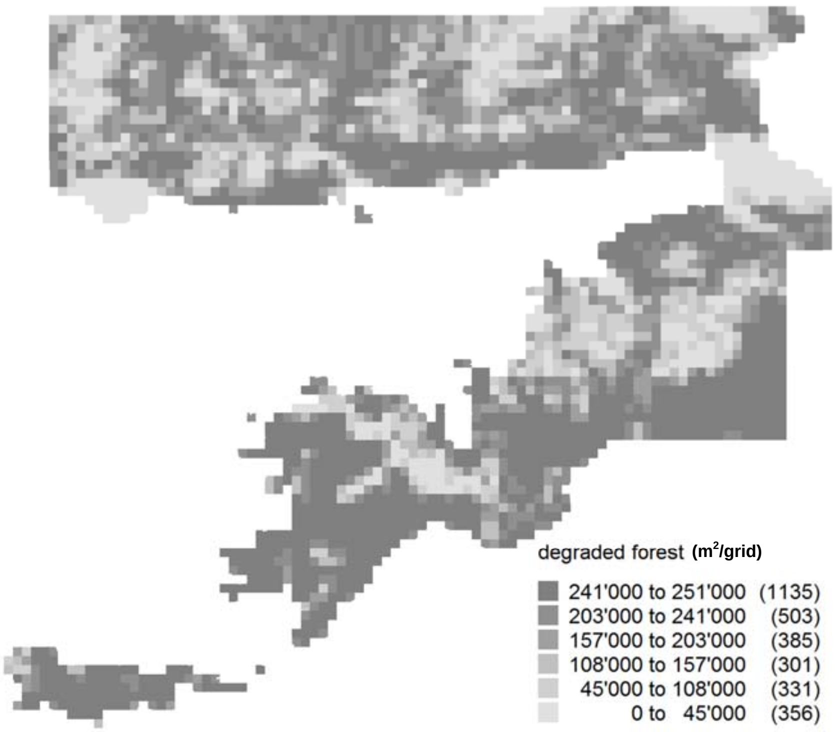


Figure 4.17 Degraded forest data grids

Figure 4.18 House counts data grids

Figure 4.19 Population density data grids

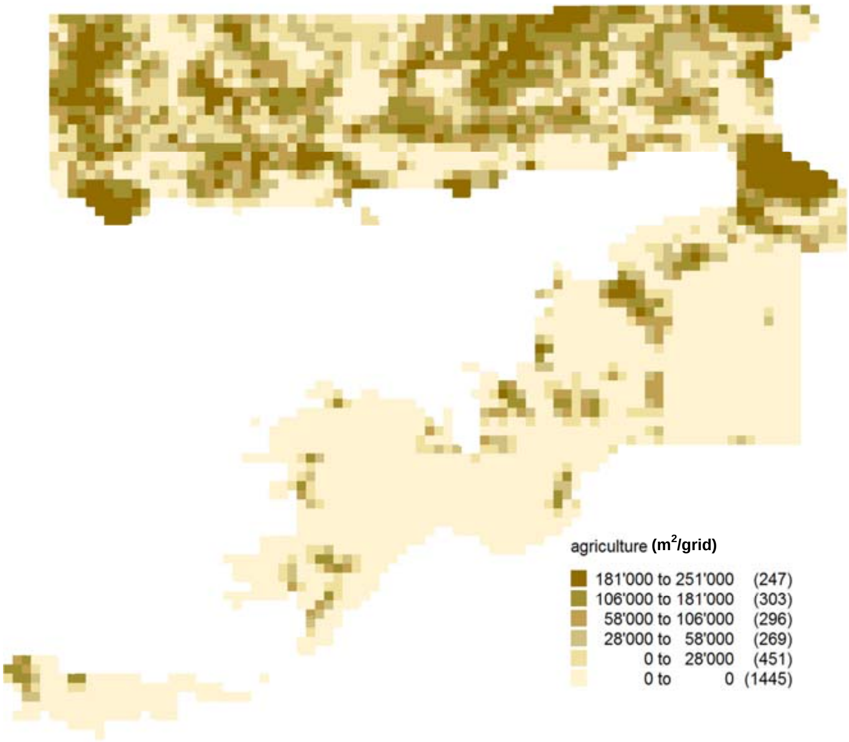


Figure 4.20 Agricultural area data grids

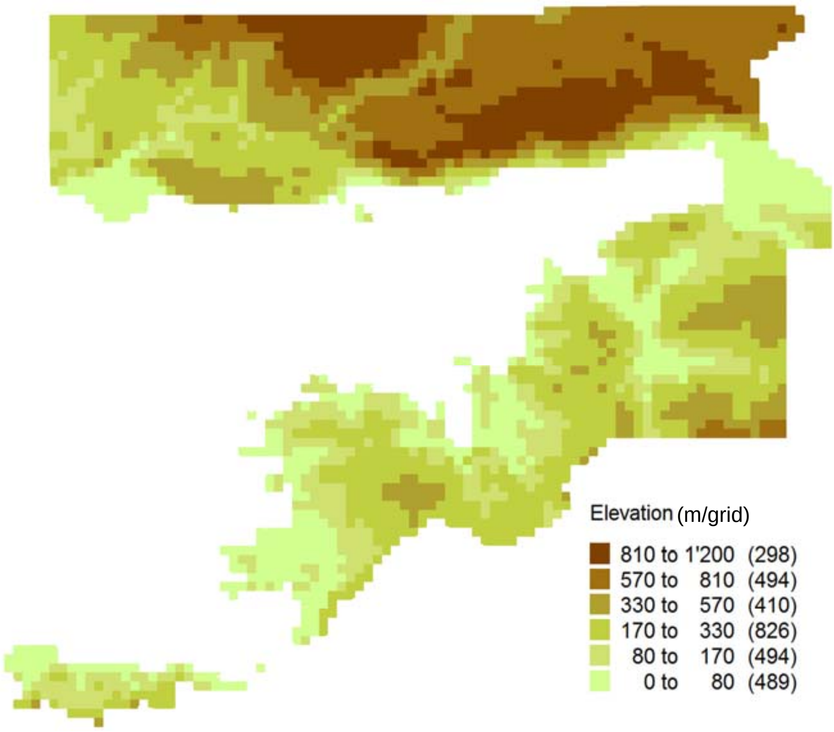


Figure 4.21 Elevation data grids

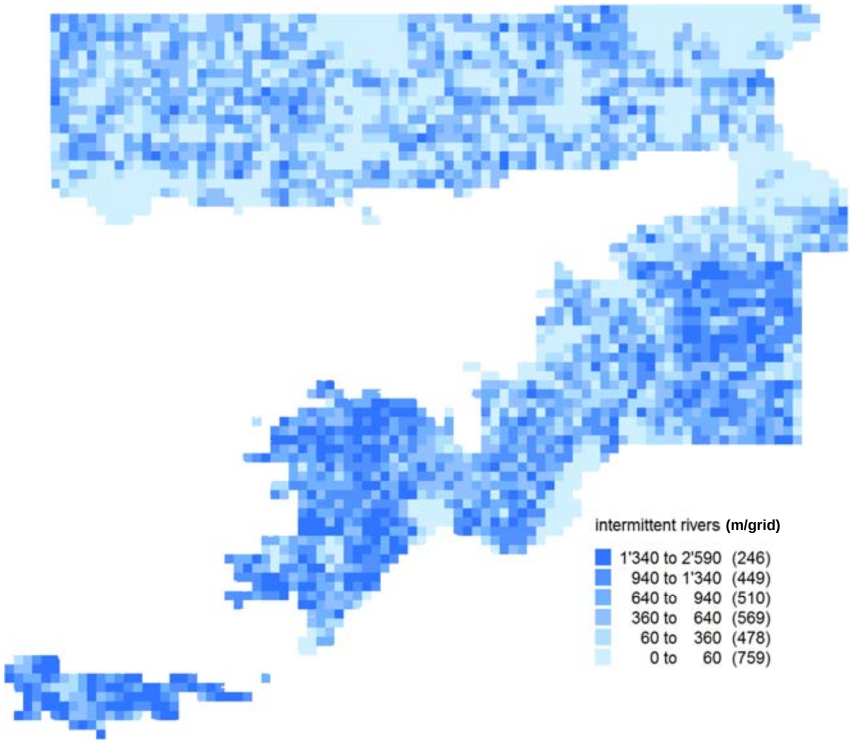


Figure 4.22 Intermittent river data grids

Figure 4.23 Unimproved roads data grids

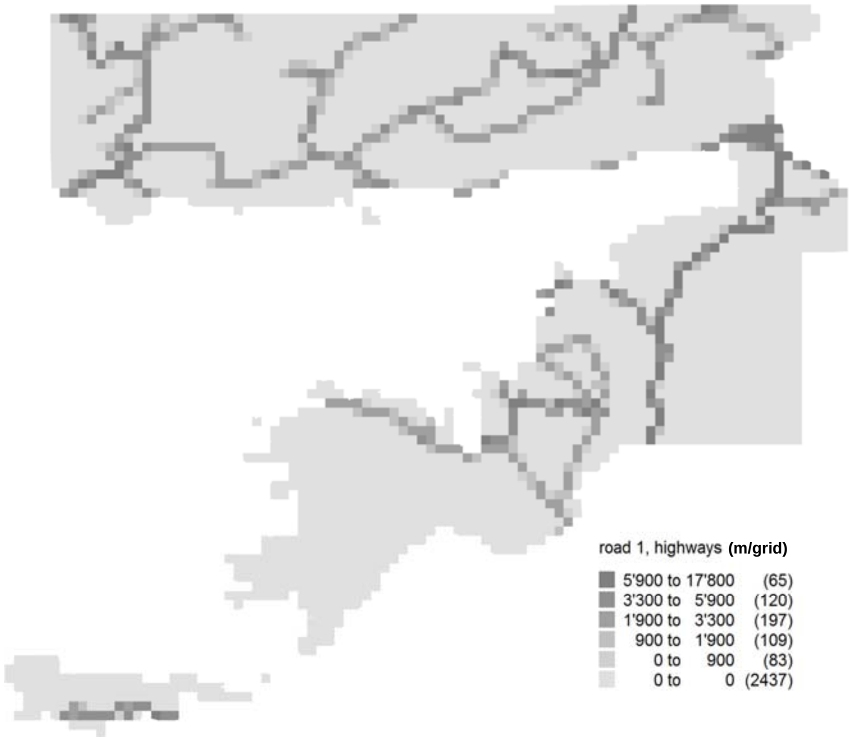


Figure 4.24 Highway roads data grids

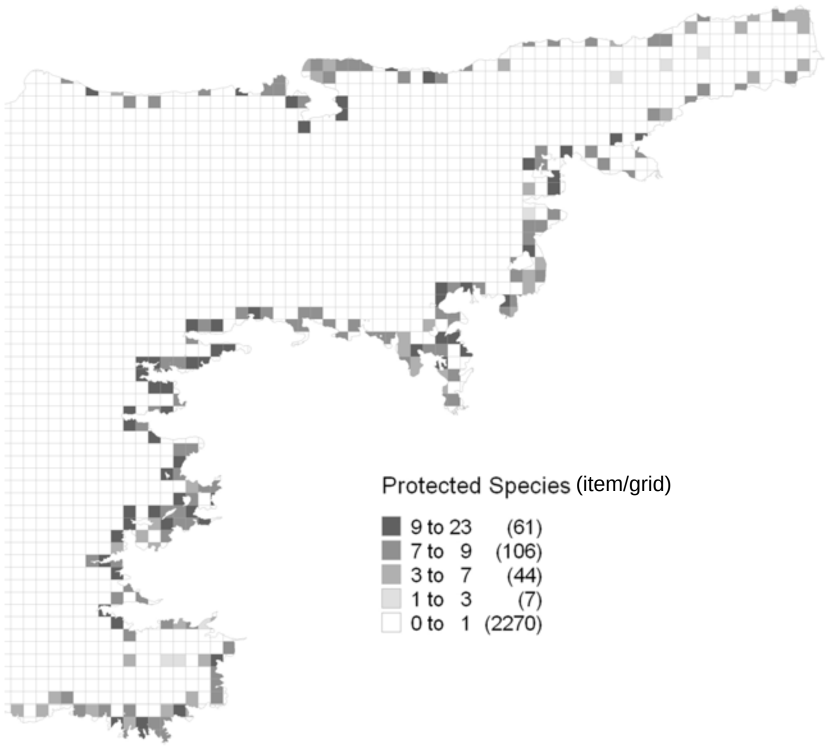


Figure 4.25 Protected species data grids

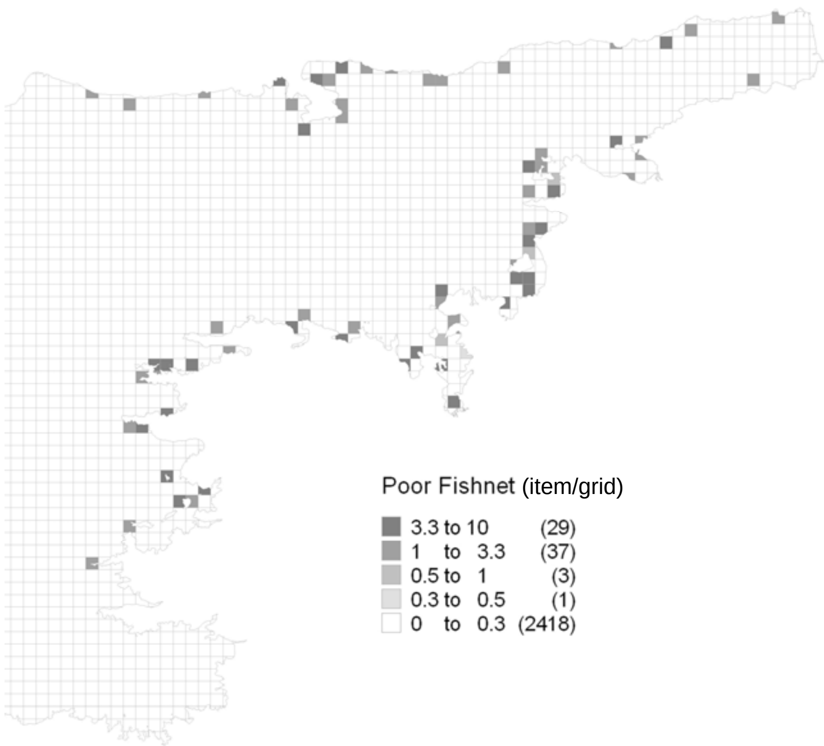


Figure 4.26 Poor fishnet data grids

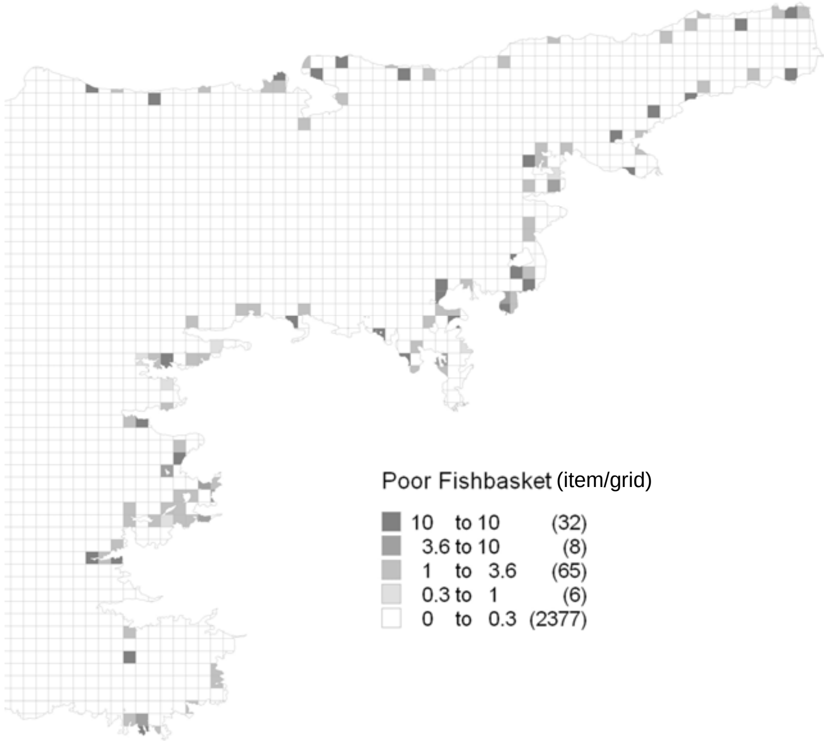


Figure 4.27 Poor fish basket data grids

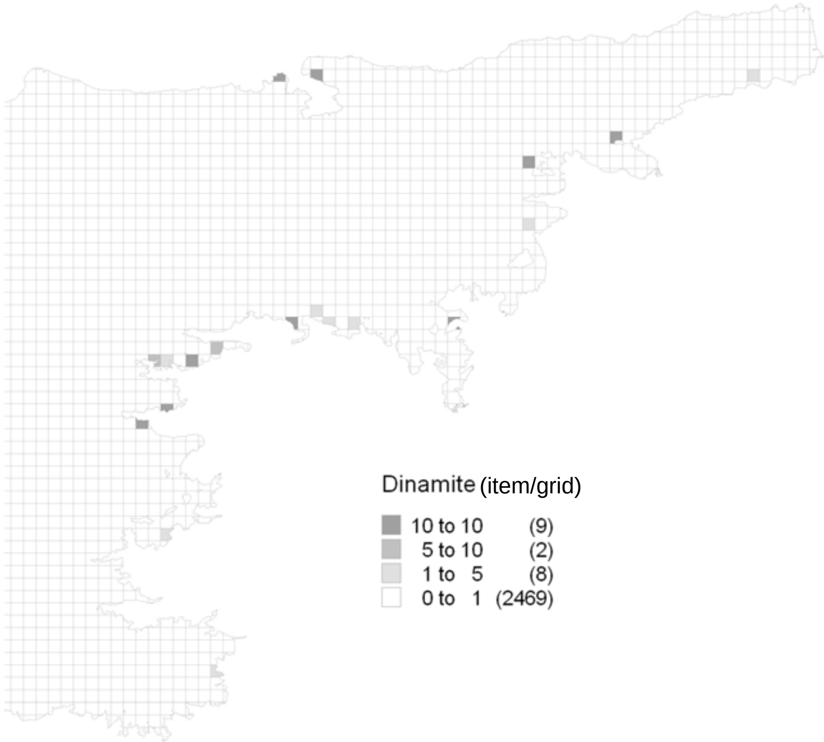


Figure 4.28 Dynamite data grids

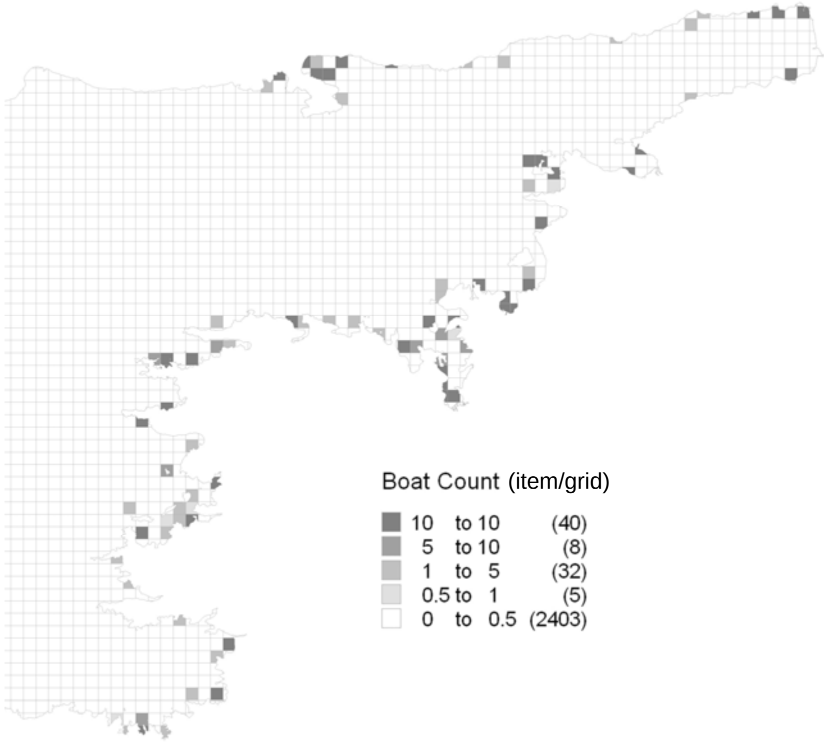


Figure 4.29 Boat count data grids

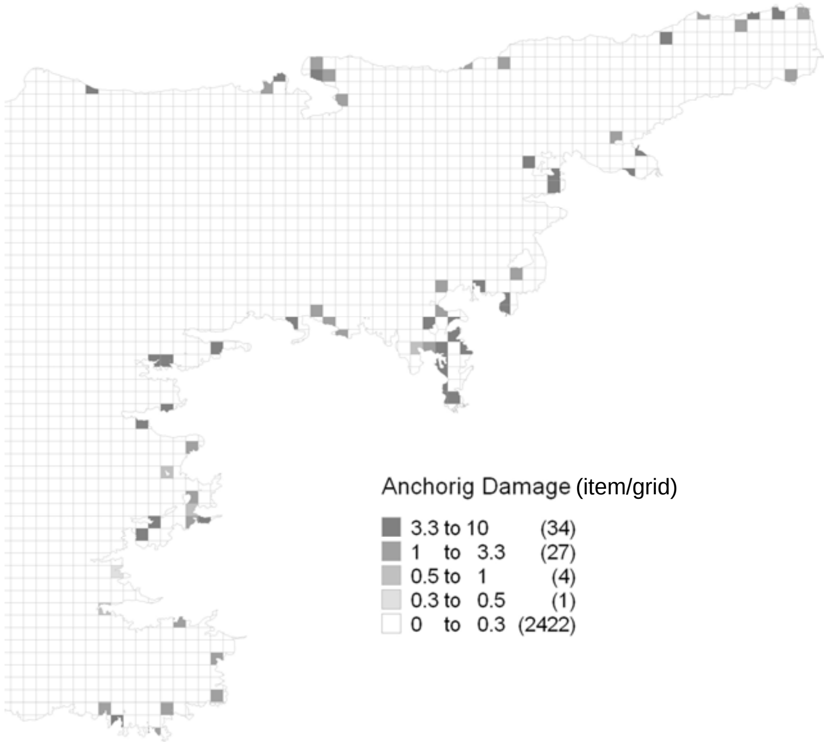


Figure 4.30 Anchoring damage data grids

CHAPTER FIVE
DATA ANALYSIS

A DSS Model was developed to see the effects of land use changes on the coastal zones (Figure 5.1). All data that could be used at the application of this method for Gökova Bay, available in low cost, was prepared in GIS. After preparing the data in GIS, a 500 m grid mesh was fitted and data on each grid was gathered. PCA was applied to the grid data to reach important parameters (variables). After defining important variables, trials were carried out via ANFIS in order to develop the DSS Model. Once ANFIS component of the Model could be set, the relationship between input and output variables would be revealed. The determination of the relations of variables might give a map about the effects on the area and future changes. The relations of the input variables and the effects of them on the output could then be transposed to GIS to produce thematic maps. These thematic maps clarify the spatial distribution of the total effect of human uses on coastal zones. The flowchart of the Model developed in this study is given in Figure 5.1. The DSS Model developed in this study has three major components as GIS, PCA and ANFIS where details of these components of the Model are given in Figure 5.2. Thereafter Model means the developed DSS Model. The PCA model and ANFIS model means components of the developed DSS Model.

The use of multiple tools, PCA and ANFIS increase the difficulty of application of this powerful and useful Model. By enhancing computational usefulness via adding interfaces and simulation ability (which can simulate the impacts of human activities), or using other web based databases or remote sensing applications, experts and decision makers can use the method effectively in future (Matthews, Sibbald & Craw, 1999). In literature, integration of technical and mathematical tools into commercial software is recommended to improve their easy and effective use (Keil, Beranek & Konsynski, 1995).

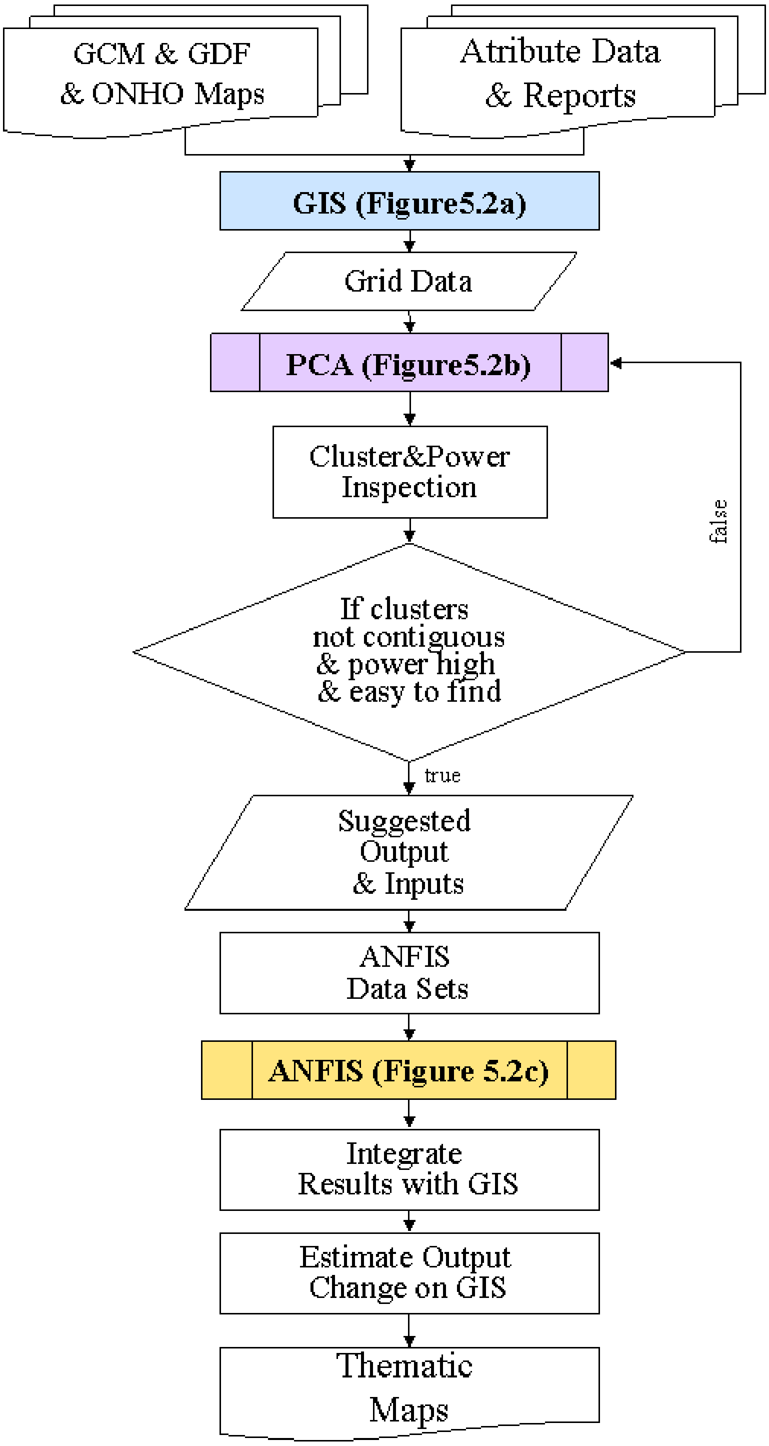


Figure 5.1 Flowchart of the developed DSS Model

The developed Model was applied to Gökova Bay as a pilot area and potential/possible changes in forests, degraded forests, houses, population density and protected species are forecasted. As a first step, especially forest degradation was forecasted. This chapter (Chapter 5) designed to give the details of forest degradation forecasting model and the following sections systematically explain the application steps of forest degradation case in detail. The analysis details of the other data sets: forest, population, housing for land and protected species for sea data, are given in Appendix B.

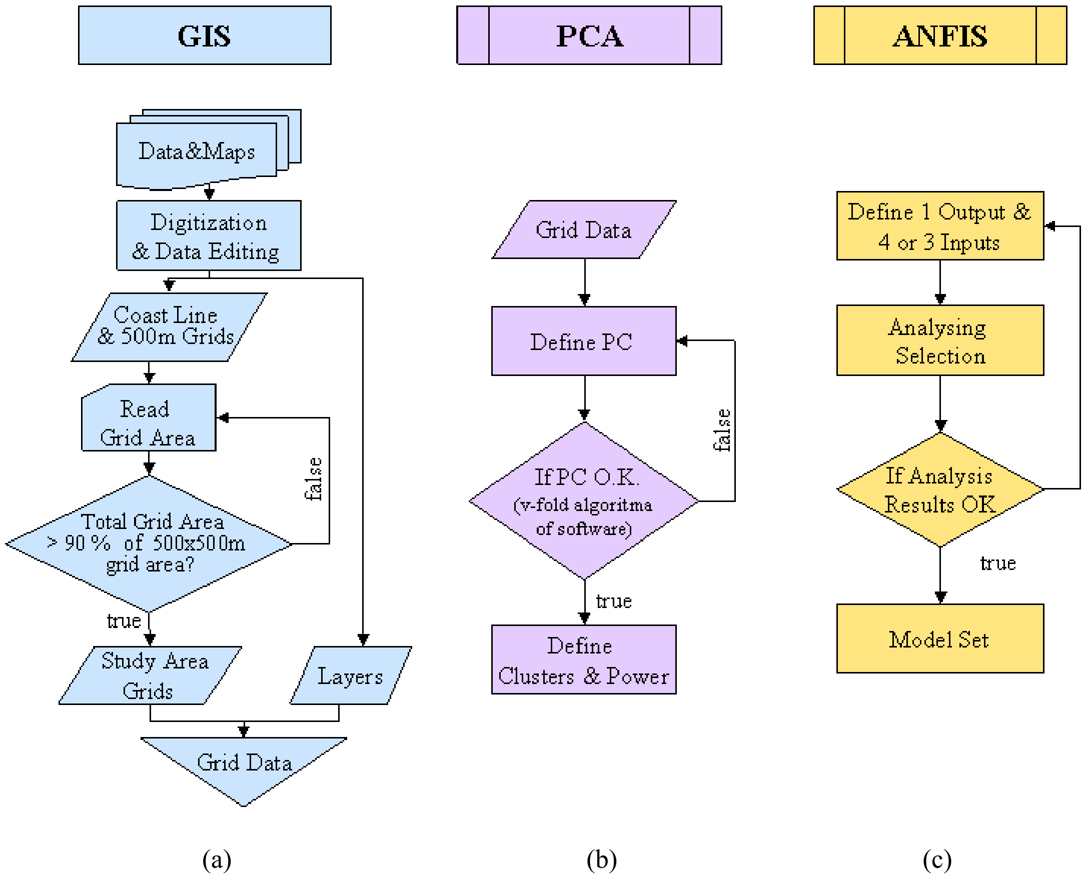


Figure 5.2 Detailed flowchart of the GIS, PCA and ANFIS components of the Model

5.1 Principal Component Analysis and Results

PCA is a valuable tool. It offers a clear vision to detect the relationship between variables. In other words, PCA tries to explain the structure of a data set multidimensionally. The statistical analysis, PCA, was not used as a decision making tool in this study. It was only used to determine the characteristics of the data that would be selected as a model input and output parameters in succeeding part for ANFIS component of the Model development.

Grouped grid data on the GIS was used on the PCA to determine important parameters. The grouped data involved rows (cases, i.e. cells of the grid) and columns (variables, i.e. forest, house...). Firstly, all data was examined by PCA and outliers were determined. Determined outliers were excluded from the data and the PCA was re-examined. After defining important variables, relevant variables (i.e., low cost and efficient ones) were selected for the ANFIS component of the Model.

In all PC Analysis NIPALS algorithm has been used. The number of components in the Principal Component model has been determined by V-fold cross-validation method. The analysis gives two Principal Components for data set which meets the requirements of Cattell for sufficiency of Principal Component (Cattell, 1966).

First of all, all land data with terrain properties; elevation, slope and aspect were analyzed. The power of aspect categories were low (Table 5.1) therefore not used in succeeding analysis. The histogram of the categorical variable aspect is provided in Figure 5.3. The results of PCA are provided in Figure 5.4 and Figure 5.5.

For the next analysis, the layers house, water resources, highways, unimproved roads, trail and other roads, river, intermittent river, forest, burnt forest, degraded forest, agriculture, wetland, pier, population, population density, mean slope, median elevation of the terrain in each 500 m grid are included. In PCA, the variables included to analysis affects the overall relations as PCA figures out the whole relationship between them, instead of one where it is the case in correlation matrices and linear regression analysis.

Table 5.1 Variable importance of all land data and aspect of the terrain

Variable	Category value	Power	Importance
forest_deg		0.744	1
agri		0.714	2
forest		0.460	3
DEM_Median_1		0.454	4
forest_burnt		0.410	5
river_intrmtd		0.361	6
house		0.325	7
Slope_Mean_1		0.207	8
pop_density		0.184	9
waterresrc		0.182	10
road3_trail		0.137	11
road1_hghw		0.113	12
road2_unpr		0.102	13
aspect_8side {5}	5	0.093	14
river		0.044	15
wetland		0.023	16
aspect_8side {1}	1	0.016	17
aspect_8side {4}	4	0.015	18
aspect_8side {6}	6	0.013	19
aspect_8side {2}	2	0.012	20
aspect_8side {7}	7	0.009	21
aspect_8side {3}	3	0.005	22
aspect_8side {8}	8	0.005	23
pier		0.002	24

Aspects: 1 ENE; 2 NNE; 3 NNW; 4 WNW; 5 WSW; 6 SSW; 7 SSE; 8 ESE

So, each time PCA is run and fitted with selected input groups. Each one gives little different results considering input groups. The difference can also be seen on variable importances and loading scatterplots graphs for all group inputs. Therefore PCA is repeated for these cases. Relations are investigated as group parameters.

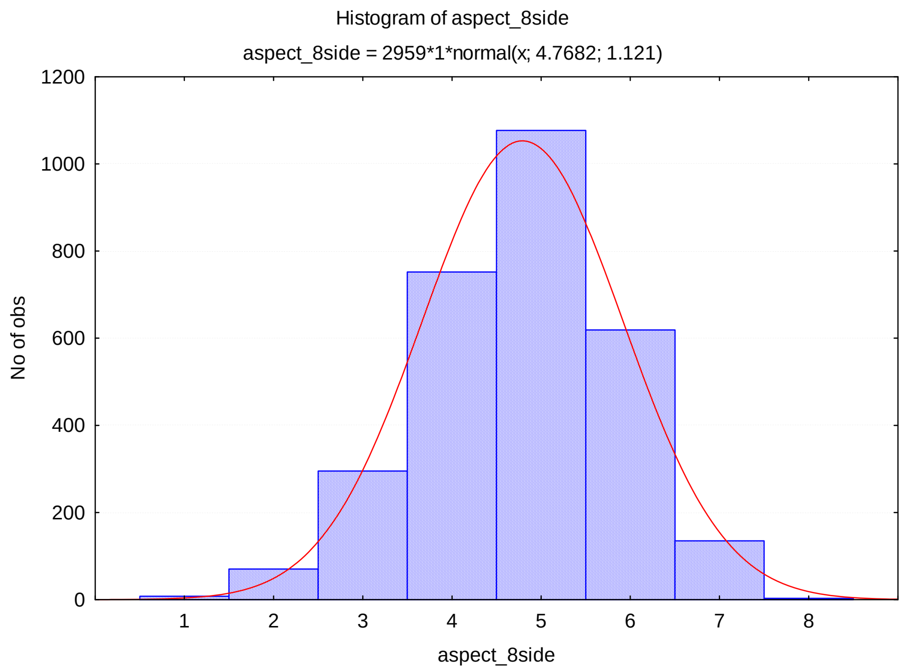


Figure 5.3 Histogram of Terrain Aspect

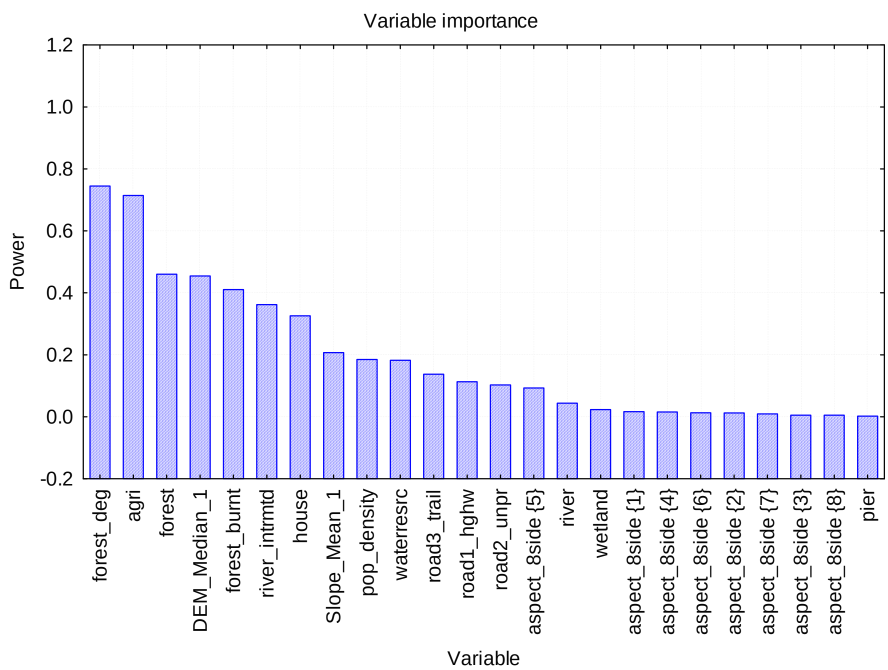


Figure 5.4 Variable importance of land data with terrain aspect

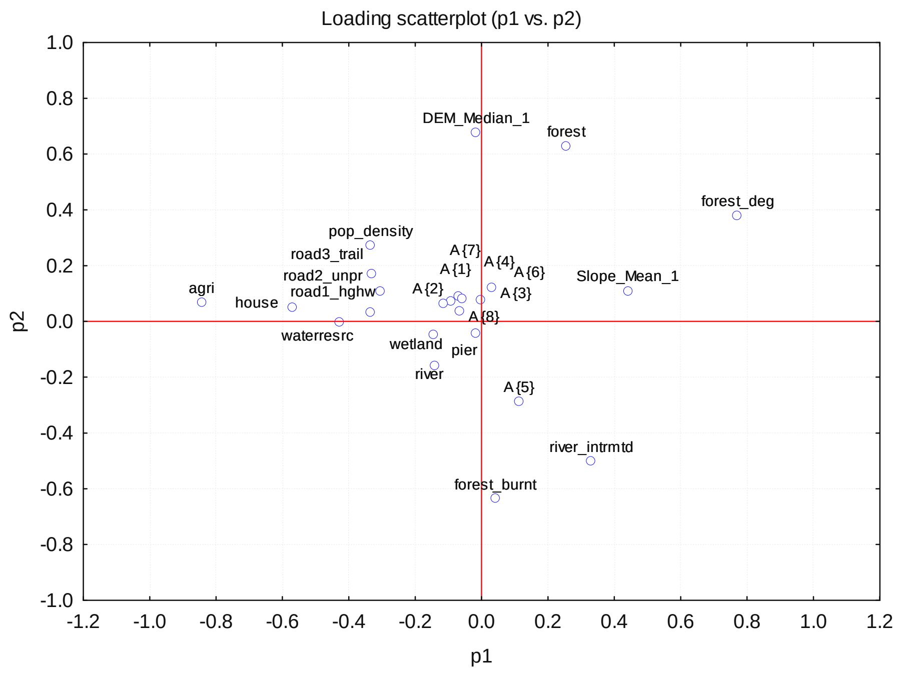


Figure 5.5 Loading scatter plot of principal components

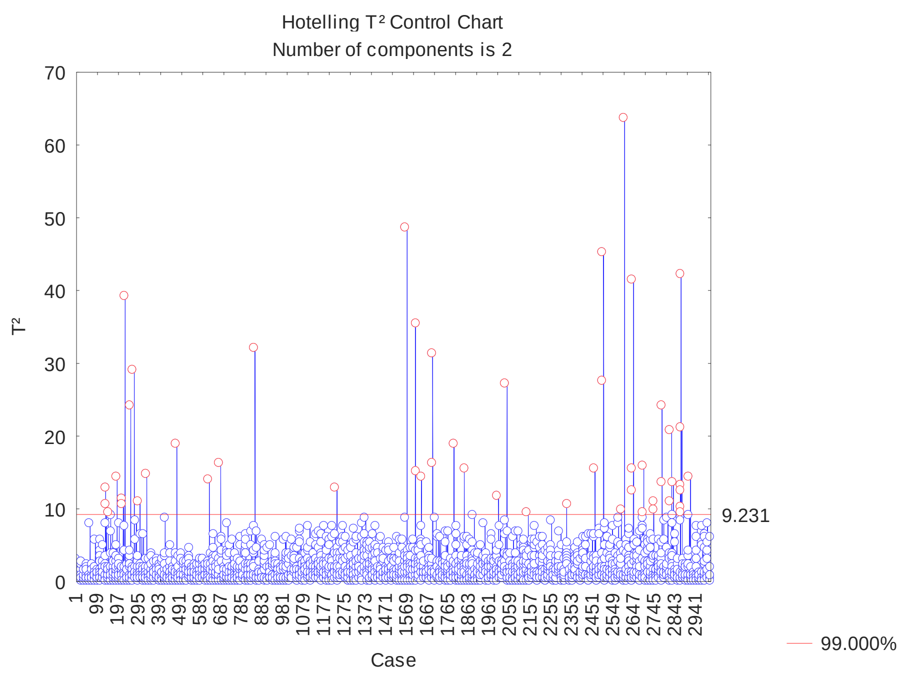


Figure 5.6 Chart of the Hotelling T^2 analysis

Another topic that affects the results of PCA is outliers. Outliers are determined with the assumption of the normal distribution of data; however abnormalities of the data affect the principal components. So, the outlier cases are excluded from data to clarify the relations. The raw grid based data examined first and outlier cases which indicate abnormalities have been excluded by the guidance of Hotelling T^2 analysis (Figure 5.6). The red points in the Figure 5.6 indicate the values remained outside the 99 % ($\mu \pm 3\sigma$) in the standardized normal distribution. Hotelling T^2 analysis shows the values falling outside the scope of normality.

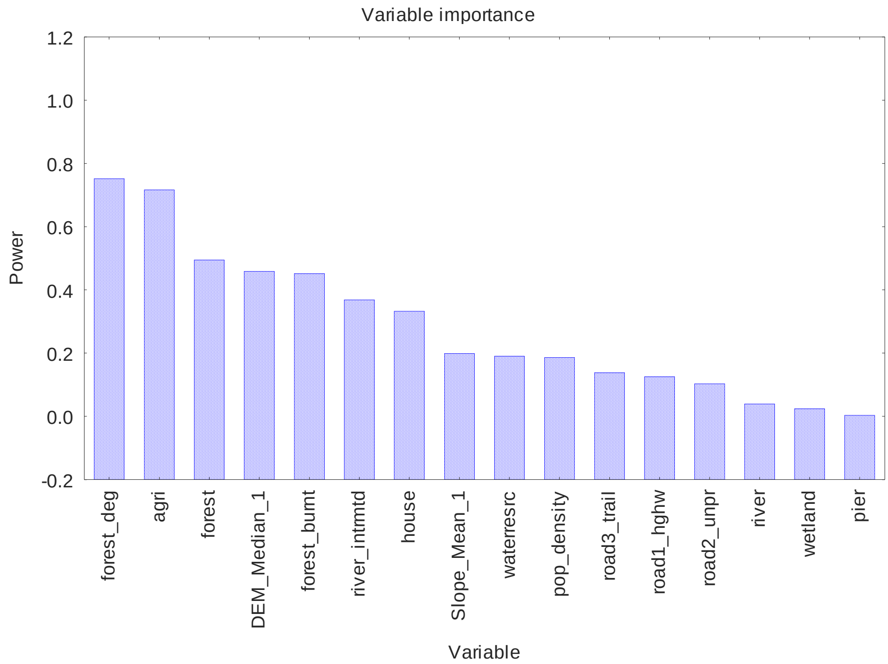


Figure 5.7 Variable importance of all land data

PCA gives the importance of variables via power which is the fraction of the residual standard variation and initial standard deviation. The variable importance of land data is given in Table 5.2 with its power values and drawn in Figure 5.7.

The variable importance of PCA measures how well a variable is represented by the principal components. The measure of this, power, is ranging from 0 to 1. As shown in Figure 5.7, while power decreases, the significance of variable decreases for the models having a sufficient number of principal components.

Table 5.2 Variable importance

Variables (GIS Layers)	Power	Importance
forest_deg	0.752	1
agri	0.716	2
forest	0.494	3
DEM_Median_1	0.458	4
forest_burnt	0.451	5
river_intrmtd	0.368	6
house	0.332	7
Slope_Mean_1	0.198	8
waterresrc	0.189	9
pop_density	0.186	10
road3_trail	0.138	11
road1_hghw	0.124	12
road2_unpr	0.102	13
river	0.039	14
wetland	0.023	15
pier	0.002	16

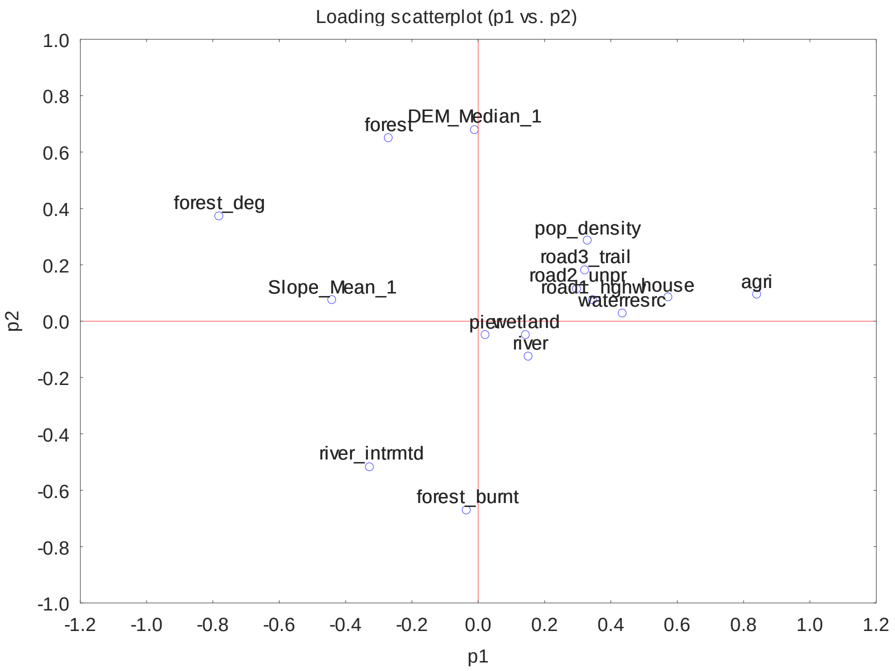


Figure 5.8 Loading scatter plot of principal components

As shown in loading scatterplot of the components (Figure 5.8) the neighboring variables exhibiting similar characteristics in PC model which also indicates they are correlated. Therefore a representative variable has been selected for further analysis from variables close to each other, and considering high power values of the variable. The statistical analysis PCA was not used as a decision making tool, used only to determine the characteristics of the data in order to be selected as a model input parameter in succeeding part.

The new revise analysis has been processed with smaller group of parameters, main land parameters; forest, degraded forest, agriculture, elevation, intermittent river, house, population density and data of road types. Preceding to the small group of land data that will be analyzed in ANFIS model development, PCA was applied to these variables.

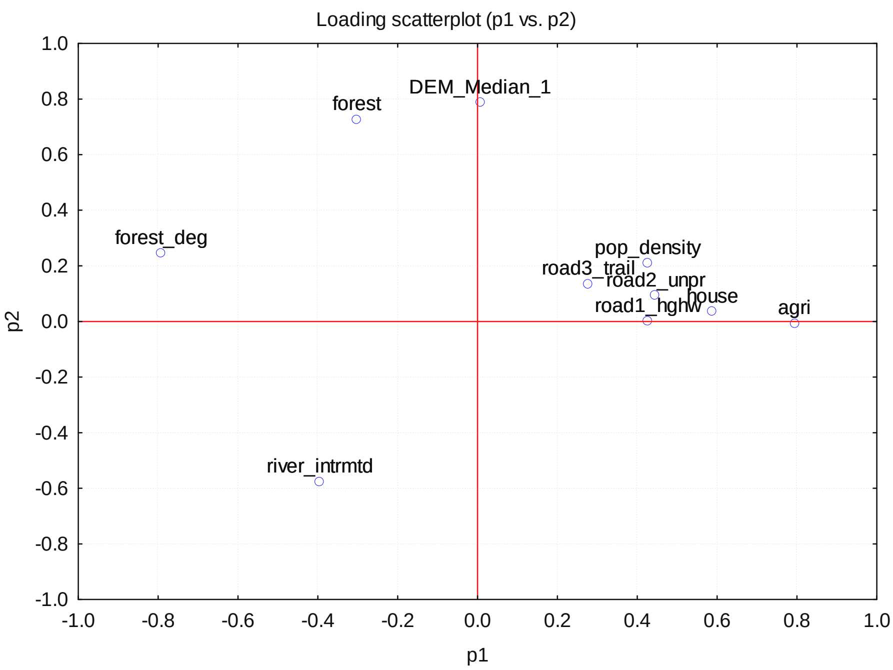


Figure 5.9 Loading Scatter plot of selected land data

Each group variables used for the model development of ANFIS are analyzed by PCA method to examine the probability distributions, relations (connections) and importance. Appropriate replacing of the variables is evaluated by considering relations of the variables. As shown in Figure 5.9, population density, house and road types are all form a group close to agricultural land area variable. This outcome shows that road types can be used interchangeably. Besides, the same relation exists between house and population density, so one of them can also be used for model development interchangeably. This interchangeability relationship of variables is important for decision support. Considering the interchangeability relationship, the data can be prepared with low cost and effort (i.e. not needing to process) on further coastal zone studies if it's already available.

The road types have little importance on the prepared data as shown in Figure 5.9 and Figure 5.10. PCA is built assuming the normal distribution of the data. However, data do not fit to normal distribution give small importance on the PCA. When such data used on ANFIS model development it gives low quality results. This situation represents the importance of gathering relevant data on purpose.

Loading scatterplot and variable importance of the selected land data analysis are given in Figure 5.9, Figure 5.10 and Table 5.3.

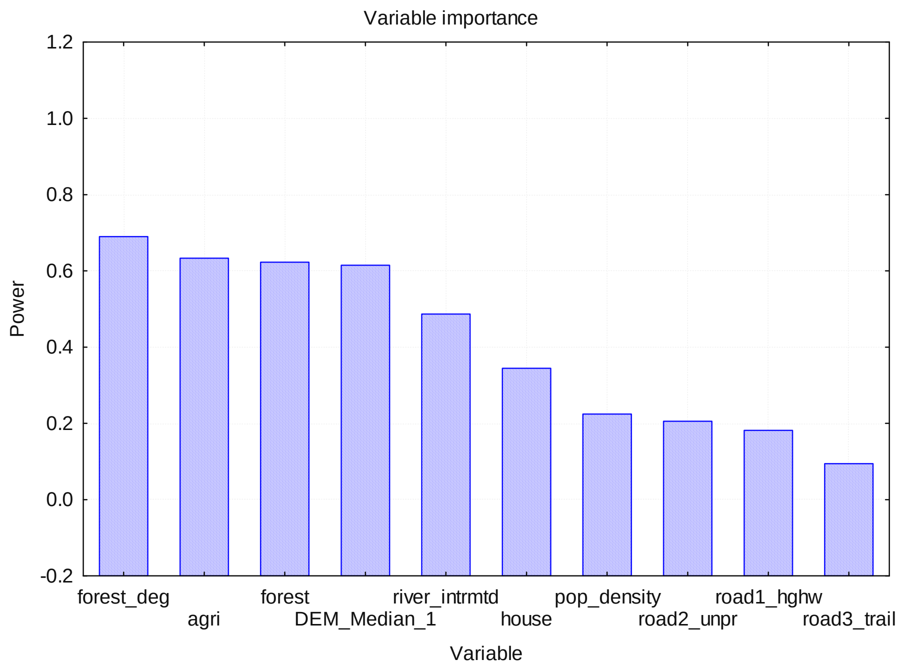


Figure 5.10 Variable importance of selected land data

Table 5.3 Variable importance of selected land data

Variables (GIS Layers)	Power	Importance
forest_deg	0.689	1
agri	0.633	2
forest	0.622	3
DEM_Median_1	0.614	4
river_intrmtd	0.486	5
house	0.344	6
pop_density	0.224	7
road2_unpr	0.205	8
road1_hghw	0.181	9
road3_trail	0.094	10

On continuing the analysis, PCA was performed for each land data group. Each one gives little different results. The difference can also be seen between Figure 5.12 and Figure 5.22.

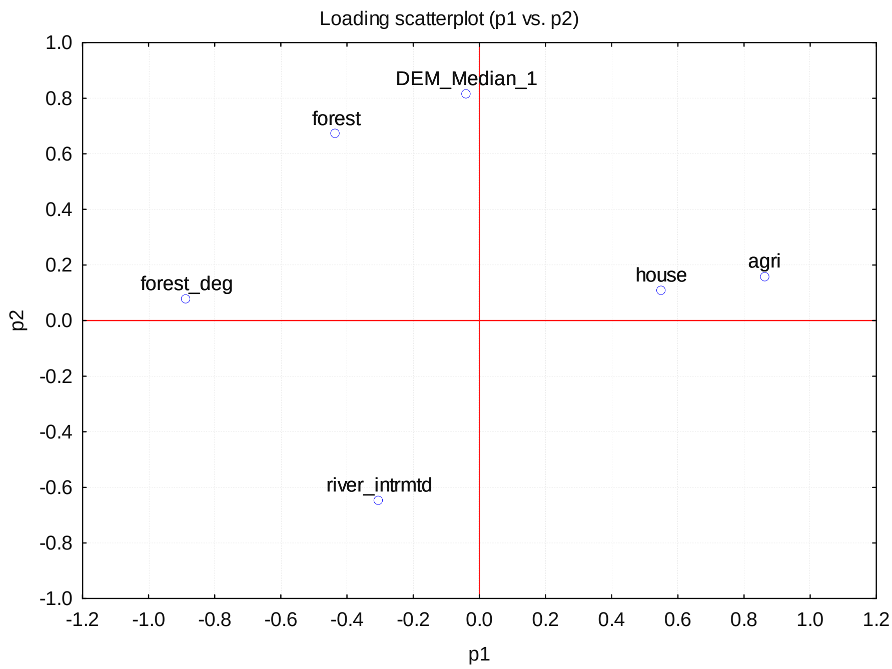


Figure 5.11 Loading Scatter plot of first land data group

Loading scatterplot and variable importance of the first to sixth land data analyses are given in Figure 5.9 to Figure 5.11 and Figure 5.12 to Figure 5.21 and Figure 5.22. The listed importances are given between Table 5.4 and Table 5.9.

First land data group consist of degraded forest, forest, elevation, house, agriculture and intermittent rivers. PCA is performed for the first group.

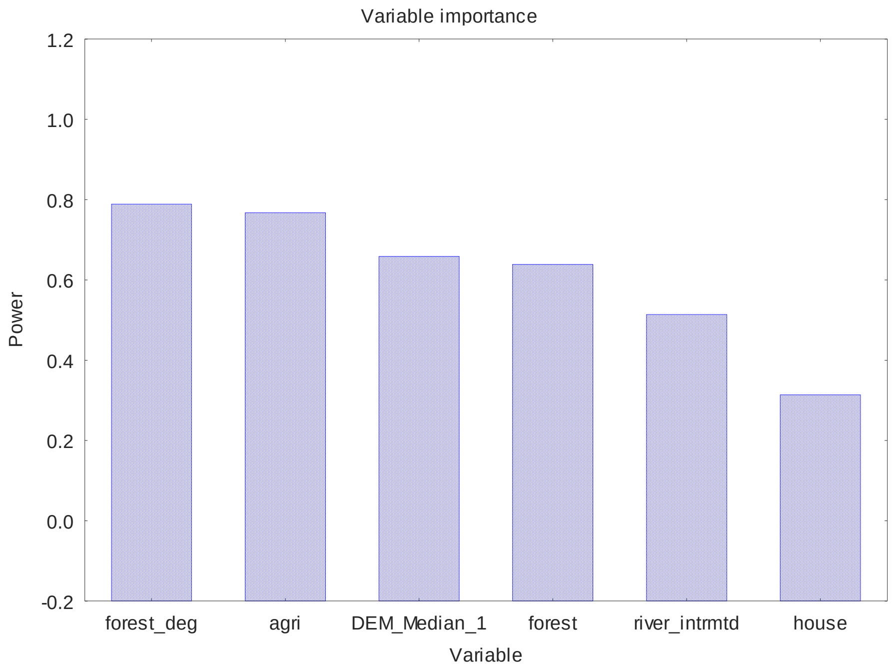


Figure 5.12 Variable importance of first land data group

Table 5.4 Variable importance of first group

Variables (GIS Layers)	Power	Importance
forest_deg	0.789	1
agri	0.767	2
DEM_Median_1	0.658	3
forest	0.638	4
river_intrmtd	0.513	5
house	0.313	6

Second land data group consist of degraded forest, forest, elevation, population density, agriculture and intermittent rivers. PCA is repeated for the second group.

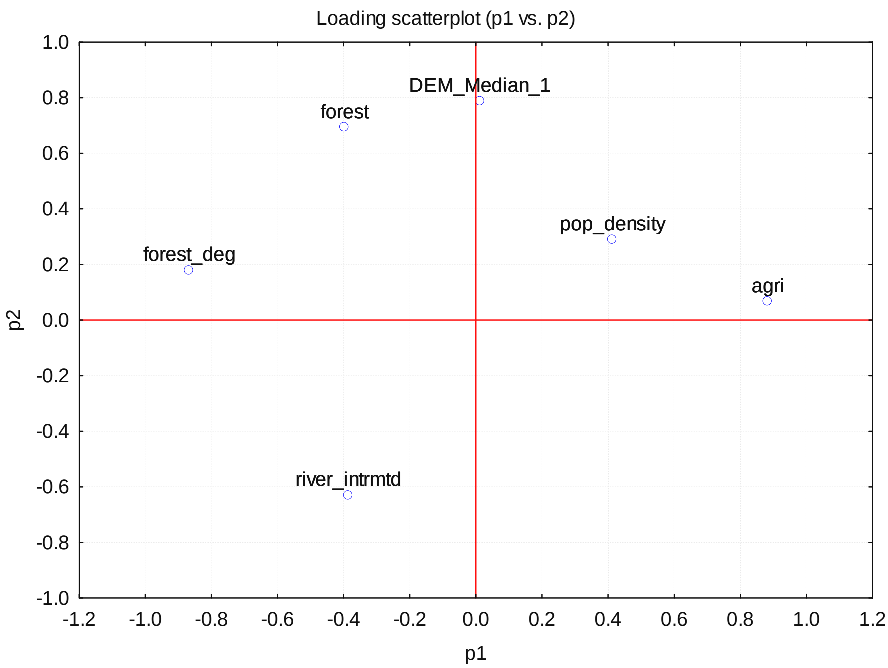


Figure 5.13 Loading Scatter plot of second land data group

Table 5.5 Variable importance of second group

Variables	Power	Importance
agri	0.785	1
forest_deg	0.785	2
forest	0.638	3
DEM_Median_1	0.617	4
river_intrmtd	0.543	5
pop_density	0.254	6

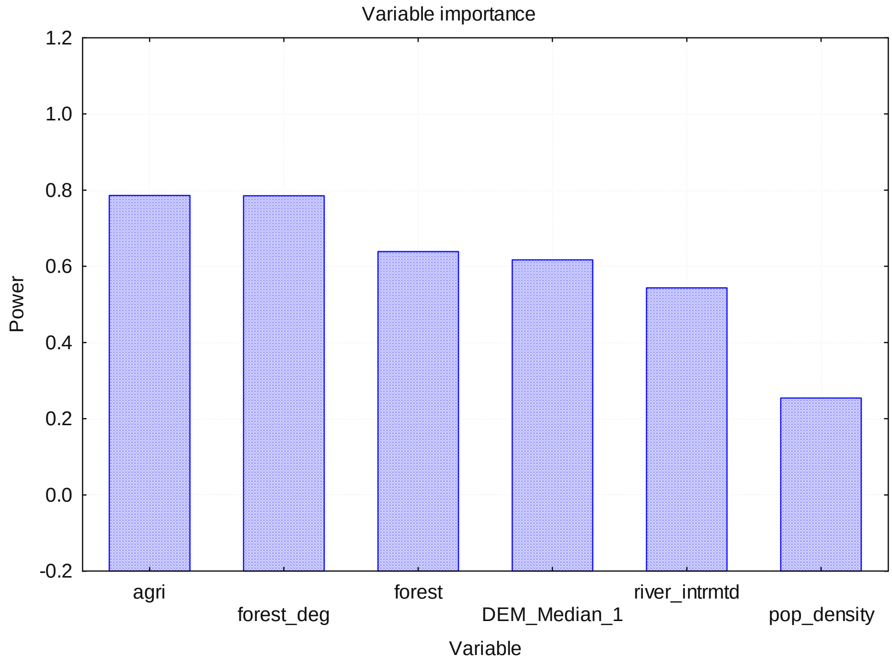


Figure 5.14 Variable importance of second land data group

Third land data group consist of degraded forest, forest, elevation, road type 1 (highways), agriculture and intermittent rivers. PCA is repeated for the third group.

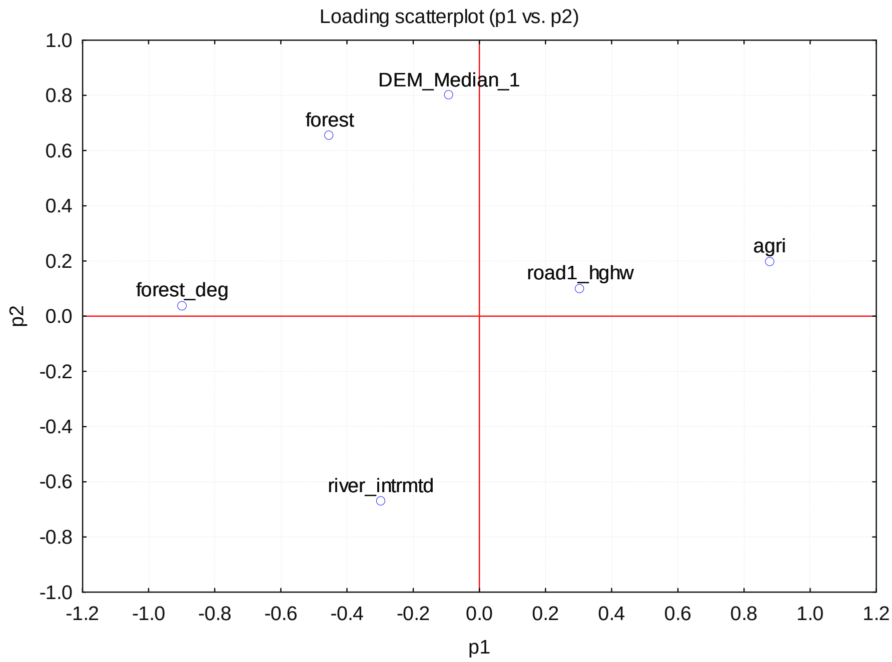


Figure 5.15 Loading Scatterplot of third land data group

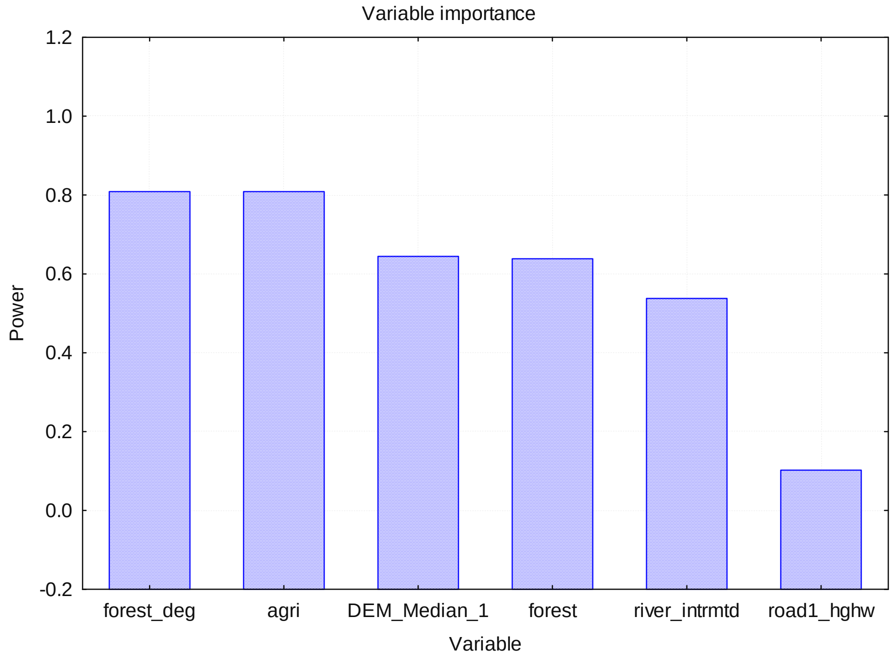


Figure 5.16 Variable importance of third land data group

Fourth land data group consist of degraded forest, forest, elevation, sum of all road types, agriculture and intermittent rivers. PCA is repeated for the fourth group.

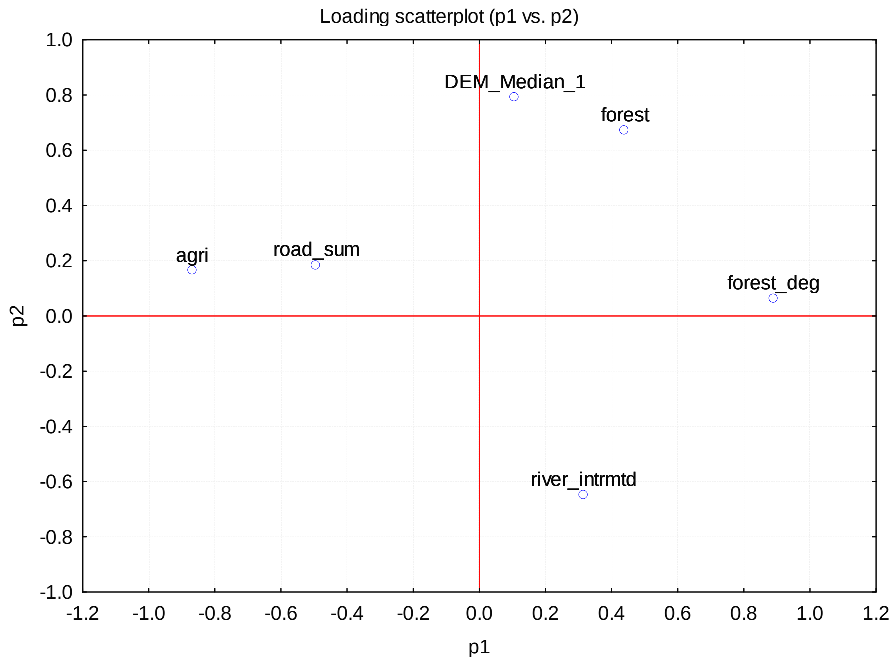


Figure 5.17 Loading Scatter plot of fourth land data group

Table 5.6 Variable importance of third group

Variables (GIS Layers)	Power	Importance
forest_deg	0.808	1
agri	0.808	2
DEM_Median_1	0.644	3
forest	0.638	4
river_intrmtd	0.537	5
road1_hghw	0.102	6

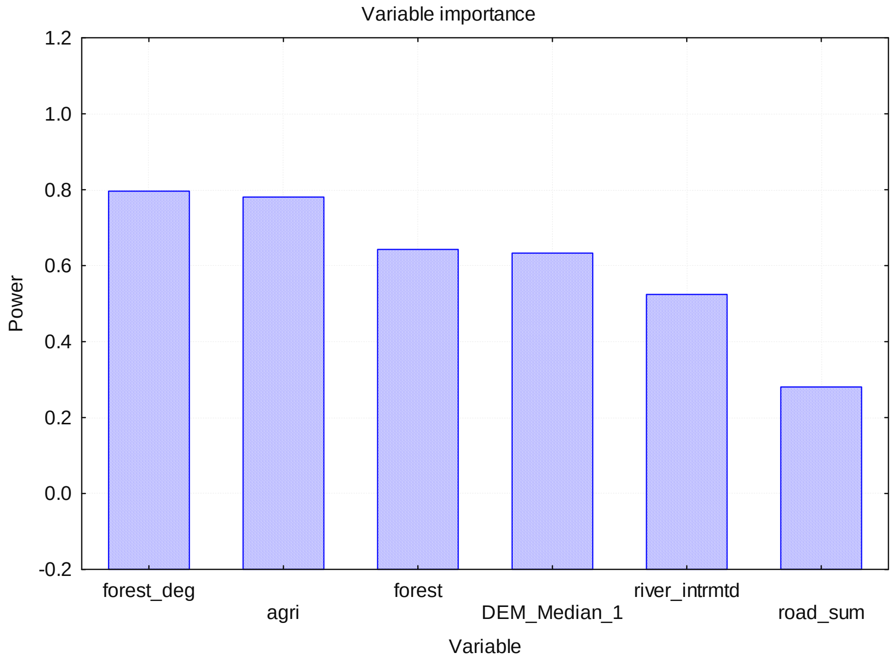


Figure 5.18 Variable importance of fourth land data group

Table 5.7 Variable importance of fourth group

Variables (GIS Layers)	Power	Importance
forest_deg	0.795	1
agri	0.780	2
forest	0.642	3
DEM_Median_1	0.632	4
river_intrmtd	0.524	5
road_sum	0.280	6

Fifth land data group consist of degraded forest, forest, elevation, road type 2 (unimproved), agriculture and intermittent rivers. PCA is repeated for the fifth group.

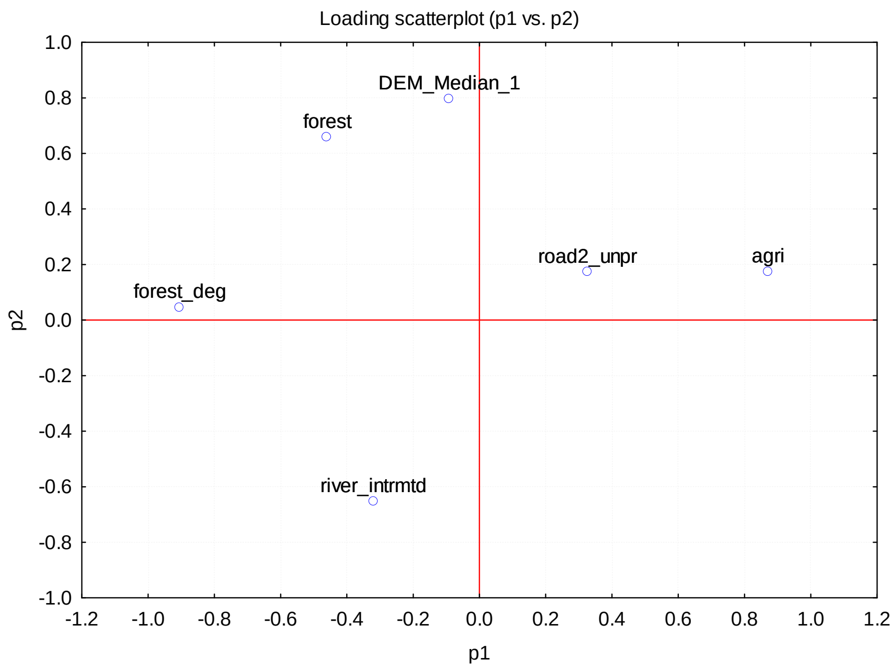


Figure 5.19 Loading Scatter plot of fifth land data group

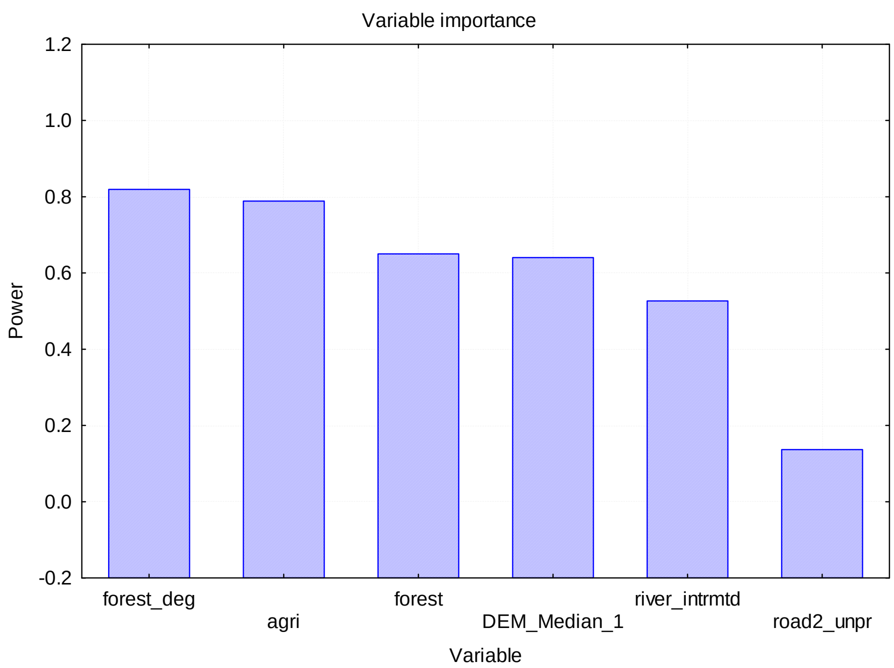


Figure 5.20 Variable importance of fifth land data group

Table 5.8 Variable importance of fifth group

Variables (GIS Layers)	Power	Importance
forest_deg	0.819	1
agri	0.788	2
forest	0.650	3
DEM_Median_1	0.640	4
river_intrmtd	0.526	5
road2_unpr	0.136	6

Sixth land data group consist of degraded forest, forest, elevation, road type 3 (trail), agriculture and intermittent rivers. PCA is repeated for the sixth group.

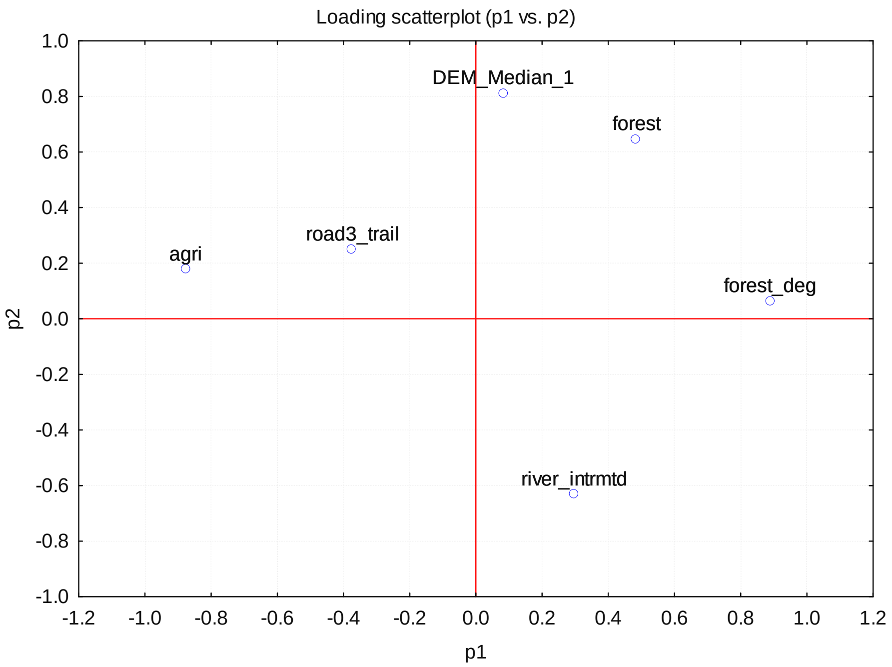


Figure 5.21 Loading Scatter plot of sixth land data group

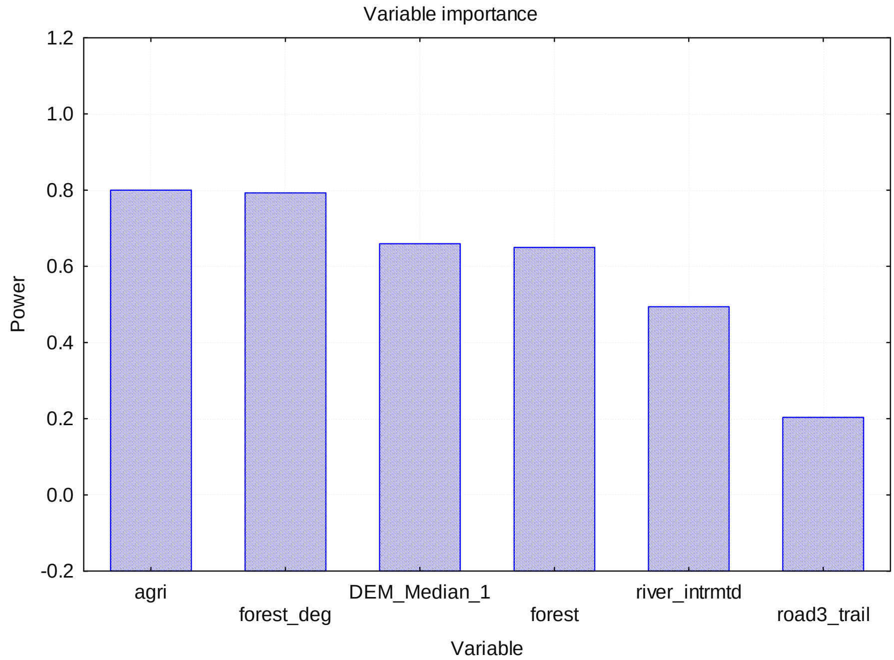


Figure 5.22 Variable importance of sixth land data group

Table 5.9 Variable importance of sixth group

Variables (GIS Layers)	Power	Importance
agri	0.800	1
forest_deg	0.792	2
DEM_Median_1	0.659	3
forest	0.649	4
river_intrmtd	0.494	5
road3_trail	0.203	6

Presented results of PCA provide the selection of variables on Table 5.11 and show the interrelationship and the effectiveness of the variables on the system. Considering the result of PCA, the input and output parameters of ANFIS component of the Model was selected.

5.2 ANFIS Model Development and Results, for Forest Degradation Model

Coastal zone management efforts should be based on mathematics through analytical tools, techniques and methodologies, because developing a reproducible, controllable system that can give feedback is very important. ANFIS is a relatively recently developed adaptive intelligent system which is a combination of ANN and FIS (Jang, 1992). ANN learns by adjusting the weights of interconnections between layers and FIS uses fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. ANFIS is capable of understanding complex nature dynamics and solving problems by human like reasoning, to enhance the decisions. ANFIS was adapted to commercial software MATLAB® which is used as a software tool in this study.

The data selected by PCA was used in the ANFIS component of the Model. The selected variables were used in the development of the reliable ANFIS model. The training and testing process of the ANFIS model was carried out until the relevant membership functions, rules and relation surfaces were found.

The variables of land 500 m grid data consist of layers such as house, water resources, highways, unimproved roads, trail and other roads, river, intermittent river, forest, burnt forest, degraded forest, agriculture, wetland, pier, population, population density, mean slope, and median elevation of the terrain. These layers are used for ANFIS model after normalization in order to overcome the problems arising from range differences. The layers used in analysis are given between Figure 4.16 and Figure 4.30.

In order to develop a reliable ANFIS model, the selection of input and output variables is very important (Jang, 1996) and model outputs and training errors are all sensitive to input change. During variable selection, especially output selection, the PCA results were used (Figure 5.7 to Figure 5.22). Combination of inputs tried many times to decrease the error while setting up ANFIS model. A sample data is given in Table 5.10 for land data. Sea data sample and analysis details can be found in Appendix B.

Table 5.10 Sample of land data for ANFIS training (1837x5)

River-int	Forest	Agri	DEM	Forest_Deg
0.06945	0.17080	0.22095	0.16204	0.3830
0.50607	0.24108	0.00000	0.12500	0.9998
0.00000	0.08334	0.22151	0.58647	0.9999
0.00199	0.70683	0.22198	0.22260	0.0343
0.23282	0.13737	0.22273	0.62502	0.8852
0.24594	0.04568	0.00243	0.06080	0.9998
0.00000	0.39716	0.22396	0.05937	0.8024
0.01382	0.04556	0.22560	0.22932	0.9999
0.26891	0.28120	0.22672	0.02571	0.9134
0.00430	0.25095	0.22720	0.08893	0.9407
0.41493	0.30234	0.22946	0.16638	0.1067
0.86117	0.04521	0.23161	0.06159	0.9998
0.00000	0.32257	0.23188	0.41669	0.8147
0.00000	0.39496	0.23659	0.33434	0.0000
0.26386	0.44605	0.23660	0.13944	0.9996
0.00000	0.50705	0.23748	0.07259	0.9483
. . .				
0.09897	0.06087	0.00000	0.08332	0.3931

For model development four or three input combinations out of 10 variables are selected and trained on ANFIS considering the computational processor and time requirement. First, forest degradation area was selected as an output to develop a model. The Forest Degradation Model was carried out to figure out the sensitivity of forest degradation to the change in agriculture, elevation, forest area, house, population density, and intermittent river and road types. The model development trials formed of four input combinations are given in Table 5.11.

Table 5.11 Trained degraded forest area estimation models for different input combinations

No	Inputs				Output
1	agri	DEM_Median_1	forest	house	forest_deg
2	agri	DEM_Median_1	forest	pop_density	forest_deg
3	agri	DEM_Median_1	forest	river_intrmtd	forest_deg*
4	agri	DEM_Median_1	forest	road_sum	forest_deg
5	agri	DEM_Median_1	forest	road1_hghw	forest_deg
6	agri	DEM_Median_1	house	pop_density	forest_deg
7	agri	DEM_Median_1	house	river_intrmtd	forest_deg
8	agri	DEM_Median_1	house	road_sum	forest_deg
9	agri	DEM_Median_1	house	road1_hghw	forest_deg
10	agri	DEM_Median_1	pop_density	river_intrmtd	forest_deg
11	agri	DEM_Median_1	pop_density	road_sum	forest_deg

Table 5.11 Trained degraded forest area estimation models for different input combinations (cont.)

No	Inputs				Output
12	agri	DEM_Median_1	pop_density	road1_hghw	forest_deg
13	agri	DEM_Median_1	river_intrmtd	road_sum	forest_deg
14	agri	DEM_Median_1	river_intrmtd	road1_hghw	forest_deg
15	agri	forest	house	pop_density	forest_deg
16	agri	forest	house	river_intrmtd	forest_deg
17	agri	forest	house	road_sum	forest_deg
18	agri	forest	house	road1_hghw	forest_deg
19	agri	forest	pop_density	river_intrmtd	forest_deg
20	agri	forest	pop_density	road_sum	forest_deg
21	agri	forest	pop_density	road1_hghw	forest_deg
22	agri	forest	river_intrmtd	road_sum	forest_deg
23	agri	forest	river_intrmtd	road1_hghw	forest_deg
24	agri	house	pop_density	river_intrmtd	forest_deg
25	agri	house	pop_density	road_sum	forest_deg
26	agri	house	pop_density	road1_hghw	forest_deg
27	agri	house	river_intrmtd	road_sum	forest_deg
28	agri	house	river_intrmtd	road1_hghw	forest_deg
29	agri	pop_density	river_intrmtd	road_sum	forest_deg
30	agri	pop_density	river_intrmtd	road1_hghw	forest_deg
31	agri	pop_density	road1_hghw	road3_trail	forest_deg
32	agri	pop_density	road1_hghw	road2_unpr	forest_deg
33	agri	pop_density	road2_unpr	road3_trail	forest_deg
34	DEM_Median_1	forest	house	pop_density	forest_deg
35	DEM_Median_1	forest	house	river_intrmtd	forest_deg
36	DEM_Median_1	forest	house	road_sum	forest_deg
37	DEM_Median_1	forest	house	road1_hghw	forest_deg
38	DEM_Median_1	forest	house	road2_unpr	forest_deg
39	DEM_Median_1	forest	house	road3_trail	forest_deg
40	DEM_Median_1	forest	pop_density	river_intrmtd	forest_deg
41	DEM_Median_1	forest	pop_density	road_sum	forest_deg
42	DEM_Median_1	forest	pop_density	road1_hghw	forest_deg
43	DEM_Median_1	forest	river_intrmtd	road_sum	forest_deg
44	DEM_Median_1	forest	river_intrmtd	road1_hghw	forest_deg
45	DEM_Median_1	forest	river_intrmtd	road2_unpr	forest_deg
46	DEM_Median_1	forest	river_intrmtd	road3_trail	forest_deg
47	DEM_Median_1	forest	road1_hghw	road2_unpr	forest_deg
48	DEM_Median_1	house	pop_density	river_intrmtd	forest_deg
49	DEM_Median_1	house	pop_density	road_sum	forest_deg
50	DEM_Median_1	house	pop_density	road1_hghw	forest_deg
51	DEM_Median_1	house	river_intrmtd	road_sum	forest_deg
52	DEM_Median_1	house	river_intrmtd	road1_hghw	forest_deg
53	DEM_Median_1	house	river_intrmtd	road2_unpr	forest_deg
54	DEM_Median_1	house	river_intrmtd	road3_trail	forest_deg
55	DEM_Median_1	house	road1_hghw	road2_unpr	forest_deg
56	DEM_Median_1	pop_density	river_intrmtd	road_sum	forest_deg
57	DEM_Median_1	pop_density	river_intrmtd	road1_hghw	forest_deg
58	DEM_Median_1	river_intrmtd	road1_hghw	road2_unpr	forest_deg

Table 5.11 Trained degraded forest area estimation models for different input combinations (cont.)

No	Inputs				Output
59	forest	house	pop_density	river_intrmtd	forest_deg
60	forest	house	pop_density	road_sum	forest_deg
61	forest	house	pop_density	road1_hghw	forest_deg
62	forest	house	river_intrmtd	road_sum	forest_deg
63	forest	house	river_intrmtd	road1_hghw	forest_deg
64	forest	house	river_intrmtd	road2_unpr	forest_deg
65	forest	house	river_intrmtd	road3_trail	forest_deg
66	forest	house	road1_hghw	road2_unpr	forest_deg
67	forest	pop_density	river_intrmtd	road_sum	forest_deg
68	forest	pop_density	river_intrmtd	road1_hghw	forest_deg
69	forest	river_intrmtd	road1_hghw	road2_unpr	forest_deg
70	house	pop_density	river_intrmtd	road_sum	forest_deg
71	house	pop_density	river_intrmtd	road1_hghw	forest_deg
72	house	river_intrmtd	road1_hghw	road2_unpr	forest_deg
73	pop_density	river_intrmtd	road_sum	road1_hghw	forest_deg
* Selected model					

For the first approximations for degraded forest, an error exceeding 20 % was not accepted as a significance level for the model (Urbanski & Szymelfenig, 2003). The selected inputs influenced the model; furthermore some inputs obstructed model development when they were used. The change of the training error can be seen in Figure 5.23. While training, optimum iteration number was selected for each run to reach a stationary error quantity.

On ANFIS model development, after trials of triangular, trapezoidal, Gaussian, bell shaped and sigmoidal membership functions, the triangular membership function was selected due to its minimum error in the models. Triangular membership functions have been used commonly in all analysis because of simplicity and computational efficiency (Yen & Langari, 1999). The backpropagation optimization and iteration counts were selected in the same manner to meet the stationary error ranges. Three linguistic terms was used for membership functions. ANFIS model structure and membership functions were shown in Figure 5.24 and Figure 5.26.

The rules were formed by first order Sugeno fuzzy model (Sugeno, M. & Kang G.T., 1988; Takagi T. & Sugeno M., 1985). The changing laws of two inputs vs. output were plotted as a surface graph and a line graph to visualize the relation in between. After 73 model trial, the change in degraded forest (Figure 4.17) was forecasted by changes of the forest, agriculture, elevation and intermittent rivers.

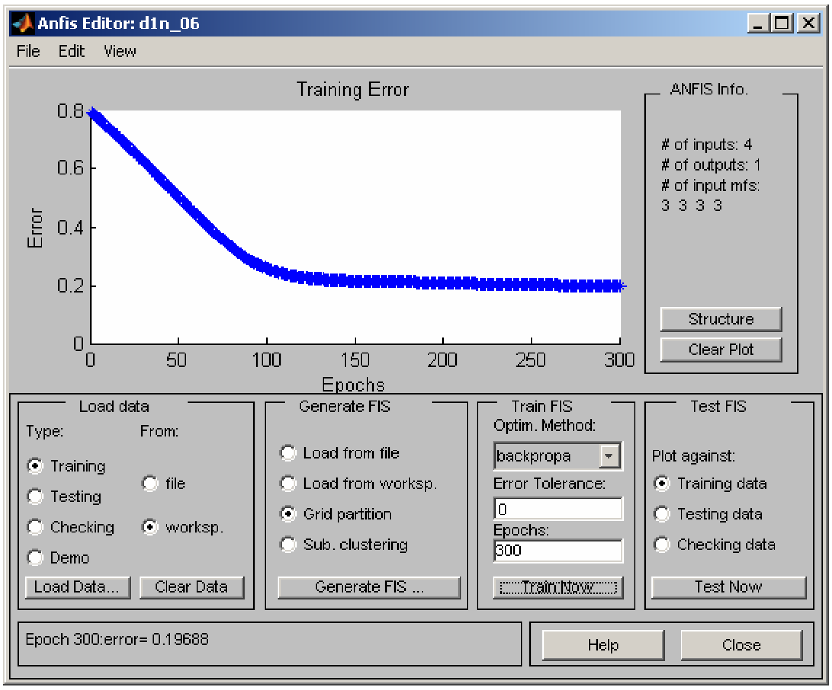


Figure 5.23 Training error of the data

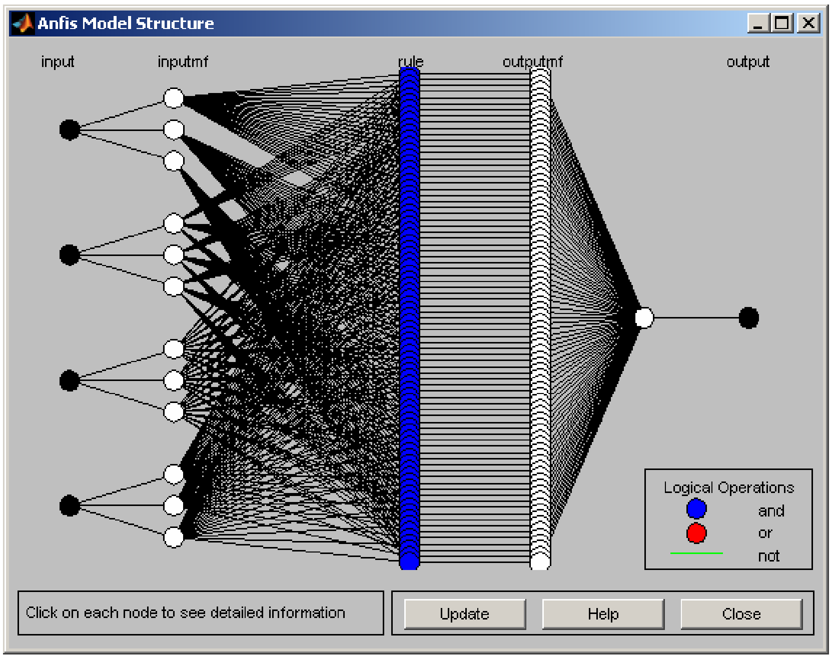


Figure 5.24 Model structure

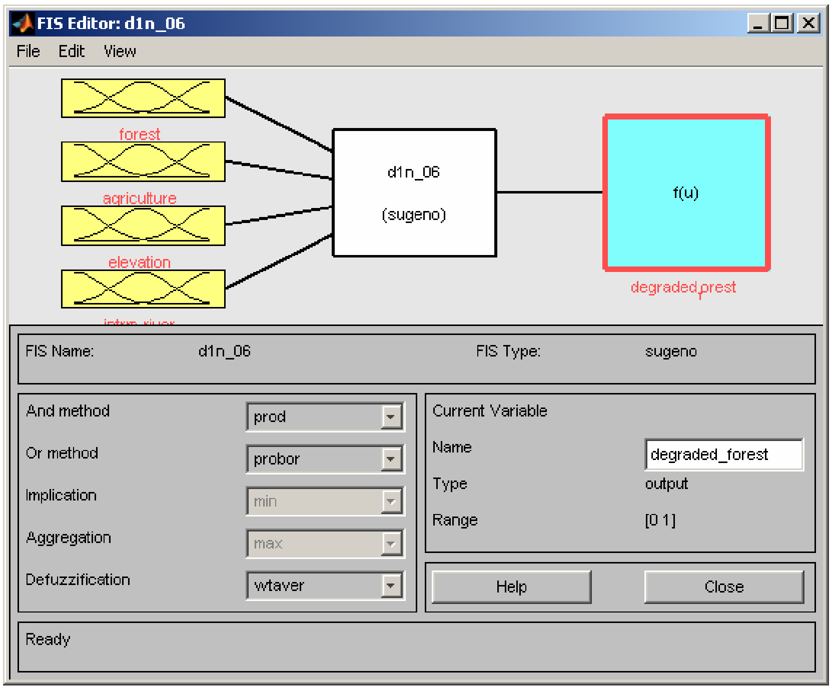


Figure 5.25 Input and output of the analysis

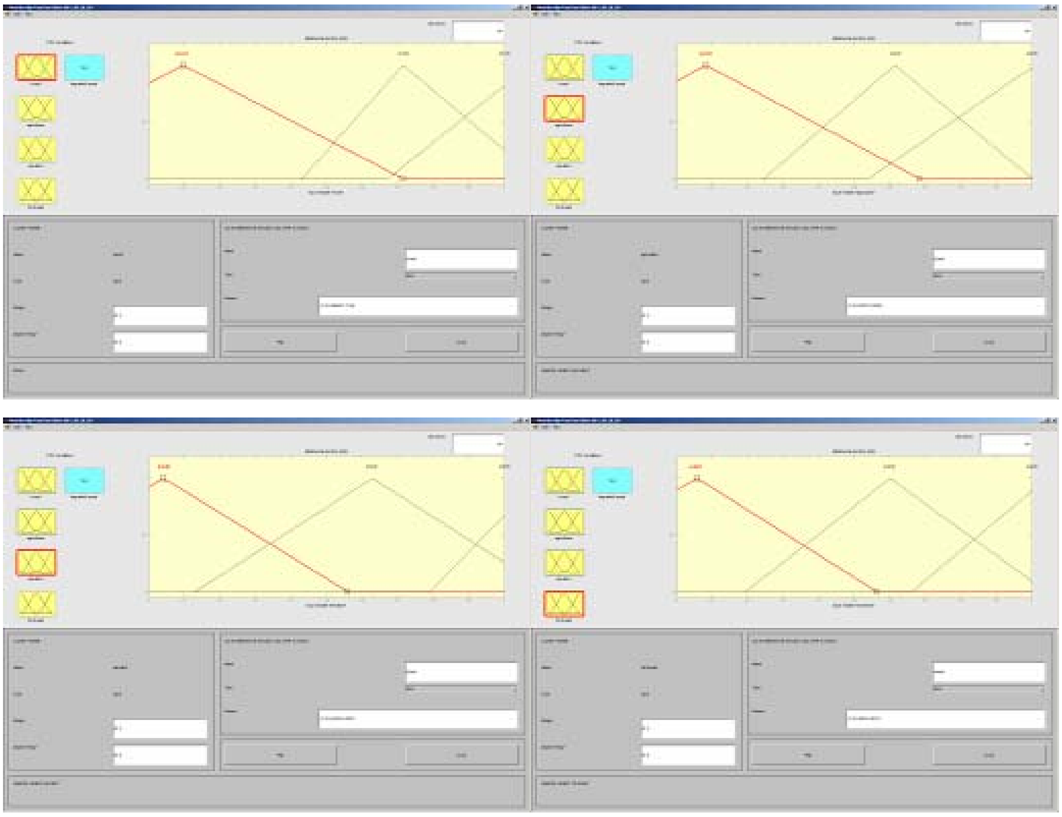
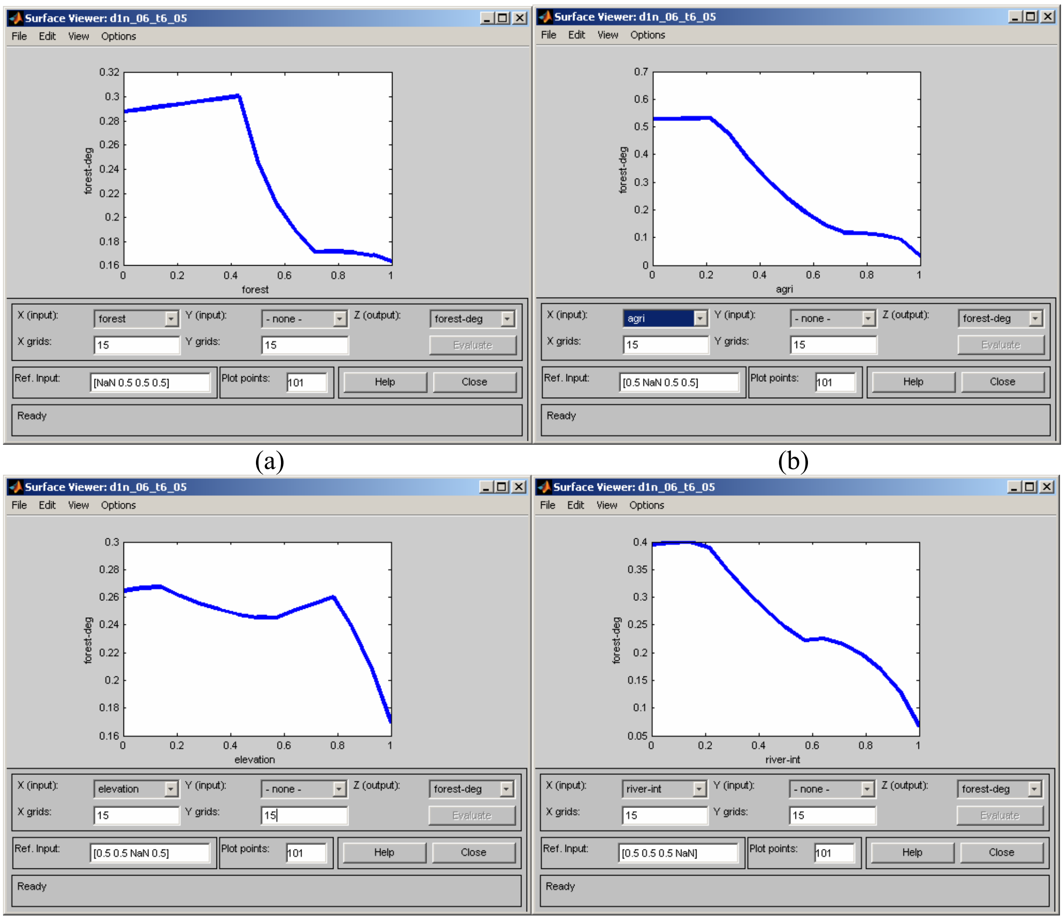


Figure 5.26 Membership functions of forest, agriculture, elevation and intermittent rivers



(a) (b) (c) (d)

Figure 5.27 The changing law between degraded forest vs. inputs forest (a), agriculture (b), elevation (c) and intermittent rivers (d)

Model interface is given in Figure 5.25. Membership functions of inputs are shown in Figure 5.26 as sample. The changing laws of two inputs vs. output were plotted as a surface graph and line graphs to visualize the relation in between (Figure 5.28 and Figure 5.27). To enhance the ANFIS component of the Model, the rules were redefined as an expert view (Abonyi & Feil, 2007; Hui et al.,2004; Salgado, 2008). The enhanced model surface graphs were shown in Figure 5.29.

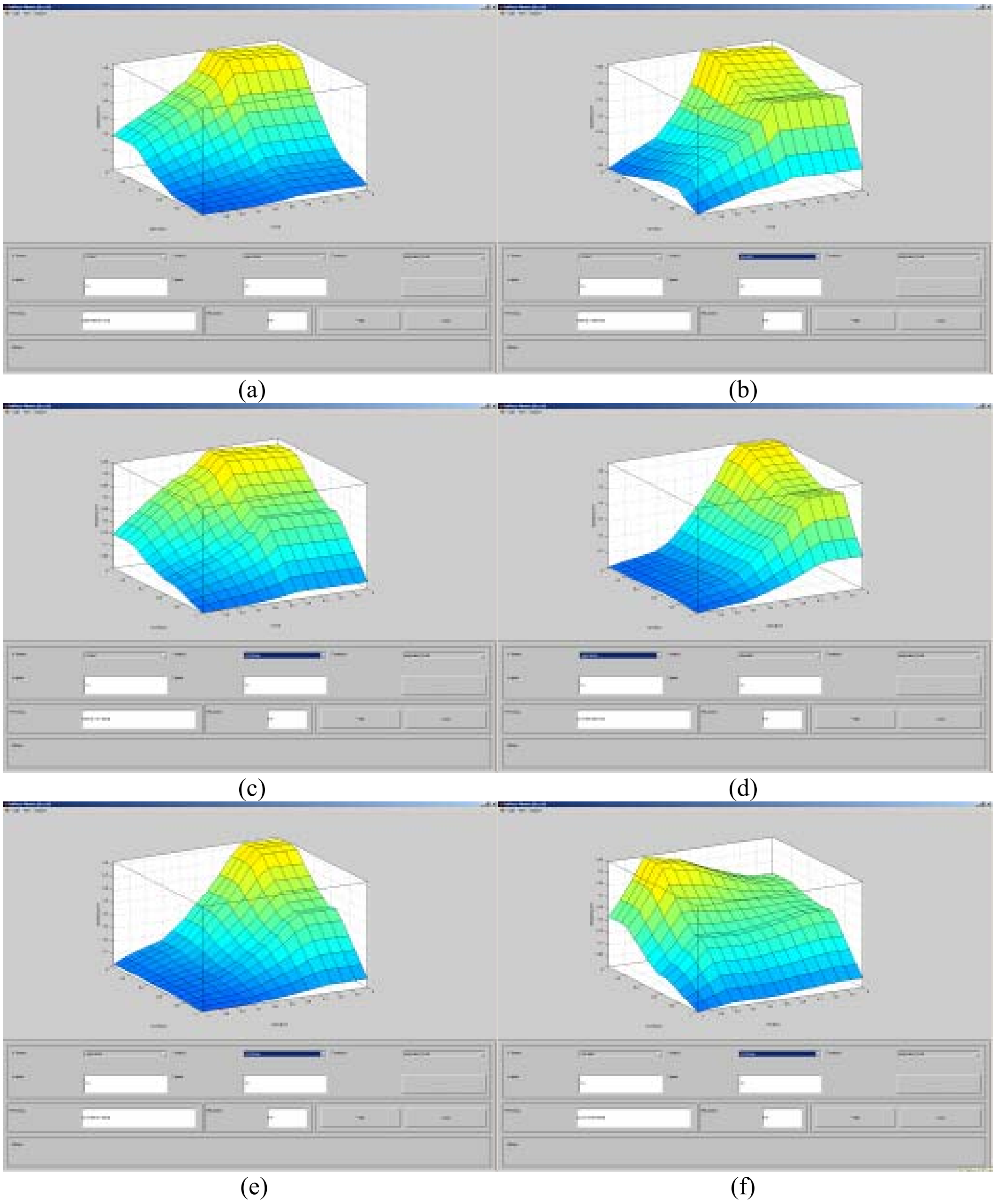
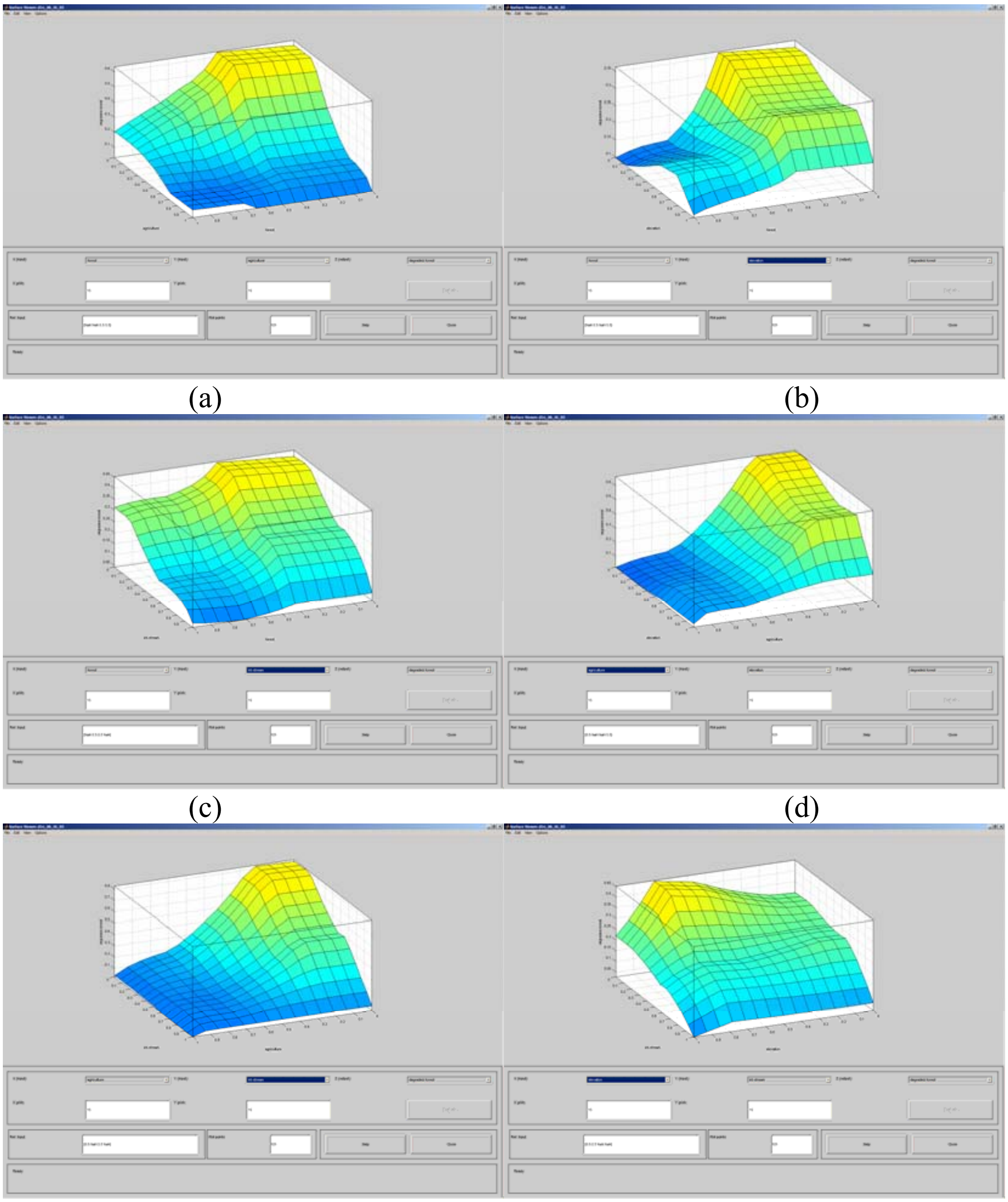


Figure 5.28 The changing law between degraded forest vs. forest and agriculture (a), forest and elevation (b), forest and intermittent rivers (c), agriculture and elevation (d), agriculture and intermittent rivers (e), elevation and intermittent rivers (f).



(a) (b) (c) (d) (e) (f)

Figure 5.29 The changing law between degraded forest vs. forest and agriculture (a), forest and elevation (b), forest and intermittent rivers (c), agriculture and elevation (d), agriculture and intermittent rivers (e), elevation and intermittent rivers (f) after enhancement.

5.3 Thematic Map of DSS results for Degraded Forest Model

The relations between input and output variables were determined by ANFIS component of the Model. Thus, any change on the input, or in other words any effect on the coastal area, could be foreseen by the developed Model. GIS was used to visualize the developed Model. On the visualization, an initial value was set to each grid. The output value was forecasted using the relations between input data. After the forecast of the output variable, the visualized map could be prepared on GIS.

Degraded forest was assumed as 100 units for each 500 m land grid equally. By using ANFIS changing laws, the degradation was forecasted from input grid values and the new unit of degraded forest was calculated. The thematic map of the degraded forest estimation is given in Figure 5.30. In this Degraded Forest Model, the change was forecasted by changes of the forest, agriculture, elevation and intermittent rivers (Figure 4.16, Figure 4.20, Figure 4.21 and Figure 4.22). The other results of DSS Model are given in the following section (Chapter 6).

In this map (Figure 5.30), brown and purple colors indicate the degradation increase and decrease within the grid area. The increase in degradation is important for the forestry and environment. The degradation increase along the southern coast, where the new road expansion projects and tourism activities have recently been taking place, can easily be detected. Again the area around Akyaka town, which suffers much from settlement stress, displays degradation increase.

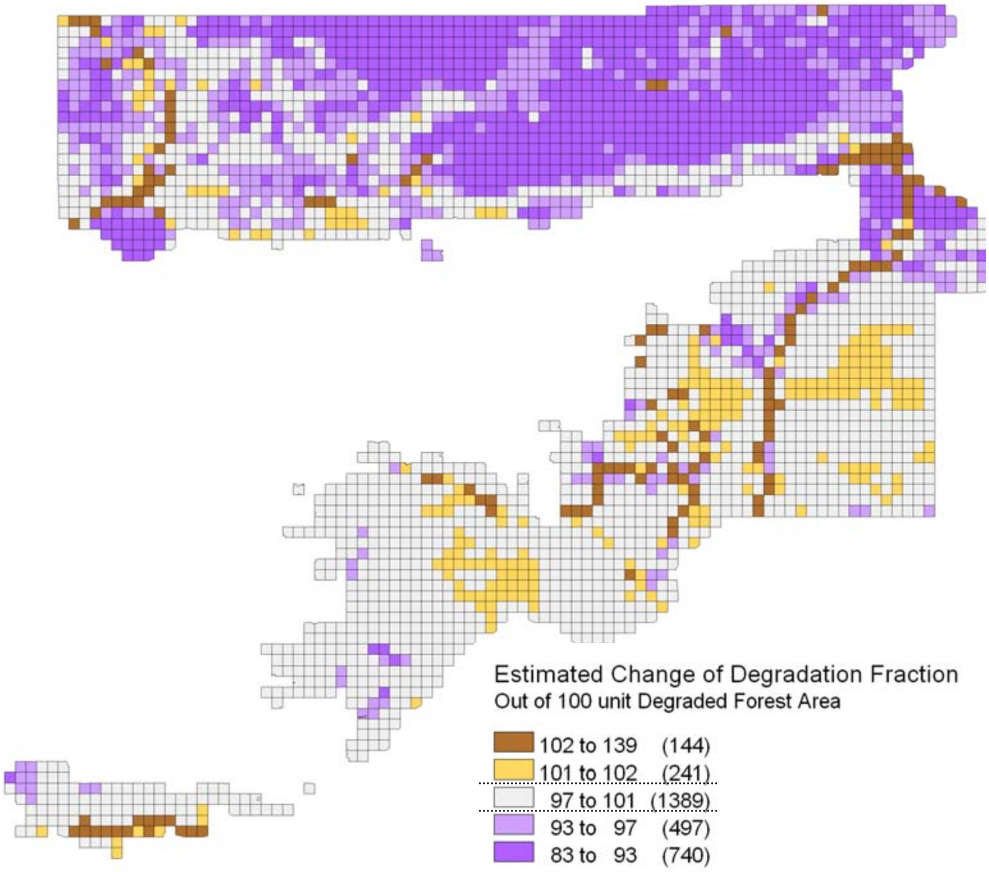


Figure 5.30 Estimation of degraded forest change according to existing data

The decrease in degradation may indicate either forest development or land use change from forest to something else. The northern region forecasts can only be interpreted with assistance from second Model development that was carried out for the forest area forecast given in the following Chapter 6.

CHAPTER SIX
RESULTS AND FINDINGS

The methodological application scheme of developed DSS Model was given in the previous chapter for the degraded forest forecast. The relations between inputs and outputs namely forest, house, population density and protected species, were determined by ANFIS component of the Model in this chapter. Thus, any change on the input, or in other words any effect on the coastal area, could be foreseen by the developed Model. GIS was used to visualize the developed Model. For visualization, an initial value was set to each grid. The output value was forecasted using the relations between input data. After the forecast of the output variable, the visualized thematic map could be prepared on GIS.

The Model results and thematic maps for forecasted changes in forests, housing, population density for land data, and protected species for sea data are given below. The details of ANFIS application steps of land data and PCA and ANFIS application steps of sea data are given in Appendix B.

6.1 Result for Forest Model

In the second Model development, forest area (Figure 4.16) was forecasted. Triangular membership function was selected for this ANFIS model run. The Forest Model was used to figure out the response of forest area to the change in agriculture, elevation, degraded forest area, house, population density, intermittent river and road types.

The rules were formed by the first order Sugeno fuzzy model. The changing laws of input vs. output were represented as surface graph to visualize the relation. The ANFIS model, the rules were redefined as an expert view (Abonyi & Feil, 2007; Hui et al.,2004; Salgado, 2008) and enhanced model surface graphs were shown in Figure 6.1.

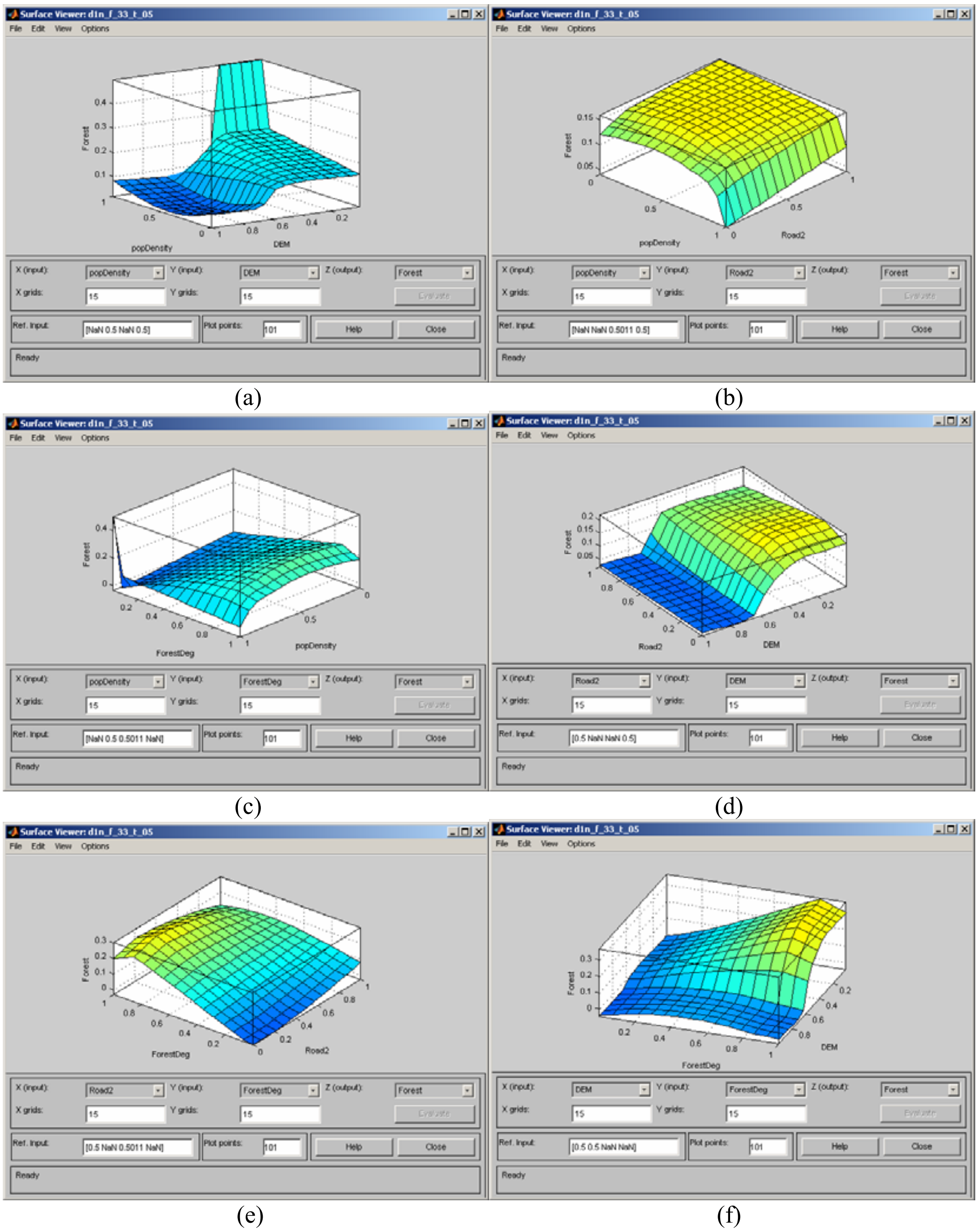


Figure 6.1 The changing law between forest vs. population density and elevation (a), population density and unimproved road (b), degraded forest and population density (c), unimproved road and elevation (d), degraded forest and unimproved road (e), degraded forest and elevation (f) after enhancement.

Forest area was assumed as 100 units equally for each 500 m land grid. By using ANFIS changing laws, the alteration was forecasted from input grid values, and the new unit of forest area was calculated. The thematic map of change in forest estimation is given in Figure 6.2.

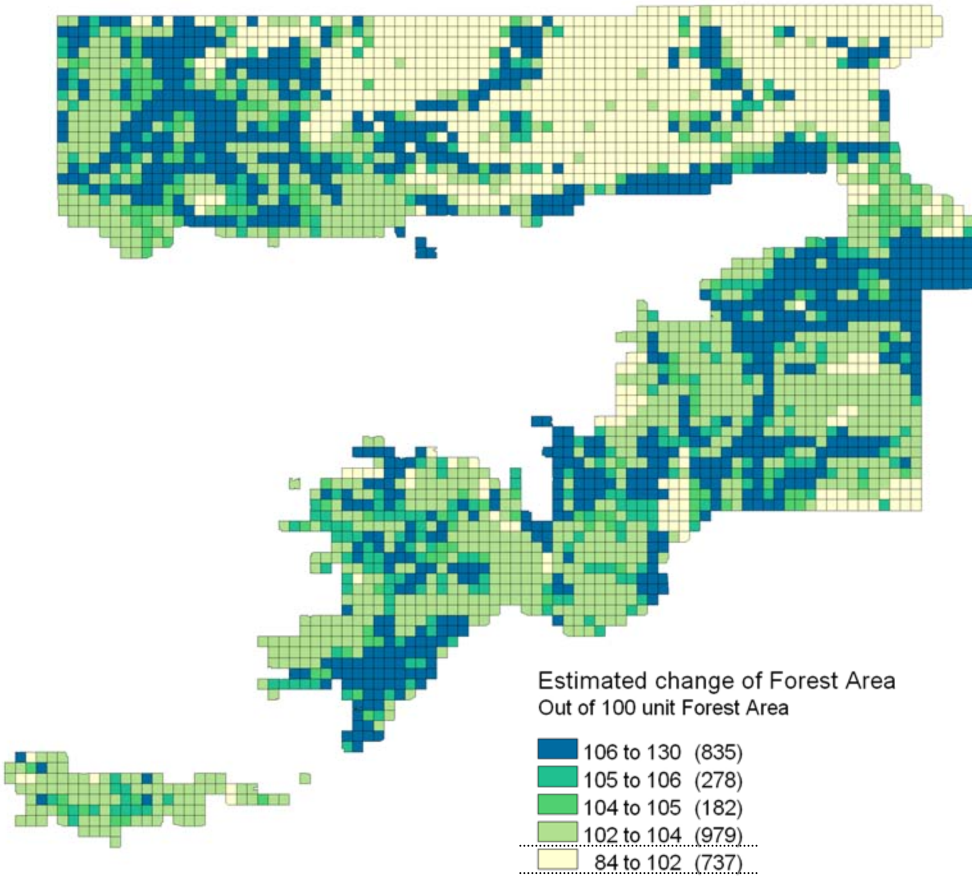


Figure 6.2 Estimation of forest change according to existing data

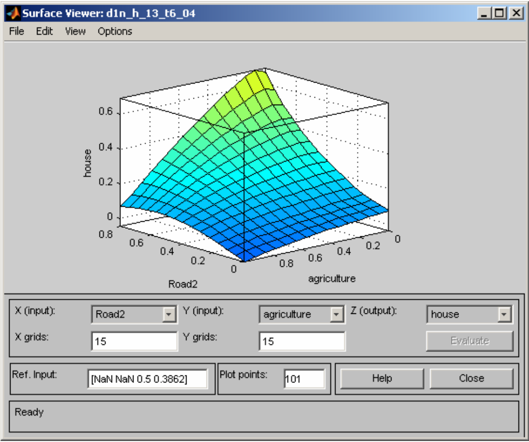
For model development, four input combinations out of 10 variables were selected and trained on ANFIS. The forecast model results of ANFIS for forest area form the thematic estimation map in Figure 6.2. In this Model, the change was forecasted out of the inputs of degraded forest, population density, unimproved roads and elevation (Figure 4.17, Figure 4.19, Figure 4.23 and Figure 4.21). In this map, dark green and beige colors indicate the forest land use increase and decrease within the grid area. The decrease in forest area is important for forestry and the environment. The land use change in the north reveals agricultural stress, which shows parallel patterns with the results of degraded forest forecasting model (Figure 5.30).

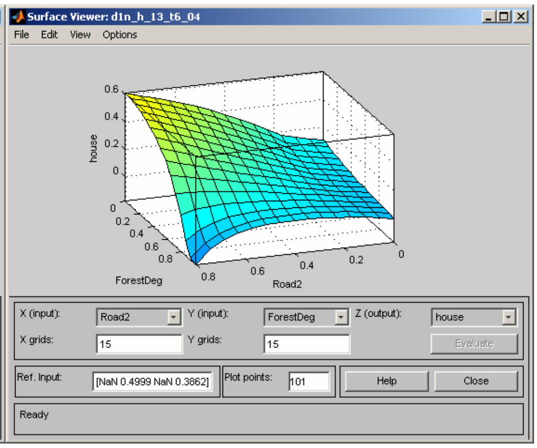
6.2 Result for Housing Model

In the third Model development, housing (Figure 4.18) was forecasted. The Housing Model was used to figure out the response of human settlements to the change in agriculture, elevation, forest area, house, population density, intermittent river and road types. Triangular membership function was selected for this ANFIS model run.

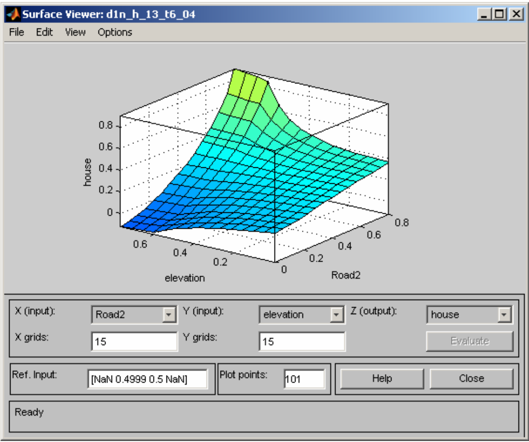
Input and output relations were solved by the first order Sugeno fuzzy model. The ANFIS model, the rules were redefined as an expert view (Abonyi & Feil, 2007; Hui et al.,2004; Salgado, 2008) and the changing laws of input vs. output of the enhanced model were represented as a surface graph shown in Figure 6.3.

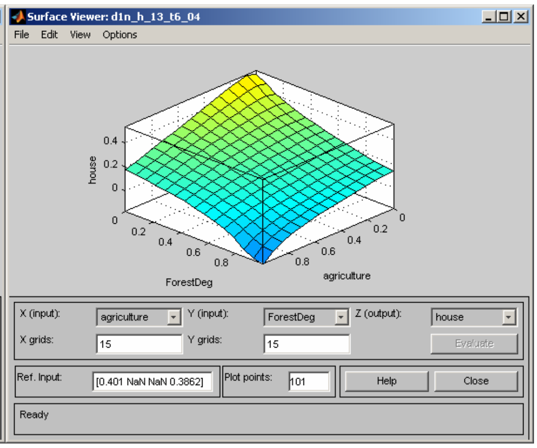
House counts were assumed as 100 units equally for each 500 m land grid. By using ANFIS changing laws, the change in settlement houses was forecasted from input grid values, and the new unit of housing was calculated. The thematic map of change estimation is given in Figure 6.4.



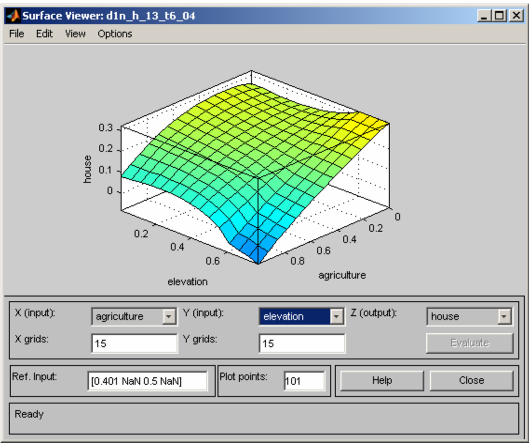


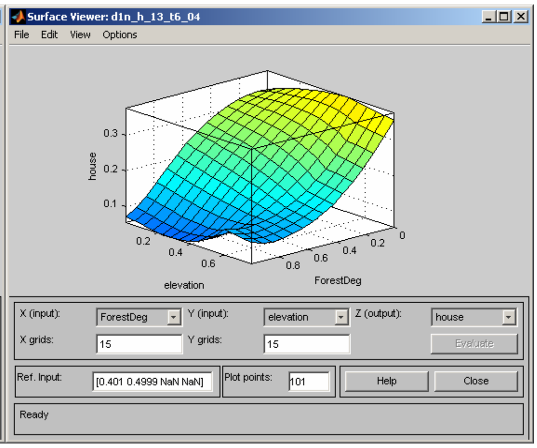
(a) (b)





(c) (d)





(e) (f)

Figure 6.3 The changing law between house vs. unimproved road and agriculture (a), degraded forest and unimproved road (b), elevation and unimproved road (c), degraded forest and agriculture (d), elevation and agriculture (e), elevation and degraded forest (f).

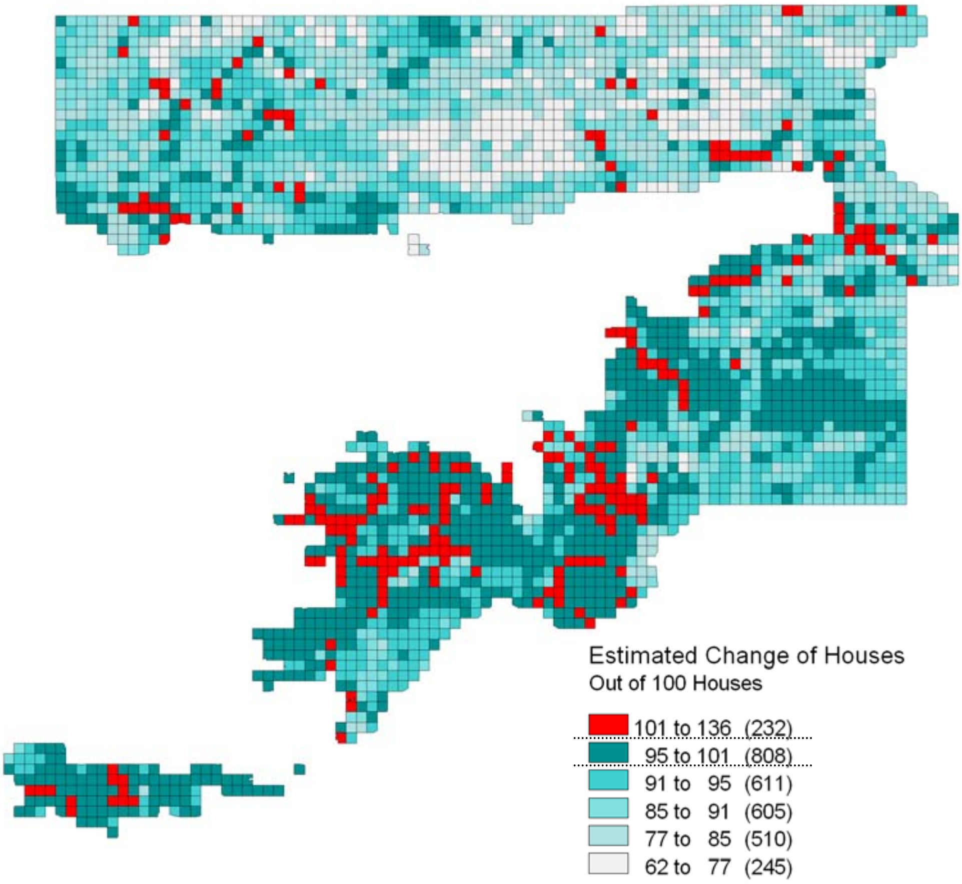


Figure 6.4 Estimation of house change according to existing data

For model development, four input combinations out of 12 variables were selected and trained on ANFIS. The forecast model results of ANFIS for housing form the thematic estimation map in Figure 6.4. In this Model, the change was forecasted out of the inputs of degraded forest, agriculture, unimproved road and elevation (Figure 4.17, Figure 4.20, Figure 4.23 and Figure 4.21).

In this map, the red color indicates the settlement stress due to the input parameters of the Model. The increase in housing in the southern part again shows the response to change and stress of settlement demands. The developing towns of Akyaka, Ören and Akçapınar also display the same stresses.

6.3 Result for Population Density Model

In the fourth Model development, population density (Figure 4.19) was forecasted. The Population Density Model was used to figure out the response of residence of population to the change in agriculture, elevation, forest area, house, population density, intermittent river and road types. Triangular membership function was selected for this ANFIS model run.

Input and output relations were solved by the first order Sugeno fuzzy model. The ANFIS model, the rules were redefined as an expert view (Abonyi & Feil, 2007; Hui et al.,2004; Salgado, 2008) and enhanced model surface graphs were shown in Figure 6.5.

Population density was assumed as 100 units equally for each 500 m land grid. By using ANFIS changing laws, the population density was forecasted from input grid values, and the new unit of population density was calculated. The thematic map of the population density estimation is given in Figure 6.6.

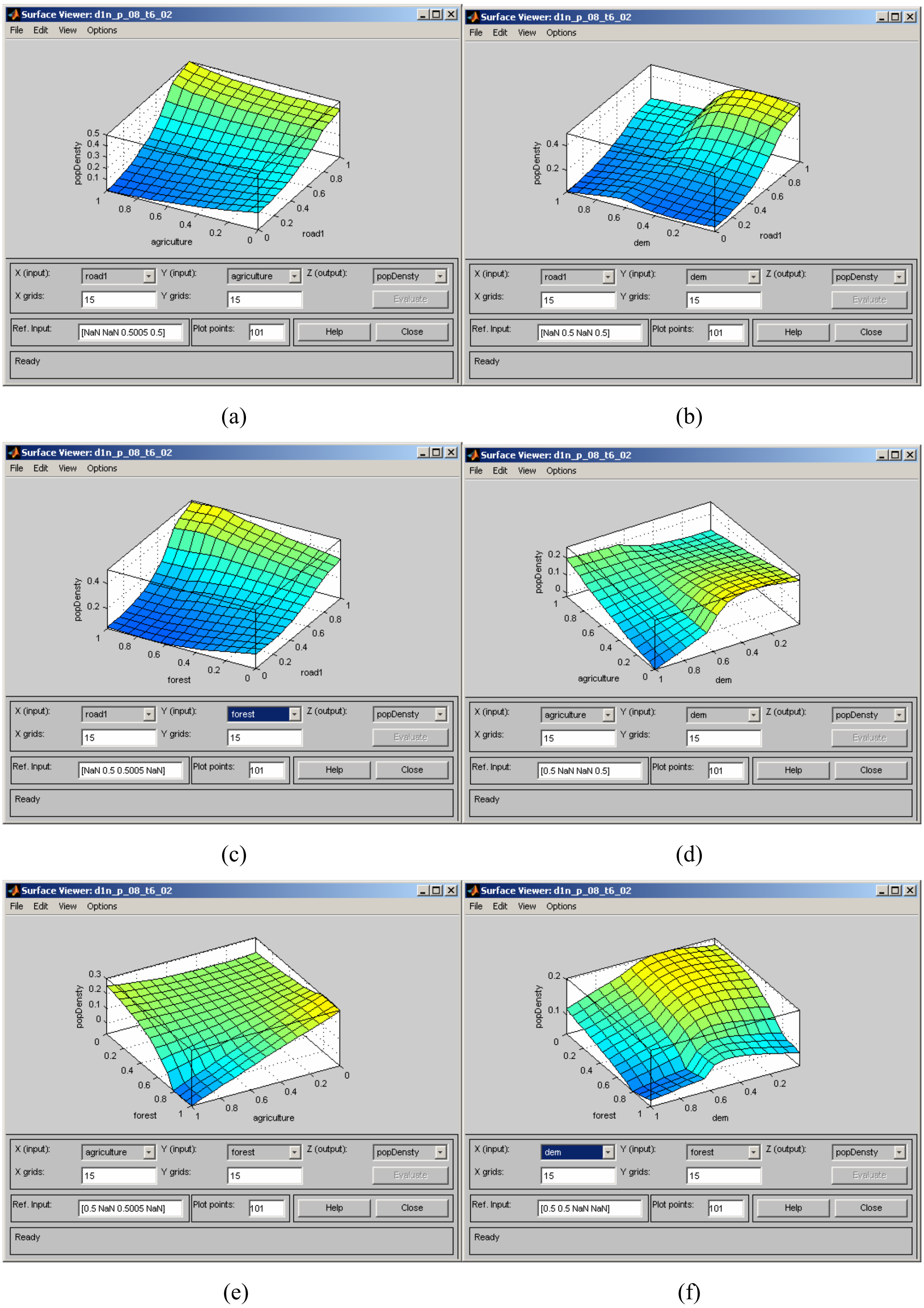


Figure 6.5 The changing law between population density vs. agriculture and highway (a), elevation and highway (b), forest and highway (c), agriculture and elevation (d), forest and agriculture (e), forest and elevation (f).

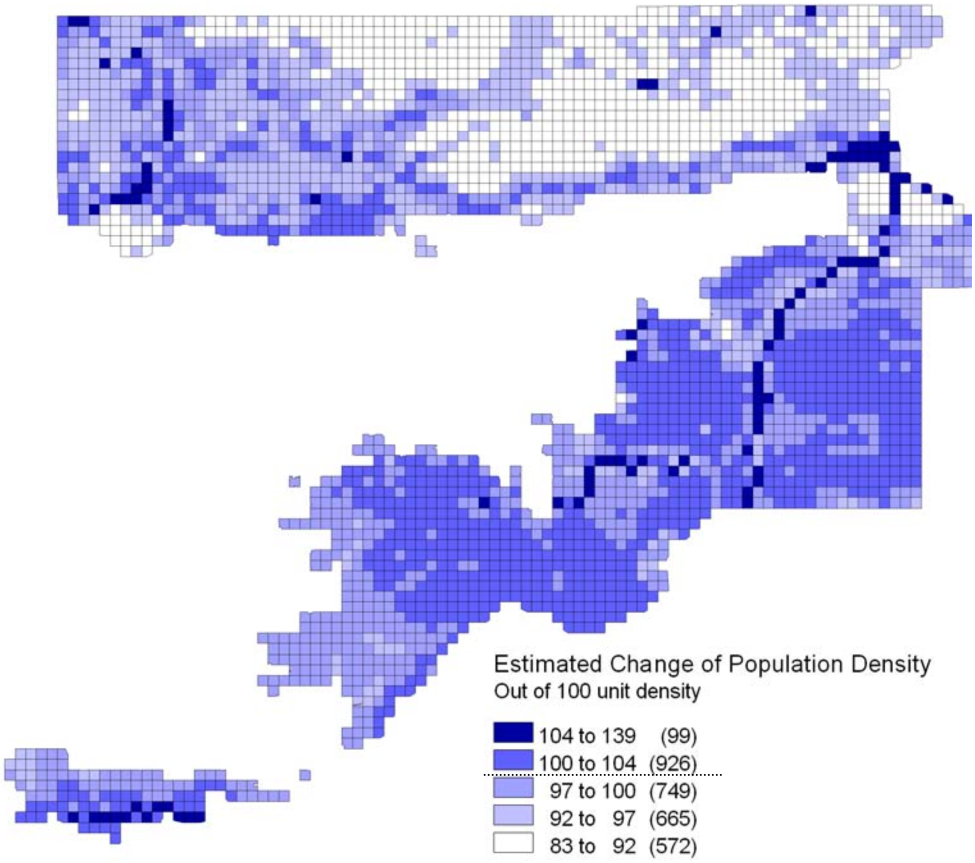


Figure 6.6 Estimation of population density change according to existing data

For model development, four input combinations out of 12 variables were selected and trained on ANFIS. The forecast model results of ANFIS for population density form the thematic estimation map in Figure 6.6. In this Model, the change in population density was forecasted out of the inputs of agriculture, forest, highway and elevation (Figure 4.20, Figure 4.16, Figure 4.24 and Figure 4.21). In this map, the dark blue color indicates the anthropogenic stress due to the input parameters of the Model. There exists an increase along the Marmaris road and southern part of the study area. The increase in the population density along the heavy loaded highway roads is an important outcome of the Model as well.

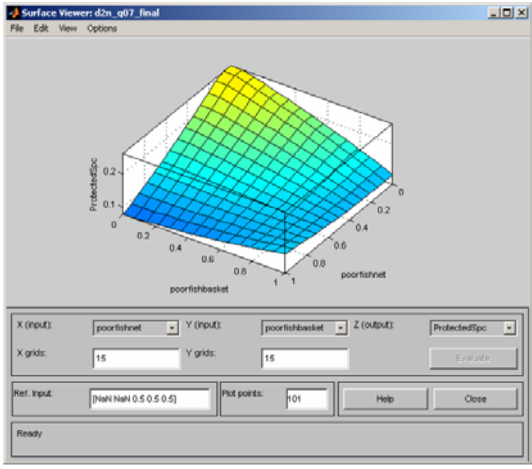
6.4 Result for Protected Species Model

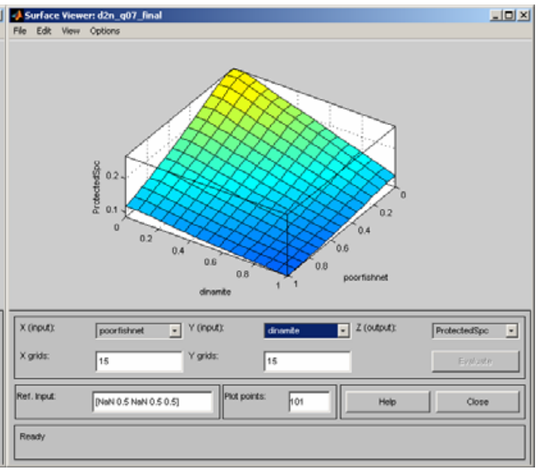
The variables of sea 500 m grid data consist of layers such as poor fishnet, poor fish basket, dynamite, gaff, anchor damage, waste, boat, exotic species and protected species counts. During Model development, PCA was used for input and output selection. While developing the model trials, some of the cases caused abnormalities in model outputs. These meaningless cases and outliers were examined and determined by statistical analysis. The selected variables were used for ANFIS model after normalization in order to overcome the problems arising from range differences.

In this Model development, protected species counts (Figure 4.25) were forecasted. The model was examined to give the response of protected species to the anthropogenic stresses, poor fishnet, poor fish basket, dynamite, gaff, anchor damage, waste, boat and exotic species. Triangular membership function was selected for this ANFIS model run.

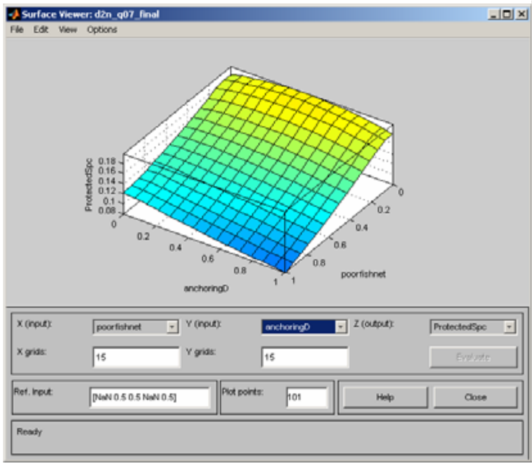
The rules were formed by the first order Sugeno fuzzy model. The ANFIS model, the rules were redefined as an expert view (Abonyi & Feil, 2007; Hui et al.,2004; Salgado, 2008) and enhanced model surface graphs were shown in Figure 6.7 and Figure 6.8.

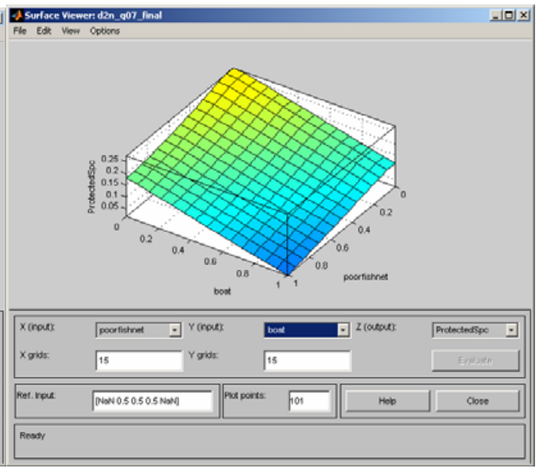
Protected species counts were assumed as 100 equally for each 500 m sea grid. By using ANFIS changing laws, the decrease was forecasted from input grid values, and the new count of protected species was calculated. The thematic map of the degraded biodiversity estimation in terms of protected species is given in Figure 6.9. The detailed PCA and ANFIS application steps can be found in Appendix B.



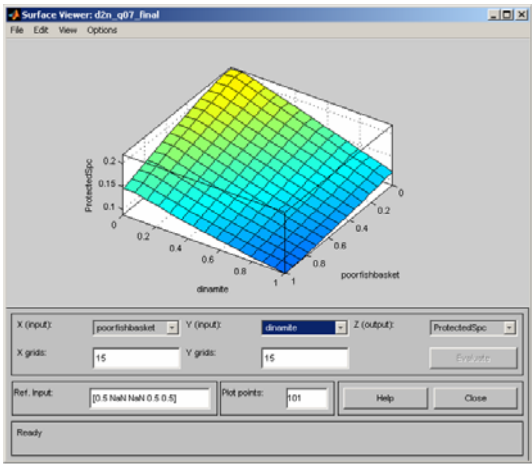


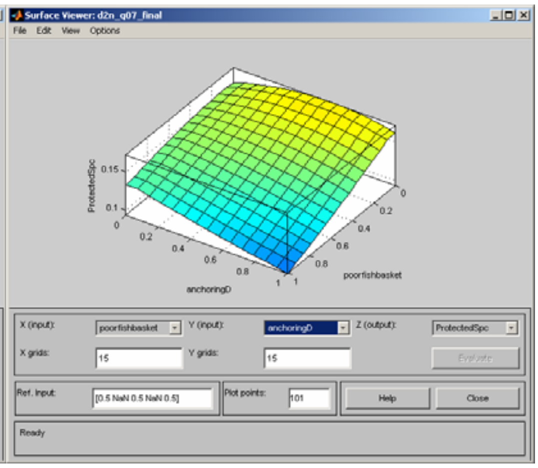
(a) (b)





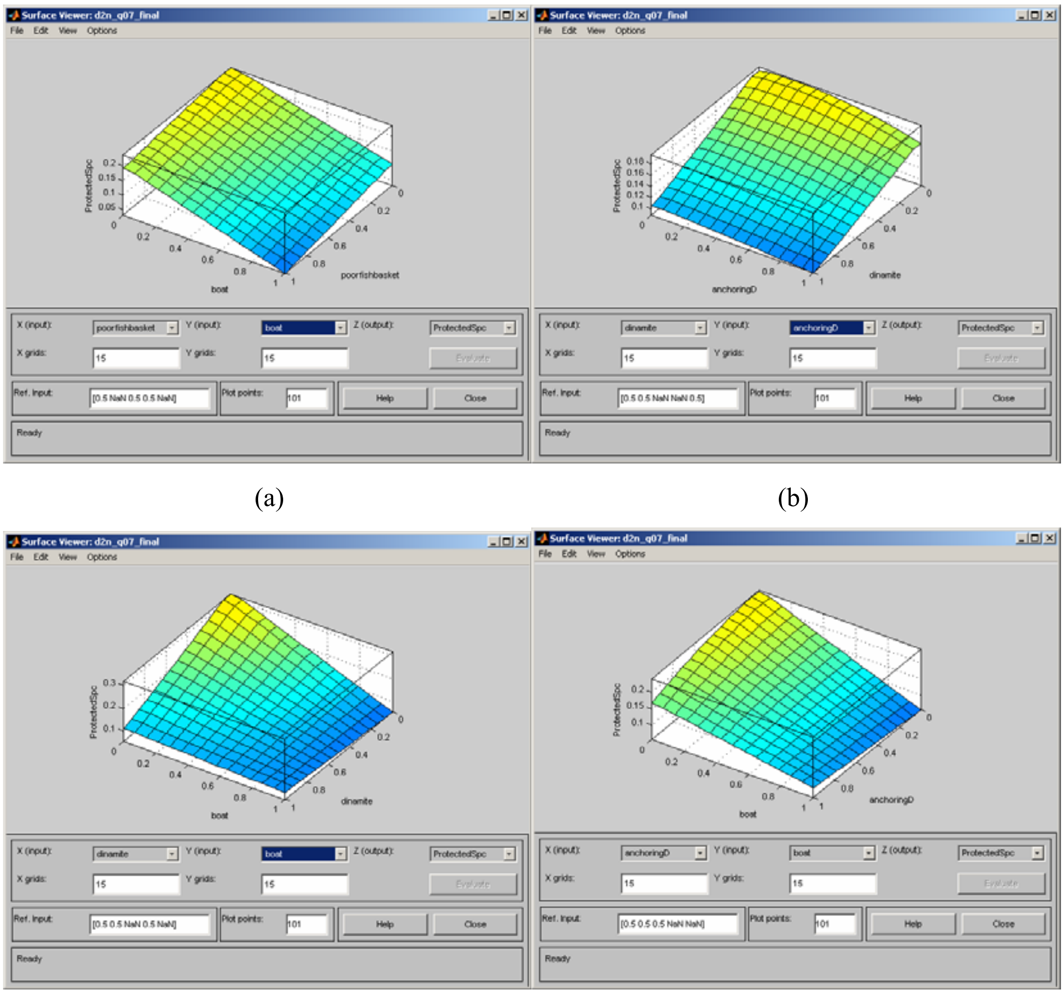
(c) (d)





(e) (f)

Figure 6.7 The changing law between protected species vs. poorfishbasket and poorfishnet (a), dynamite and poorfishnet (b), anchoring and poorfishnet (c), boat and poorfishnet (d), dynamite and poorfishbasket (e), anchoring and poorfishbasket (f).



(a) (b)

(c) (d)

Figure 6.8 The changing law between protected species vs. boat and poorfishbasket (a), anchoring and dynamite (b), boat and dynamite (c), boat and anchoring (d).

For model development, five input combinations out of 8 variables were selected and trained on ANFIS. The forecast model results of ANFIS for protected species form the thematic estimation map in Figure 6.9. In this Model, the decrease in protected species counts was forecasted out of the inputs of poor fishnet, poor fish basket, dynamite, boat and anchoring damage (Figure 4.26, Figure 4.27, Figure 4.28, Figure 4.29 and Figure 4.30). The decrease in protected species counts in the bays Akbük, Okluk, Ayın, Tuzla, Hırsız and Gelibolu shows human stress, especially arising from tourism demand of both yachting and land based uses.

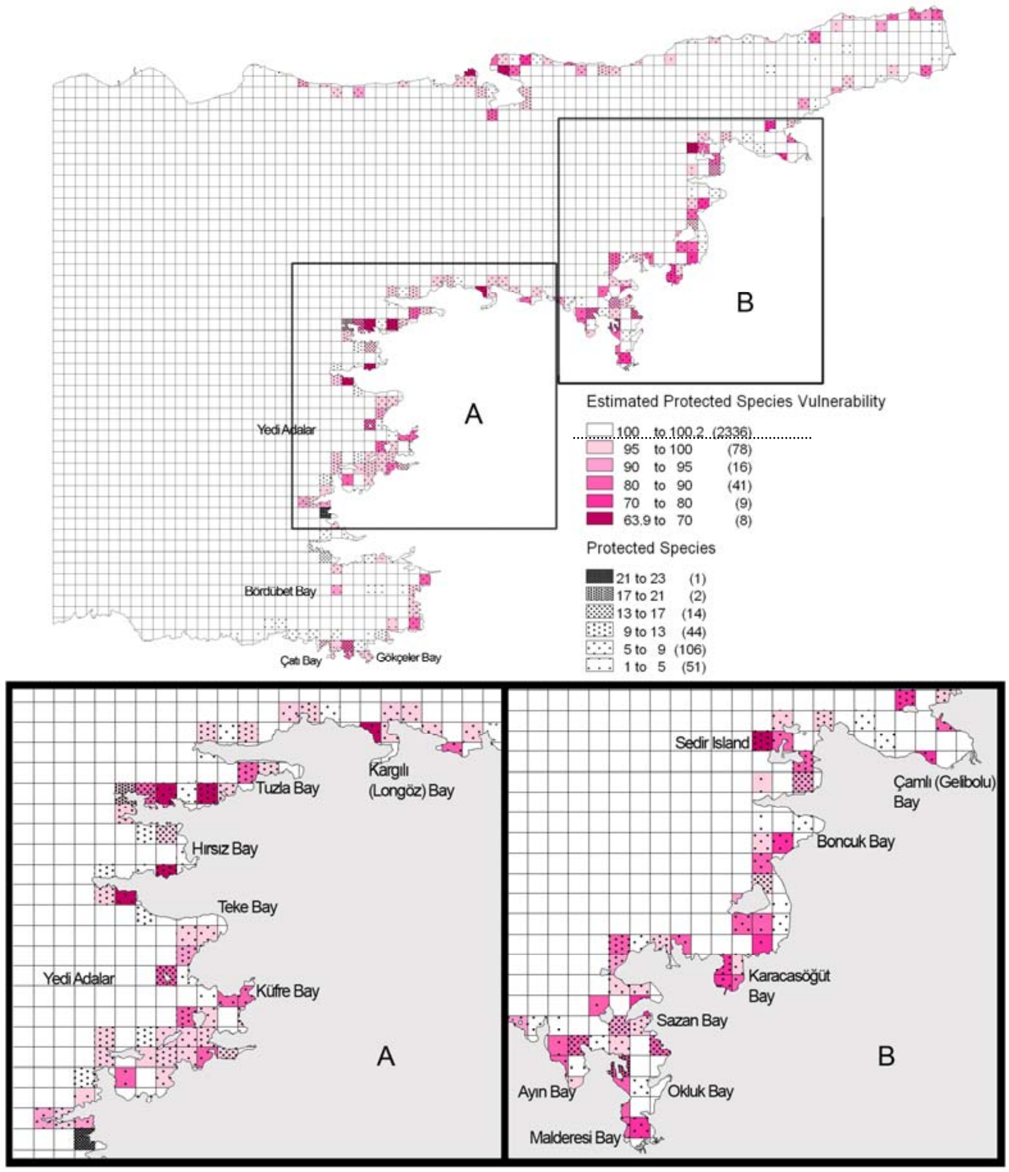


Figure 6.9 Estimated protected species vulnerability and species density

A valuable research project, which is supported by the BBI Matra Funding of the Netherlands Ministry of Agriculture, involves monitoring and management efforts broadly and proposes higher level protection for the small bays of Gökova SEPA (Kıraç et al.,2010). The outcomes of this dissertation analysis show parallel results. In addition to the valuable outcomes of the project, this developed mathematical DSS Model showed that Çatı, Gökçeler, Tuzla, Kargılı (Longöz) Bays are also at least vulnerable as Aşağıbördübet, Küçükgünlük, Okluk, Boncuk, Çamlı, Akbük Bays and Akyaka-Akçapınar coast which were proposed by the project (Kıraç et al., 2010).

CHAPTER SEVEN
CONCLUSION

It is vital to estimate the effects of any interference in the coastal zones faced with many pressures and uses. For decision makers to anticipate the affects of any interference, they need a strong DSS. In the last decade, use of information technologies in decision making in many areas ranging from medicine to engineering has increased.

In this study, a new DSS approach was developed to estimate the response of complex and vague nature to anthropogenic effects in Gökova SEPA (Chapter 3) which has been protected by the Special Environmental Protection Area Regulation since 1988 (Section 3.2.1).

Among the methods used in environmental DSS's, the one used expansively is MCA. This method is carried out by using the indicators pre-defined by the specialists whose relations and priorities are also defined and known by the specialists. In this newly developed system, DSS Model presents the relations among all variables and their effect on the system in cases of healthy and sufficient data availability. The new system can both reveal the hidden effect which even a specialist may skip and catch the effective communication between the system data/components. However, atypical results to be accumulated in this system should be interpreted carefully to avert user errors or improper data use. The Model is not sensitive to lack of quality in data during the phases of determination of inter data relations and the level of significance.

This new methodology allows the preparation of thematic maps of the estimated change of degradation of forest area, change in the population, future housing and status of the protected species based on selected several input.

Components of the developed DSS Model are GIS, PCA and ANFIS (Figure 5.1). GIS is developed both for monitoring the current status and for indicating thematic maps formed at the end of the Model. GIS is used both for seeing the Model result and preparing and submitting the input data. Initially, hardcopy maps were acquired and transferred to GIS environment via digitization. Available military maps of General Command of Mapping and forest management maps of General Directorate of Forestry were used as two main data sources for the land part. These hardcopy data sources were digitized. Infrastructure and land use data were gathered from these data sources. The census data was gathered from the Turkish Statistical Institute archives. The biodiversity and anthropogenic stress information of Gökova SEPA were integrated from EPASA report (EPASA, 2006) (Chapter 4).

First, data used in this study was compiled in GIS with 500 m grid mesh and each layer gathered in grid system. The prepared grid data was used in PCA and ANFIS analysis. In this way, through PCA, the relation revealing the complicated inter data structure is multidimensionally established and importance is identified. Through ANFIS, inter data relations are defined mathematically using the feature of ANFIS's learning and connectionist structure and human-like reasoning. By this way, the effects of land usage are estimated. The input and output parameters of ANFIS component of the Model (forest, degraded forest, population density, elevation, intermittent rivers, unimproved road, house, agriculture, highway, protected species, poorfishbasket, poorfishnet, dynamite, anchoring, boat (Figure 4.16 to Figure 4.30)) are determined by using PCA component of the Model from land and sea data.

Land and sea data are composed of land use - land cover, infrastructures, terrain data, anthropogenic stresses and biodiversity (degraded forest, agriculture, forest, elevation, burnt forest, intermittent rivers, house, slope, population density, water resources, trail roads, highway, unimproved road, aspect, river, wetland, pier, protected species, exotic species, gaff, dynamite, poor fishnet, anchor damage, boat, *Pinna nobilis*, specie counts, poor fish basket, *Strombus persicus,* waste, *Epinephelus marginatus , Ephinephelus costae, Axinella cannabia, Caulerpa rasemosa, Aplysina aerophoba, Posidonia oceanica, Halophila stipulacea, Tethya aurantium, Axinella polypoides, Echinaster* *sepositus sepositus, Paracentrotus lividus, Spongia officinalis, Scyllarus arctus, Centrostephanus longispinus, Lithophaga lithophaga, Charonia variegata, Haliotis tuberculata lamellosa, Spongia agaricina, Scyllarides latus, Flabellia petiolota, Cymodocea nodosa*).

Relations of outputs: degraded forest, forest, population, house and protected species, and inputs were presented by ANFIS component of the Model in Chapters 5, 6 and Appendix B (degraded forest: Figure 5.27, Figure 5.28 and Figure 5.29; forest: Figure 11.5, Figure 6.1; house: Figure 11.10, Figure 6.3; population density: Figure 11.15 and Figure 6.5; protected species: Figure 11.32, Figure 6.7 and Figure 6.8). The thematic map of each forecast was visualized in GIS and given in Figure 5.30, Figure 6.2, Figure 6.4, Figure 6.6 and Figure 6.9 (Chapter 5 and 6). The forecast of the Model output can clarify the stress due to human existence on the coastal zone and provides spatial information for decision makers.

The forecast result of Degraded Forest Model (Figure 5.30) was forecasted by changes of the “forest”, “agriculture”, “elevation” and “intermittent rivers”. In the map, the increase in degradation along the southern coast, where the new road expansion projects and tourism activities have recently been taking place, can easily be detected. Similarly, the area around Akyaka town, which suffers much from settlement stress, displays degradation increase. The decrease in degradation may indicate either forest development or land use change from forest to something else.

The forecast result of Forest Model (Figure 6.2) was forecasted out of the inputs of “degraded forest”, “population density”, “unimproved roads” and “elevation”. The land use change in the north reveals agricultural stress that shows parallel patterns with the results of degraded forest forecasting Model.

The forecast result of Housing Model (Figure 6.4) was forecasted out of the inputs of “degraded forest”, “agriculture”, “unimproved road” and “elevation”. The increase in housing in the southern part shows the response to change and stress of settlement demands. Developing towns such as Akyaka, Ören and Akçapınar also display the same stresses.

The forecast result of Population Density Model (Figure 6.6) was forecasted out of the inputs of “agriculture”, “forest”, “highway” and “elevation”. There exists an increase along the Marmaris road and southern part of the study area. The increase in the population density along the heavy loaded highway roads is an important outcome of the Model as well.

The forecast result of Protected Species Model (Figure 6.9) were forecasted out of the inputs of anthropogenic stresses: “poor fishnet”, “poor fishbasket”, “dynamite”, “anchor damage”, “boat counts”. The decrease in protected species counts in the bays of Çatı, Gökçeler, Akbük, Okluk, Ayın, Tuzla, Kargılı, Hırsız and Çamlı (Gelibolu) shows the human stress especially arising from tourism demand of both yachting and land based uses.

Distribution and scope of the water quality measurements of the OCEANOS project data on this grid system are not taken into account as they are not sufficient for obtaining healthy results.

This DSS Model developed for ICZM efforts cover biodiversity, socio-economy and anthropogenic effects. Developed DSS Model could be used for forecasting multidimensional and complex systems considering different data requirements. This study could meet the need for evaluation of ICZM efforts to produce measurable outcomes. Furthermore the Model is reproducible and re-applicable for different coastal regions.

In spite of the poor data conditions of this study, the Model provides the protection needs of the Gökova region for the terrestrial and marine environment. Vulnerability and protection needs of the region derived from the results given in Chapter 5 and 6 are parallel with the results of ICZM projects that also carried out in the Gökova region (Section 3.1). In addition, the results of the new DSS Model presented in findings

(Chapter 6, Figure 6.9) show that Çatı, Gökçeler, Tuzla and Kargılı (Longöz) Bays are also under equivalent anthropogenic stress for biodiversity loss, similar to those proposed regions by Integrated Coastal and Marine Management Planning Project of Underwater Research Society-Mediterranean Seal Research Group (Chapter 1), Aşağıbördübet, Küçükgünlük, Okluk, Boncuk, Çamlı, Akbük Bays and Akyaka-Akçapınar coast (Figure 3.1).

CHAPTER EIGHT
DISCUSSIONS AND RECOMMENDATIONS

Generally, the lack of a national spatial database results in avoidance in the use of information technologies use. Therefore, information technology is not used or is used to a limited extent in some parts of scientific studies. Besides, an advanced level of development in integration of information technologies may not be attained as it requires labor force and resources. Moreover, contribution to database in the use of information technologies which is a research field in many countries is not available in our country. Primary concerns on this issue are: lack of standard in data, inability to attain data, lack of quality standard in data, lack of period standard in data, lack of update in data, especially reluctance in data share.

The available data, raster or vector based, is prepared upon the needs of the national association. It cannot be integrated to other uses. Therefore, there should be national projects combining these data into a national GIS. Data prepared upon the needs of national association should be available for research. For instance, in this study all data was digitized from hardcopy rasters, although it was available in vector format.

Lack of a national system for data collection and GIS development, together with unavailability of reaching data in a vectorized environment, represent substantial restrictions in developing such studies.

Using appropriate data that is particular to the type of study is of great importance. This reveals the need for vision of long term monitoring projects, which should be carried out by national agencies.

For further studies, this DSS can be enhanced by integrating economical pattern data to this Model to visualize the dynamics of sectoral impacts.

The developed Model can be used to determine the relationship between water quality vs. land uses of coastal regions, especially as catchments. In this study, the available data did not cover the whole catchments, so the water quality parameters of the Gökova Bay and land uses were not used in the Model.

For integrating social concerns, Multi Criteria Decision Analysis tools can be used to improve the Model and integrate expert knowledge about politics and law.

The method can also be improved by the integration of remote sensing or updated data provided by the related associations to analyze consequences of the management efforts as feedback.

As the Model requires careful interpretation of atypical results and as it is a complicated system with many software transitions (3 software used in 4 levels), it is sensitive to user error. In order to eliminate this disadvantage, developing, with the aid of information technologies, a one-piece expert system requiring no expert utilization or an expert system comprising of multiple parts and requiring intermediate-level expert utilization will facilitate and enhance the use of the developed Model in the next ICZM studies. (Also, development of an expert system for land uses and conflicts of coastal zone would worth to study in the future).

As it is not sensitive to lack of quality in data, this developed DSS Model may be carried out with available data for pre-studies for a region before execution of detailed projects in order to figure out the relations and magnitude of variables. The new DSS methodology may be applied following a disaster to monitor sudden changes. Furthermore, it may be carried out in monitoring activities to see the effectiveness after an ICZM application period of a project. Additionally, it may be used effectively in long term monitoring activities as it can present the significance of cost-efficient data. Besides, it may reduce research costs in that it enables to choose indicator parameters from the parameters with similar qualities.

According to the DSS Model results for Gökova, there is pressure towards settlement and population increase at the south part of the study area. Correspondingly, the intensity of pressure on protected species in the southern region on sea areas is also remarkable. Within this context, it is vital to make careful land usage decisions, and to take preventive measures against illegal uses/activities in both sea and land parts of southern part of the study area. In this south part of the region, especially in coastal line between Sazan Cape and Gerence Cape (Figure 3.1) including the Ayın, Longöz, Tuzla, Hırsız, Bördübet bays, there is no village center which is the smallest civil administration unit of Turkish law. As a result, in order to carry out the controls and inspections in the region, indeed for protecting the natural wealth of our country and region, an administrative structuring in this field would be useful.

Furthermore, it is suggested for the relevant authorities to evaluate Çatı, Gökçeler, Tuzla and Kargılı (Longöz) bays as restricted areas and include them into conservation sites in addition to the fishery conservation sites suggested by Underwater Research Society-Mediterranean Seal Research Group.

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APPENDIX A
DEFINITONS

10.1 Integrated Coastal Zone Management

There is deterioration in coastal zones in terms of natural, environmental, as well as economic, social and cultural resources, and ICZM will be the comprehensive approach in promoting sustainable development in these areas. ICZM aims at an improvement of the situation in the coastal zones through a continuous, proactive and adaptive process of resource planning and management. It is a process of achieving goals of sustainability in consideration of a large number of sectors, such as species and habitat protection, resource management, fisheries, agriculture, transport, energy, industry, employment, tourism and recreation, education, culture, regional development. ICZM requires the conservation of ecosystems as well as the management of land and marine-based human activities.

Clark (1992) defines ICZM in broad terms as planning and coordinating process which deals with development management and coastal resources and which is focused on the land/water interface.

Cicin-Sain and Knecht (1998) give the definition of ICZM as continuous and dynamic process by which decisions are made for the sustainable use, development, and protection of coastal and marine areas and resources. First and foremost, the process is designed to overcome the fragmentation inherent in both the sectoral management approach and the split in jurisdiction among levels of government and the land-water interface. This is done by ensuring that the decisions of all sectors (e.g., fisheries, oil and gas production, water quality) and all levels of government are harmonized and consistent with the coastal policies of the nation in question. A key part of ICZM is the design of institutional processes to accomplish this harmonization in a politically acceptable manner.

According to Sorensen (2002), ICZM is a Multidisciplinary process that unites levels of government and the community, science and management, sectoral and public interests in preparing and implementing a program for the protection and the sustainable development of coastal resources and environments. The overall goal of ICZM is to improve the quality of life of the communities that depend on coastal resources as well as providing for needed development (particularly coastal dependent development) while maintaining the biological diversity and productivity of coastal ecosystems in order to achieve and maintain desired functional and/or quality levels of coastal systems, as well as to reduce the costs associated with coastal hazards to acceptable levels.

FAO defines Integrated Coastal Area Management (ICAM) or ICZM as a dynamic process by which actions are taken for the use, development and protection of coastal resources and areas to achieve national goals established in cooperation with user groups and regional and local authorities. In this definition, integrated management refers to the management of sectoral components as parts of a functional whole with explicit recognition that it is the users of resources, not the stocks of natural resources that are the focus of management. For the purpose of integrated management, the boundaries of a coastal area should be defined according to the problems to be resolved. The definition thus implies a pragmatic approach to the defining of coastal areas in which the area under consideration might change over time as additional problems are addressed that require resolution over a wider geographical area.

10.1.1 ICZM Goals and Objectives

Main goals of ICZM can be summarized as follows:

a) Promoting the sustainable development of coastal and marine areas;
b) Reducing coastal vulnerability of coastal areas and their inhabitants to coastal hazards;
c) Maintaining or restoring the health of coastal ecosystems;
d) Promoting the sustainable quality of life in coastal communities;

e) Improving governance processes and coordination.

To achieve these goals, ICZM programs use a list of functions. The most important ones are

a) Area planning, to plan for present and future uses of coastal and marine areas and provide a long-term vision;
b) Promotion of economic development, to promote appropriate uses of coastal and marine areas;
c) Stewardship of resources, to protect the ecological base of coastal and marine areas, preserve biological diversity and ensure sustainability of uses;
d) Conflict resolution, to harmonize and balance existing and potential uses and address conflicts among coastal and marine uses;
e) Protection of public safety, to protect public safety in coastal and marine areas typically prone to significant natural, as well as human-made hazards; and
f) Proprietorship of public submerged lands and waters, to, as governments are often outright owners of specific coastal and marine areas, manage government-held areas and resources wisely and with good economic return to the public.

10.1.2 Evaluation of ICZM efforts

There are many ICZM efforts over the world and consequently the evaluation efforts gaining acceleration. For this purpose there are many approaches and evaluation methods.

Pertaining the evaluation, drawing the framework "result" is important. Results of a ICZM may contain outputs like quantifiable goods and services; or outcomes referring long-term efforts in environment and socioeconomic gains; performance indicating achievement to the objectives, integration and sustainability of ICZM efforts from an institutional, social, economic and environmental standpoint.

Considering these evaluation methods indicator developments is important (Clark, 1992).

There are many performance measurement efforts developed and used by many institutions of NOAA, EU and OECD.

There are three stages in ICZM:

a) Initiation of an ICZM effort,
b) Implementation of the effort, and
c) Evaluation of the effort and adjustment.

After realizing the importance of evaluation, the forth stage being common in the literature can be identified as long-term sustainability. The objective, geographical, thematic and temporal scope can be altered related with the priorities.

Indicator systems for monitoring and evaluation generally have mainly concerned inputs, outputs, and daily management processes, while less effort has been used to the measurement of outcomes, long-term impacts, and the sustainability of efforts. Outcome-based assessments are much more complicated when ICZM efforts considered which is constitute a broader scale study areas with national level institutions (Cicin-Sain & Knecht, 1998)

According to Cicin-Sain & Knecht, 1998, it is possible to identify four main goals pursued by most ICZM programs, namely:

1. Improving or non-deteriorating the environmental conditions of coastal habitats, ecosystems, and resources;
2. Fostering of coastal developmental activities while reducing the impacts on the natural resources;
3. Protecting and restoring the productivity and resilience of coastal ecosystems to provide goods and services; and
4. Reducing the vulnerability of coastal communities to coastal hazards.

10.1.3 Environmental Economics and Importance

Environmental Economics is important for ICZM. In traditional economics the role and value of environment was ignored. It is important to define the interaction between ecological systems and economics. Human system and environmental system conflict in many ways. Indicators make it clear and simplify the understanding of these interactions. Decision making can only be worthy if it internalize environmental and ecological issues to the whole problem. Researchers incorporate environmental concerns by using system analysis, which leads to the DSS tools (Chapman, D., 2000).

Developing indicators for complex systems that are having complex interactions may be very difficult. The choice of indicator requires deep understanding of the system. There are variable indicators in use. Many of these indicate the present state of the environment. But there is still a gap in indicator development for bring more clearness to environment/society relation (Smeets, E. & Weterings R., 1999; Adjaye J.A., 2005; Bateman I.J., Carson R., T., Day B., Hanneman M. & Hanley N., 2002).

10.1.4 Indicator Systems and Applications

Indicators draw out the relation between problems and their impacts by simplifying a complex reality. They are also powerful tools for public awareness. In research community, most indicator reports compile sets of physical, biological or chemical indicators. They generally reflect a systems analysis view of the relations between the environmental system and the human system. To clarify the system and analyze it more effectively, the relation structure should be based on the information of:

- Driving forces,
- the resulting environmental Pressures,
- the State of the environment,
- Impacts resulting from changes in environmental quality and
- the societal Response to these changes in the environment.

DPSIR is a causal framework for describing the interactions between society and the environment which has been adopted by the European Environment Agency. This framework enable feedback to policy makers and enhances the understanding of complex systems to distinguish indicators. As the sectors and uses get more eco-efficient, the pressure, state and impact decrease consequently.

Indicator types are descriptive, performance, efficiency and total welfare indicators. In many analysis such as Multi Criteria Analysis, the indicators (criteria) should be selected appropriately.

10.2 Decision Support Systems

The DSS studies have been built and developed since the 1960s by the Information Systems researchers and technologists and in the 1980s it started to be implemented widely in financial planning systems. It evolved from data intended systems to model driven systems with development in information technologies.

First computer aided DSS research examples are appears in universities as doctorate dissertations and applied in industrial production management applications. Today DSS applications range from marketing and production planning, land-use planning with GIS, environmental management (social, economic and ecological indicators are modeled in an integrated way), monitoring urban dynamics (with a focus on expanding settlements, transport and tourism), water management, tax deviation, analysis of fishery information, analysis of VIP (very important person) for telecom corporation. Computerized DSS are used in many areas in various shapes, sizes and forms like the ones on airplanes unavoidable technologically in many organizations.

There are five broad DSS categories: data-driven, communications-driven, document driven, model-driven and knowledge-driven DSS is an applied discipline that uses knowledge and especially theory from other disciplines and provides more rational decisions.

10.3 DSS Categories

10.3.1 Model-driven DSS:

Many of the early decision systems are model-driven DSS. A model-driven DSS emphasizes access to and manipulation of financial, optimization and/or simulation models. Generally large data bases are not needed. Microsoft Excel is one of the first examples. As number of computerized models increased, more diverse types of models such as multi-criteria, optimization and simulation models are developed for use in DSS (Burstein F. & Holsapple C. W., 2008).

10.3.2 Data-driven DSS:

A data-driven DSS emphasizes access to and manipulation of data. To access to the files of data, query and retrieval tools widely used. As the computerization become available, data driven DSS systems use analytical processing to handle large set of data. Simple file systems accessed by query and retrieval tools. Data warehouse systems that allow the manipulation of data by computerized tools created to a specific task and setting or by more general tools and operators provide additional functionality.

10.3.3 Communications-driven DSS:

Communications-driven DSS use network and communications technologies to facilitate decision-relevant collaboration and communication. In these systems, communication technologies are the dominant architectural component.

10.3.4 Document-driven DSS:

A document-driven DSS uses computer storage and processing technologies to provide document retrieval and analysis. Large document databases may include scanned documents, hypertext documents, images, sounds and video. Examples of documents that might be accessed by a document-driven DSS are policies and procedures, product specifications, catalogs, and corporate historical documents, including minutes of meetings and correspondence. A search engine is a primary decision-aiding tool associated with a document-driven DSS. The World-wide web technologies significantly increased the availability of documents and facilitated the development of document-driven DSS (Klein M. R. and Traunmüller R., 1993).

10.3.5 Knowledge-driven DSS:

Knowledge-driven DSS can give suggestions or recommendations to managers. These DSS are person-computer systems with specialized problem-solving expertise consisting of knowledge about a particular field, understanding of problems within that domain, and "skill" at solving some of these problems. The first example is for medical purposes, which helped physicians diagnosing blood diseases based on sets of clinical symptoms. With evolving computation knowledge and skills, Artificial Intelligence systems have been developed and used in DSS. These thinking expert systems used in many areas such as financial transactions, medical diagnostic systems, scheduling in manufacturing operation and in web-based systems (Klein M. R. and Traunmüller R., 1993; C. W. Holsapple and A. B. Whinston, 1993).

10.3.6 Web-based DSS:

Web-based DSS as a computerized system that delivers decision support information or decision support tools to a manager or business analyst using a Web browser like Netscape Navigator or Internet Explorer. In recent years many database management system shifted their systems to the Web-based analytical applications and solutions (Klein M. R. and Traunmüller R., 1993).

10.3.7 GIS-Based DSS:

GIS-Based DSS deliver decision support information or decision support tools to a manager or business analyst using GIS. GIS tools have extensive functionality and can be difficult for users unfamiliar with GIS and cartographic principles to learn. While computation skills developed, stand-alone easy to use interfaces developed for decision makers that can be used through the World Wide Web.

Trends suggest that data-driven DSS will use faster, real-time access to larger, better integrated databases. Model-driven DSS will be more complex, yet understandable, and systems built using simulations and their accompanying visual displays will be increasingly realistic. Communications-driven DSS will provide more real-time video communications support. Document-driven DSS will access larger repositories of unstructured data and the systems will present appropriate documents in more useable formats. Finally, knowledge-driven DSS will likely be more sophisticated and more comprehensive. The advice from knowledge-driven DSS will be better and the applications will cover broader domains. (Burstein F. & Holsapple C. W., 2008)

DSS is categorized into seven distinct types in terms of the generic operations. These are; file drawer systems that provide access to data items, Data Analysis Systems that support the manipulation of data by computerized tools tailored to a specific task and setting or by more general tools and operators, Analysis information systems that provide access to a series of decision-oriented databases and small models, accounting and financial models that calculate the consequences of possible actions, Representational Models that estimate the consequences of actions on the basis of simulation models, Optimization Models that provide guidelines for action by generating an optimal solution consistent with a series of constraints and Suggestion Models that perform the logical processing leading to a specific suggested decision for a fairly structured or well-understood task. (Klein M. R. & Traunmüller, R., 1993)

10.4 DSS types

DSS Developers designed in four ways namely Multi-Criteria Decision Analysis, Multidimensional Analysis, Optimization and Simulation. A Multi-criteria Decision Model helps evaluate a set of discrete actions, i.e., alternatives, projects, or proposals. A variety of approaches are available. Multi-dimensional Analysis handles data hierarchically in each dimension to extract useful information and develop conclusions. Decisions arise from question which requires multiple perspectives on the data, such as time, regions and usages. Each of these perspectives is called dimensions (Burstein F. & Holsapple C. W., 2008; Niu, L., Lu, J. & Zhang, G., 2009; Klein M. R. & Traunmüller, R., 1993).

10.4.1 Multi-Criteria Decision Analysis

Multi-Criteria Analysis (MCA) is a decision-making tool developed for complex problems. In ICZM; there are sectors, resources, uses and administrative bodies. All of these draw a frame where reaching a general consensus in a multidisciplinary team for decision making can be very difficult to achieve. For decision support MCA is a valuable tool. Some of the MCA methods are found in web search. Fuzzy Logic is another tool that was used for MCA by many researchers (Burstein F. & Holsapple C. W., 2008; Smeets, E. & Weterings R., 1999; Cicin-Sain B & Knecht RW, 1999).

10.4.2 Multidimensional Analysis

In statistics, econometrics, and related fields, multidimensional analysis is a data analysis process that groups data into two or more categories: data dimensions and measurements. For example, a data set consisting of precipitation for a station of several years is a single-dimensional (in this case, longitudinal) data set. A data set consisting of precipitation for several stations in a single year is also a single-dimensional (in this case, cross-sectional) data set. A data set consisting of precipitations for several years is a two-dimensional data set.

While, strictly speaking, two- and higher- dimensional data sets are "multi-dimensional," the term "multidimensional" tends to be applied only to data sets with three or more dimensions. The three dimensions provide more information than can be gleaned from two dimensional data sets. For example, some forecast data sets provide forecasts for multiple target periods, conducted by multiple forecasters, and made at multiple horizons.

10.4.3 Optimization

Optimization is obtaining the best result under given conditions. In design, construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of certain decision variables, optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function.

There is no single method available for solving all optimization problems efficiently. Hence a number of optimization methods have been developed for solving different types of optimization problems. The optimum seeking methods are also known as mathematical programming techniques and are generally studied as a part of operations research. Operations research is a branch of mathematics concerned with the application of scientific methods and techniques to decision making problems and with establishing the best or optimal solutions.

Table 10.1 lists various mathematical programming techniques together with other well-defined areas of operations research. Mathematical programming techniques are useful in finding the minimum of a function of several variables under a prescribed set of constraints. Stochastic process techniques can be used to analyze problems described by a set of random variables having known probability distributions. Statistical methods enable one to analyze the experimental data and build empirical models to obtain the most accurate representation of the physical situation. This book deals with the theory and application of mathematical programming techniques suitable for the solution of engineering design problems (Singiresu S. Rao, 1996).

Table 10.1 Methods of operations research (adapted from Singiresu S. Rao, 1996)

Mathematical programming or optimization techniques	Stochastic process techniques	Statistical methods
Calculus methods Calculus of variations Nonlinear programming Geometric programming Quadratic programming Linear programming Dynamic programming Integer programming Stochastic programming Separable programming Multiobjective programming Network methods: CPM and PERT Game theory	Statistical decision theory Markov process Queueing theory Renewal theory Simulation methods Reliability theory	Regression analysis Cluster analysis, pattern recognition Design of experiments Discriminate analysis (factor analysis)
Modern or nontraditional optimization techniques		
Genetic algorithms *Simulated annealing* *Ant colony optimization* *Particle swarm optimization* *Neural networks* *Fuzzy optimization*		

10.4.4 Simulation

The development and use of models of various objects is becoming more important. This is due to the ease with which models can be developed and examined through the use of computers and appropriate software. Usually a model show correlations between some processes and their interactions. It details and characterizes a part of the real world taking into account a structure of phenomena, as well as quantitative and qualitative relations. There are a great variety of models. Modeling is carried out in many diverse fields. All types of natural phenomena in the area of biology, ecology and medicine are possible subjects for modeling. Models stand for and represent technical objects in physics, chemistry, engineering, social events and behaviors in sociology, financial matters, investments and stock markets in economy, strategy, defense, security and safety in military fields. There is one common point for all models. We expect them to fulfill the validity of prediction. It means that through the analysis of models it is possible to predict phenomena, which may occur in a fragment of the real world represented by a given model. We also expect to be able to predict future reactions to signals from the outside world (Layer E. & Tomczyk K., 2010).

There are many ways of the describing a system or its events, which means many ways of constructing a model. The model must also enable us to predict the progression of events in the future. Obviously, all those features are linked directly to the accuracy of the model, which in turn depends on the construction of the model and its verifications. The most common and basic approach to modeling is the identification approach. When using it, we observe actual inputs and outputs and try to fit a model to the observations. In other words, models and their parameters are identified through experiments. Two methods of identification can be distinguished, namely the active and passive. After gathering observations by measuring or experiments, we try to fit a model to the observations. At this point, parameters should be estimated. After these steps, model is verified and checked whether it satisfies a requirement. The model's quality is verified again and again until the result is satisfactory.

In such modeling, difficulties can be expected in two areas and can be related to model structure and parameter estimation. One potential problem is nonlinearity of elements or environment during dynamic operation. This can increase the number of difficulties in the development of a model's structure. An estimation of parameters can also be difficult, usually burdened with errors related to interference and random noise in the experiment (Layer E. & Tomczyk K., 2010; Altıok T & Melamed B., 2007).

APPENDIX B
DATA ANALYSIS

11.1 Principal Component Analysis

PCA was applied to the variables of land and sea 500 m grid data (Figure 4.14). In all PCA analysis, NIPALS algorithm was used. The number of components in the Principal Component model was determined by V-fold cross-validation method. The analysis enables two Principal Components for a data set, which meets the requirements of Cattell for sufficiency of Principal Component (Cattell, 1966). The details of land data PCA was given in Chapter 5. Sea data PCA details are given below.

11.1.1 Land Data Principal Component Analysis

First, all land data with terrain properties elevation, slope and aspect was analyzed. The power of aspect categories was found to be low and therefore not used in succeeding analysis.

For the next analysis, the layers such as house, water resources, highways, unimproved roads, trail and other roads, river, intermittent river, forest, burnt forest, degraded forest, agriculture, wetland, pier, population, population density, mean slope, and median elevation of the terrain in each 500 m grid were included. In PCA, the variables were included to analyze the effects of the overall relations as PCA figures out the whole relationship between them, instead of analyzing them one by one in terms of correlation matrices and linear regression analysis.

The variable importance of PCA measures how well a variable is represented by the principal components. The measure of this involves power ranging from 0 to 1.

The statistical analysis PCA was not used as a decision making tool; however it was only used to determine the characteristics of the data that would be selected as a model input parameter in the succeeding part. The relations were investigated as group parameters taken from variable importance tables, figures and loading scatter plots, which are explained in detail in Chapter 5.

PCA reveals the importance of variables via power, which composes the fraction of the residual standard variation and initial standard deviation. The variable importance of land data is provided below in Table 11.1.

Table 11.1 Variable importance

Variables (GIS Layers)	Power	Importance
forest_deg	0.752	1
agri	0.716	2
forest	0.494	3
DEM_Median_1	0.458	4
forest_burnt	0.451	5
river_intrmtd	0.368	6
house	0.332	7
Slope_Mean_1	0.198	8
waterresrc	0.189	9
pop_density	0.186	10
road3_trail	0.138	11
road1_hghw	0.124	12
road2_unpr	0.102	13
river	0.039	14
wetland	0.023	15
pier	0.002	16

The new revised analysis was processed with a smaller group of main land parameters: forest, degraded forest, agriculture, elevation, intermittent river, house, population density and data of road types. Prior to the small group of land data that would be analyzed in ANFIS model development, PCA was applied to these variables. The variable importance of the PCA is given in Table 11.2.

Table 11.2 Variable importance of selected land data

Variables (GIS Layers)	Power	Importance
forest_deg	0.689	1
agri	0.633	2
forest	0.622	3
DEM_Median_1	0.614	4
river_intrmtd	0.486	5
house	0.344	6
pop_density	0.224	7
road2_unpr	0.205	8
road1_hghw	0.181	9
road3_trail	0.094	10

Each group of variables for the model development of ANFIS was analyzed by PCA method to examine the probability distributions, relations (connections) and importance. Appropriate replacing of the variables was evaluated by PCA. Considering the interchangeability relationship, the data can be prepared with low cost and effort (i.e. not needing to process) on further coastal zone studies if it is already available. During the ongoing analysis, PCA was performed for each land data group. Each gave slightly different results. The listed importances are given in Table 5.4 to Table 5.9. The detailed analysis results are given in Chapter 5 and 6 for outputs degraded forest, forest, house and population density.

11.2 Land Data ANFIS Model Development

The variables of land 500 m grid data consist of layers house, water resources, highways, unimproved roads, trail and other roads, river, intermittent river, forest, burnt forest, degraded forest, agriculture, wetland, pier, population, population density, mean slope, median elevation of the terrain. These layers are used for ANFIS model after normalization in order to overcome the problems arising from range differences. In the following part, the details of forest, house and population density ANFIS models whose model results were given in Chapter 6 are given.

11.2.1 ANFIS Model For Forest

On second ANFIS model, forest area is forecasted. The change of the training error can be shown in Figure 11.1. While training, optimum iteration number was selected for each run to reach a stationary error quantity.

For model development four or three input combinations out of 10 variables are selected and trained on ANFIS considering the computational processor and time requirement. Forest area was selected as an output to develop a model. The model carried out to figure out the response of forest area to the change in agriculture, elevation, forest area, house, population density, and intermittent river and road types. The model development trials formed of four input combinations are given in Table 11.3.

Table 11.3 Trained degraded forest area estimation models for different input combinations

No	Inputs				Output
1	agri	DEM_Median_1	forest_deg	house	forest
2	agri	DEM_Median_1	forest_deg	pop_density	forest
3	agri	DEM_Median_1	forest_deg	river_intrmtd	forest
4	agri	DEM_Median_1	forest_deg	road_sum	forest
5	agri	DEM_Median_1	house	pop_density	forest
6	agri	DEM_Median_1	house	river_intrmtd	forest
7	agri	DEM_Median_1	house	road_sum	forest
8	agri	DEM_Median_1	house	road_sum	forest
9	agri	DEM_Median_1	road_sum	pop_density	forest
10	agri	DEM_Median_1	road_sum	river_intrmtd	forest
11	agri	forest_deg	house	pop_density	forest
12	agri	forest_deg	house	river_intrmtd	forest
13	agri	forest_deg	house	road_sum	forest
14	agri	forest_deg	pop_density	road_sum	forest
15	agri	forest_deg	road_sum	river_intrmtd	forest
16	agri	house	road_sum	pop_density	forest
17	agri	house	road_sum	river_intrmtd	forest
18	DEM_Median_1	forest_deg	house	pop_density	forest
19	DEM_Median_1	forest_deg	house	river_intrmtd	forest
20	DEM_Median_1	forest_deg	house	road_sum	forest
21	DEM_Median_1	forest_deg	pop_density	road_sum	forest
22	DEM_Median_1	forest_deg	pop_density	road1_hghw	forest
23	DEM_Median_1	forest_deg	pop_density	road2_unpr	forest*
24	DEM_Median_1	forest_deg	pop_density	road3_trail	forest
25	DEM_Median_1	forest_deg	road_sum	pop_density	forest
26	DEM_Median_1	forest_deg	road_sum	river_intrmtd	forest

No	Inputs				Output
27	DEM_Median_1	forest_deg	road_sum	road1_hghw	forest
28	DEM_Median_1	forest_deg	road_sum	road2_unpr	forest
29	DEM_Median_1	forest_deg	road_sum	road3_trail	forest
30	DEM_Median_1	forest_deg	road1_hghw	road2_unpr	forest
31	DEM_Median_1	forest_deg	road1_hghw	road3_trail	forest
32	DEM_Median_1	forest_deg	road2_unpr	road3_trail	forest
33	DEM_Median_1	house	pop_density	river_intrmtd	forest
34	DEM_Median_1	house	pop_density	road1_hghw	forest
35	DEM_Median_1	house	pop_density	road2_unpr	forest
36	DEM_Median_1	house	river_intrmtd	road1_hghw	forest
37	DEM_Median_1	house	river_intrmtd	road2_unpr	forest
38	DEM_Median_1	house	road_sum	pop_density	forest
39	DEM_Median_1	house	road_sum	river_intrmtd	forest
40	DEM_Median_1	house	road1_hghw	road2_unpr	forest
41	DEM_Median_1	pop_density	river_intrmtd	road1_hghw	forest
42	DEM_Median_1	pop_density	river_intrmtd	road2_unpr	forest
43	DEM_Median_1	pop_density	road1_hghw	road3_trail	forest
44	DEM_Median_1	river_intrmtd	road1_hghw	road2_unpr	forest
45	DEM_Median_1	road1_hghw	road2_unpr	road3_trail	forest
46	forest_deg	house	pop_density	road_sum	forest
47	forest_deg	house	river_intrmtd	road_sum	forest
48	forest_deg	house	road_sum	river_intrmtd	forest
49	forest_deg	pop_density	river_intrmtd	road_sum	forest
50	forest_deg	pop_density	road1_hghw	road2_unpr	forest
51	pop_density	road1_hghw	road2_unpr	road3_trail	forest
* Selected model					

Triangular membership function was selected for this ANFIS model run. Two linguistic term was used for membership functions. ANFIS model structure and membership functions were shown in Figure 11.2 and Figure 11.4.

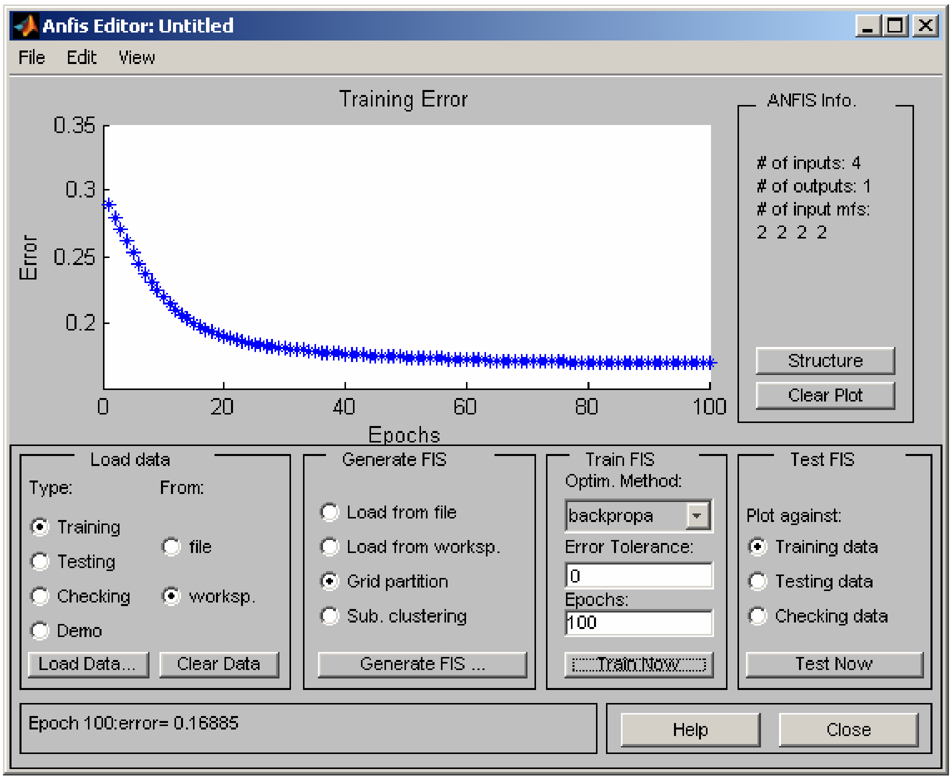


Figure 11.1 Training error of the data

The rules are formed by first order Sugeno fuzzy model. Model interface is given in Figure 11.3. Membership functions of inputs are shown in Figure 11.4 as sample graphical views are given in Figure 11.5 and Figure 6.1.

Input and output relations solved by first order Sugeno fuzzy model. The changing laws of input vs. output were represented as a line graph to visualize the relation (Figure 11.5).

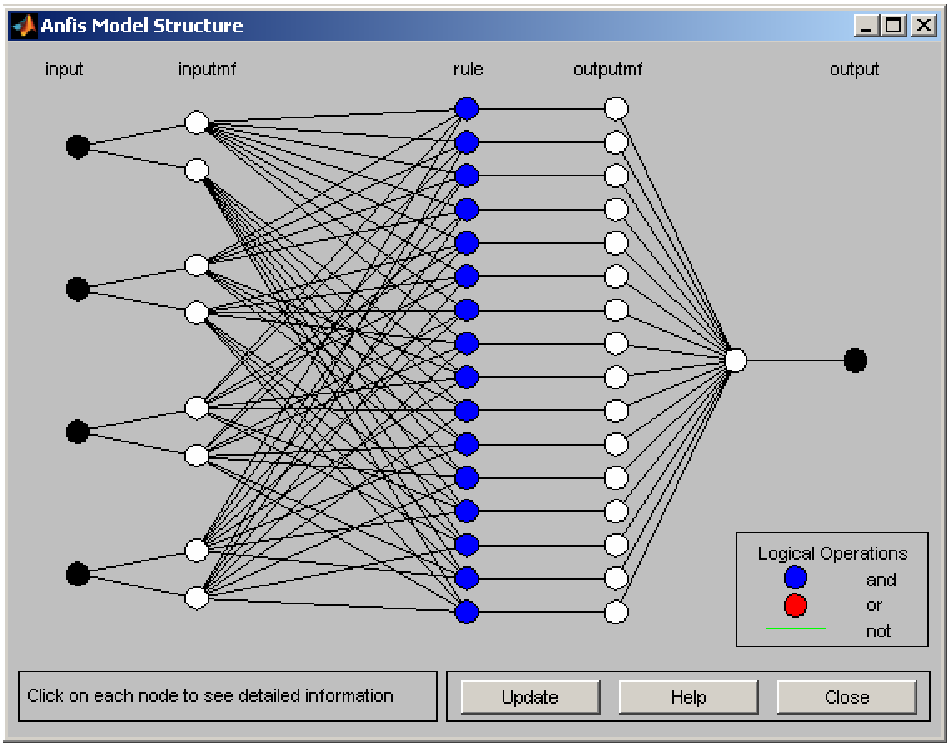


Figure 11.2 Model structure

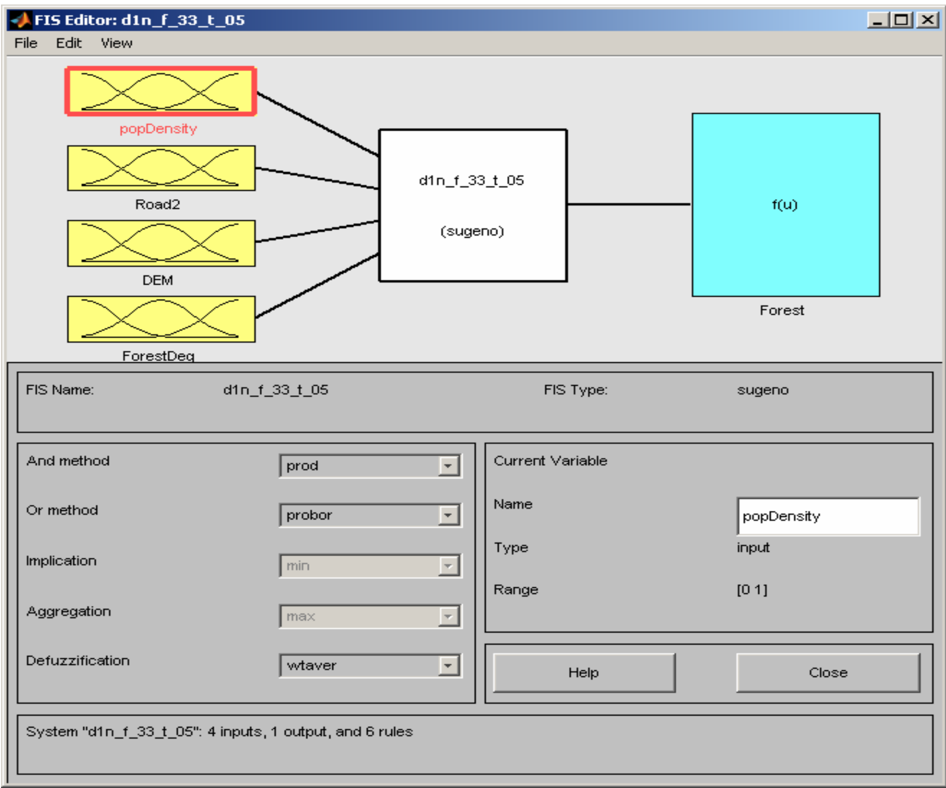


Figure 11.3 Input and output of the analysis

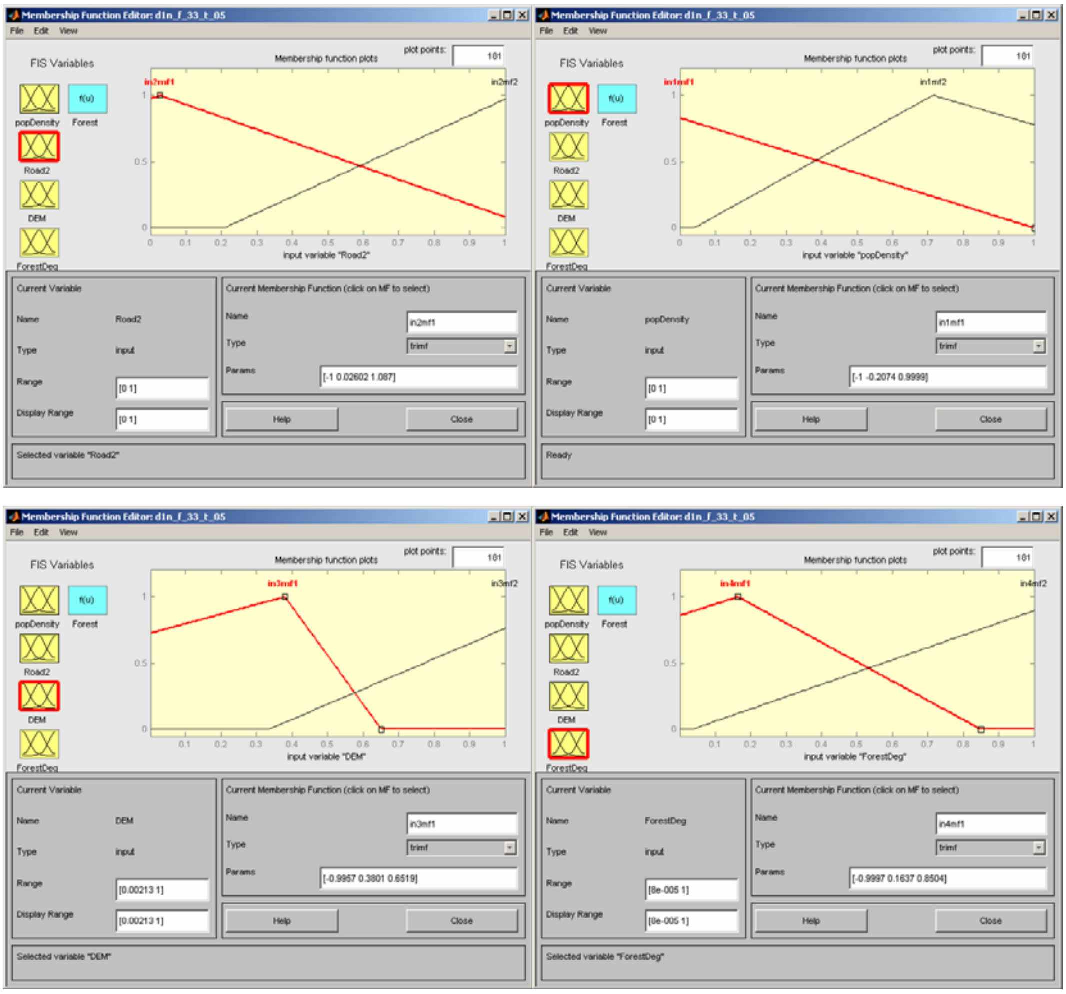


Figure 11.4 Membership functions of unimproved road, population density, elevation and degraded forest

The ANFIS model, the rules were redefined as an expert view (Abonyi and Feil, 2007; Hui et al.,2004; Salgado P., 2008) and enhanced model surface graphs shown on Figure 6.1.

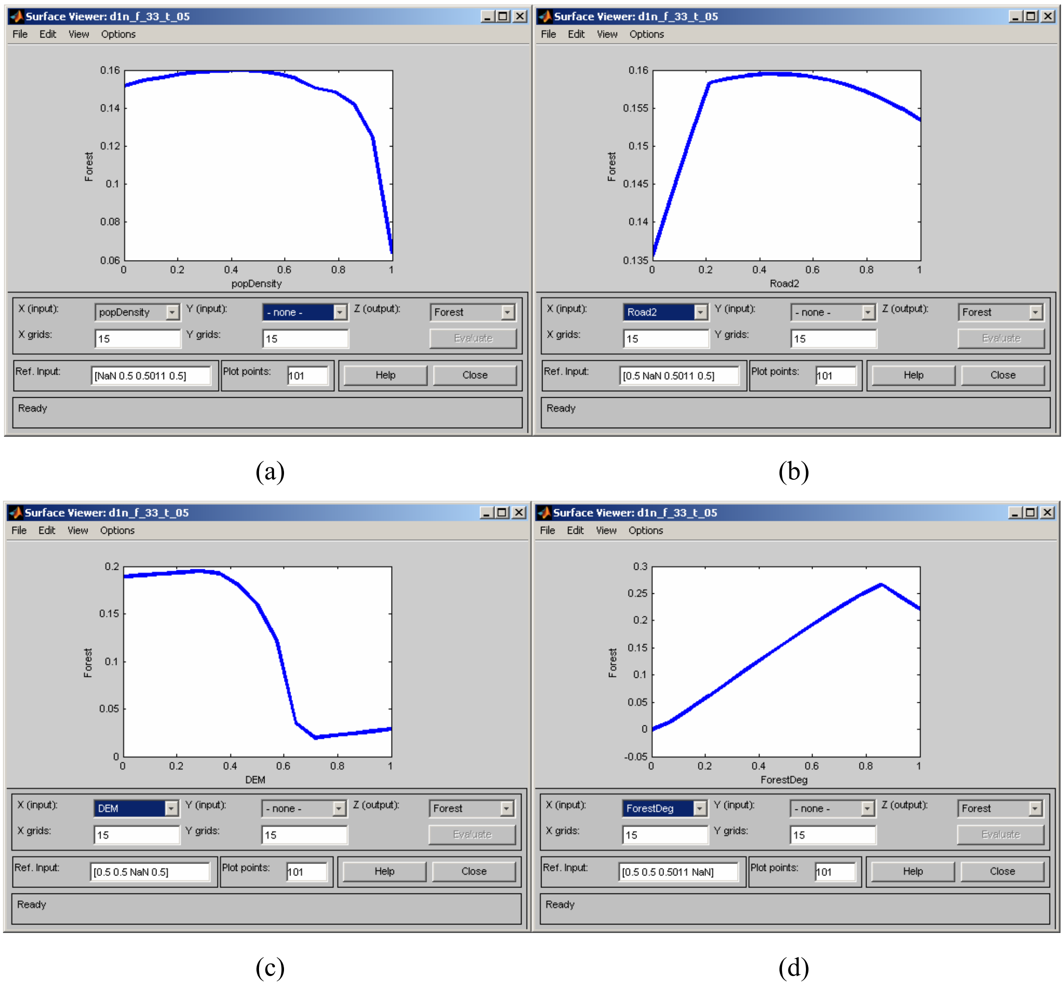


Figure 11.5 The changing law between forest vs. inputs population density (a), unimproved road (b), elevation (c) and degraded forest (d)

Forest area was assumed as 100 unit for each 500 m land grid equally. By using ANFIS changing laws, the alteration was forecasted from input grid values and the new unit of forest area was calculated. The thematic map of change in forest estimation is given in Figure 6.2.

11.2.2 ANFIS Model For Housing

On third ANFIS model, housing are forecasted. The change of the training error can be shown in Figure 11.6. While training, optimum iteration number was selected for each run to reach a stationary error quantity.

For model development four or three input combinations out of 12 variables are selected and trained on ANFIS considering the computational processor and time requirement. House counts were selected as an output to develop a model. The model carried out to figure out the response of human settlements to the change in agriculture, elevation, forest area, house, population density, and intermittent river and road types. The model development trials formed of four input combinations are given in Table 11.4.

Table 11.4 Trained degraded forest area estimation models for different input combinations

No	Inputs				Output
1	agri	DEM_Median_1	forest	forest_deg	house
2	agri	DEM_Median_1	forest	pop_density	house
3	agri	DEM_Median_1	forest	river_intrmtd	house
4	agri	DEM_Median_1	forest	road_sum	house
5	agri	DEM_Median_1	forest	road1_hghw	house
6	agri	DEM_Median_1	forest	road2_unpr	house
7	agri	DEM_Median_1	forest_deg	pop_density	house
8	agri	DEM_Median_1	forest_deg	river_intrmtd	house
9	agri	DEM_Median_1	forest_deg	road_sum	house
10	agri	DEM_Median_1	forest_deg	road1_hghw	house
11	agri	DEM_Median_1	forest_deg	road2_unpr	house*
12	agri	DEM_Median_1	forest_deg	road3_trail	house
13	agri	DEM_Median_1	river_intrmtd	road_sum	house
14	agri	DEM_Median_1	river_intrmtd	road1_hghw	house
15	agri	DEM_Median_1	river_intrmtd	road2_unpr	house
16	agri	DEM_Median_1	road_sum	Slope_Mean_1	house
17	agri	DEM_Median_1	road1_hghw	road2_unpr	house
18	agri	forest	forest_deg	pop_density	house
19	agri	forest	forest_deg	river_intrmtd	house
20	agri	forest	forest_deg	road_sum	house
21	agri	forest	forest_deg	road1_hghw	house
22	agri	forest	forest_deg	road2_unpr	house
23	agri	forest	forest_deg	road3_trail	house
24	agri	forest	pop_density	river_intrmtd	house
25	agri	forest	river_intrmtd	road_sum	house
26	agri	forest	river_intrmtd	road1_hghw	house

No	Inputs				Output
27	agri	forest	river_intrmtd	road2_unpr	house
28	agri	forest	river_intrmtd	road3_trail	house
29	agri	forest	road1_hghw	road2_unpr	house
30	agri	forest	road1_hghw	road3_trail	house
31	agri	forest	road2_unpr	road3_trail	house
32	agri	forest_deg	pop_density	road1_hghw	house
33	agri	forest_deg	river_intrmtd	road_sum	house
34	agri	forest_deg	river_intrmtd	road1_hghw	house
35	agri	forest_deg	river_intrmtd	road2_unpr	house
36	agri	forest_deg	river_intrmtd	road3_trail	house
37	agri	forest_deg	road1_hghw	road2_unpr	house
38	agri	forest_deg	road1_hghw	road3_trail	house
39	agri	forest_deg	road2_unpr	road3_trail	house
40	agri	pop_density	road1_hghw	road2_unpr	house
41	agri	pop_density	road1_hghw	road3_trail	house
42	agri	pop_density	road2_unpr	road3_trail	house
43	agri	river_intrmtd	road1_hghw	road2_unpr	house
44	agri	river_intrmtd	road1_hghw	road3_trail	house
45	agri	river_intrmtd	road2_unpr	road3_trail	house
46	agri	road1_hghw	road2_unpr	road3_trail	house
47	DEM_Median_1	forest	forest_deg	pop_density	house
48	DEM_Median_1	forest	forest_deg	river_intrmtd	house
49	DEM_Median_1	forest	forest_deg	road_sum	house
50	DEM_Median_1	forest	forest_deg	road1_hghw	house
51	DEM_Median_1	forest	forest_deg	road2_unpr	house
52	DEM_Median_1	forest	river_intrmtd	road_sum	house
53	DEM_Median_1	forest	river_intrmtd	road1_hghw	house
54	DEM_Median_1	forest	river_intrmtd	road2_unpr	house
55	DEM_Median_1	forest	river_intrmtd	Slope_Mean_1	house
56	DEM_Median_1	forest	road1_hghw	road2_unpr	house
57	DEM_Median_1	forest_deg	pop_density	road2_unpr	house
58	DEM_Median_1	forest_deg	river_intrmtd	road_sum	house
59	DEM_Median_1	forest_deg	river_intrmtd	road1_hghw	house
60	DEM_Median_1	forest_deg	river_intrmtd	road2_unpr	house
61	DEM_Median_1	forest_deg	road_sum	Slope_Mean_1	house
62	DEM_Median_1	forest_deg	road1_hghw	road2_unpr	house
63	DEM_Median_1	pop_density	river_intrmtd	road_sum	house
64	DEM_Median_1	pop_density	river_intrmtd	road1_hghw	house
65	DEM_Median_1	pop_density	road1_hghw	road2_unpr	house
66	DEM_Median_1	river_intrmtd	road1_hghw	road2_unpr	house
67	forest	forest_deg	pop_density	road1_hghw	house
68	forest	forest_deg	pop_density	road2_unpr	house
69	forest	forest_deg	pop_density	road3_trail	house
70	forest	forest_deg	river_intrmtd	road1_hghw	house
71	forest	forest_deg	river_intrmtd	road2_unpr	house
72	forest	forest_deg	road1_hghw	road2_unpr	house
73	forest	forest_deg	road1_hghw	road3_trail	house
74	forest	forest_deg	road2_unpr	road3_trail	house
75	forest	pop_density	river_intrmtd	road1_hghw	house

No	Inputs				Output
76	forest	pop_density	road1_hghw	road2_unpr	house
77	forest	pop_density	road1_hghw	road3_trail	house
78	forest	pop_density	road2_unpr	road3_trail	house
79	forest	river_intrmtd	road1_hghw	road2_unpr	house
80	forest	river_intrmtd	road1_hghw	road3_trail	house
81	forest	river_intrmtd	road2_unpr	road3_trail	house
82	forest_deg	pop_density	river_intrmtd	road1_hghw	house
83	forest_deg	pop_density	road1_hghw	road2_unpr	house
84	forest_deg	pop_density	road1_hghw	road3_trail	house
85	forest_deg	pop_density	road2_unpr	road3_trail	house
86	forest_deg	river_intrmtd	road1_hghw	road2_unpr	house
87	forest_deg	river_intrmtd	road1_hghw	road3_trail	house
88	forest_deg	river_intrmtd	road2_unpr	road3_trail	house
89	river_intrmtd	road1_hghw	road2_unpr	road3_trail	house
* Selected model					

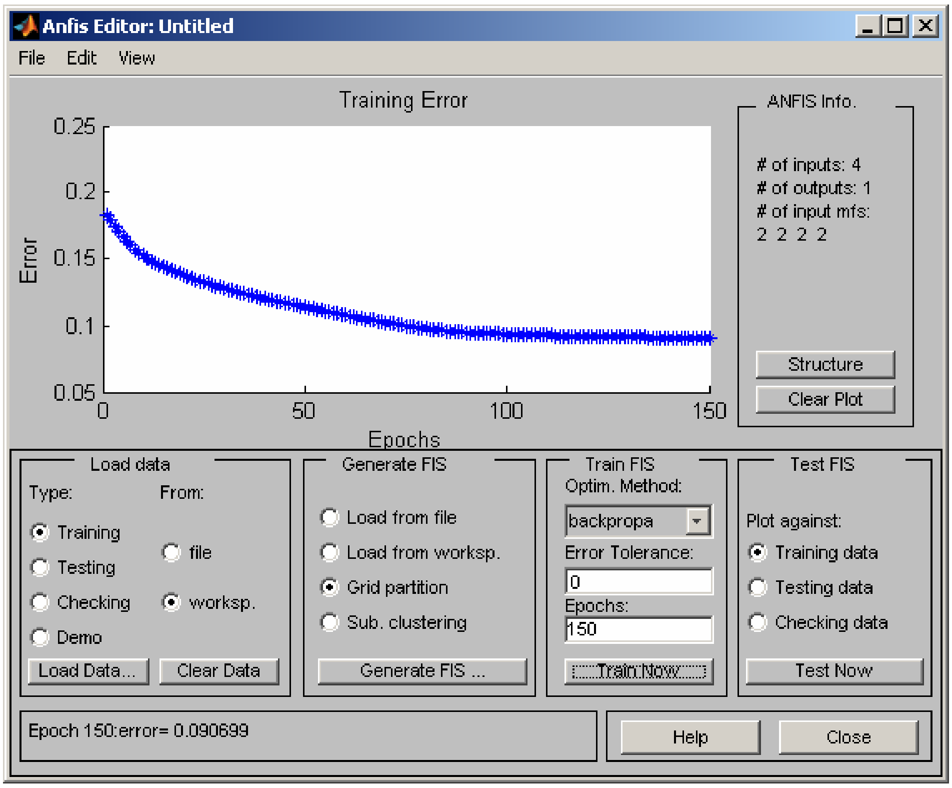


Figure 11.6 Training error of the data

Triangular membership function was selected for this ANFIS model run. Two linguistic term was used for membership functions. ANFIS model structure and membership functions were shown in Figure 11.7 and Figure 11.9.

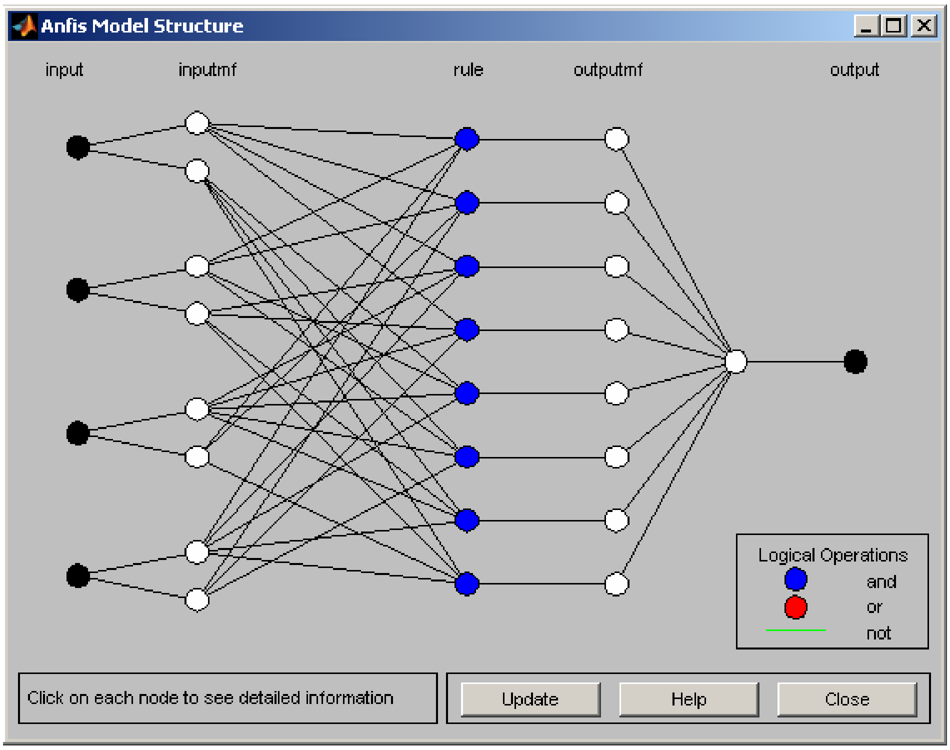


Figure 11.7 Model structure

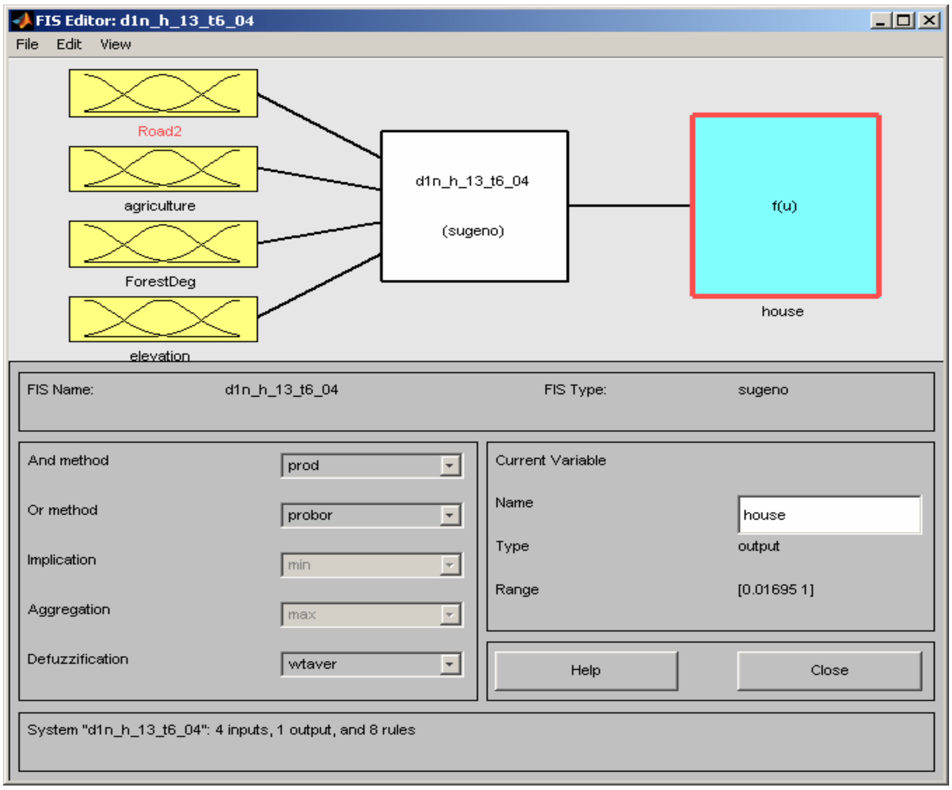


Figure 11.8 Input and output of the analysis

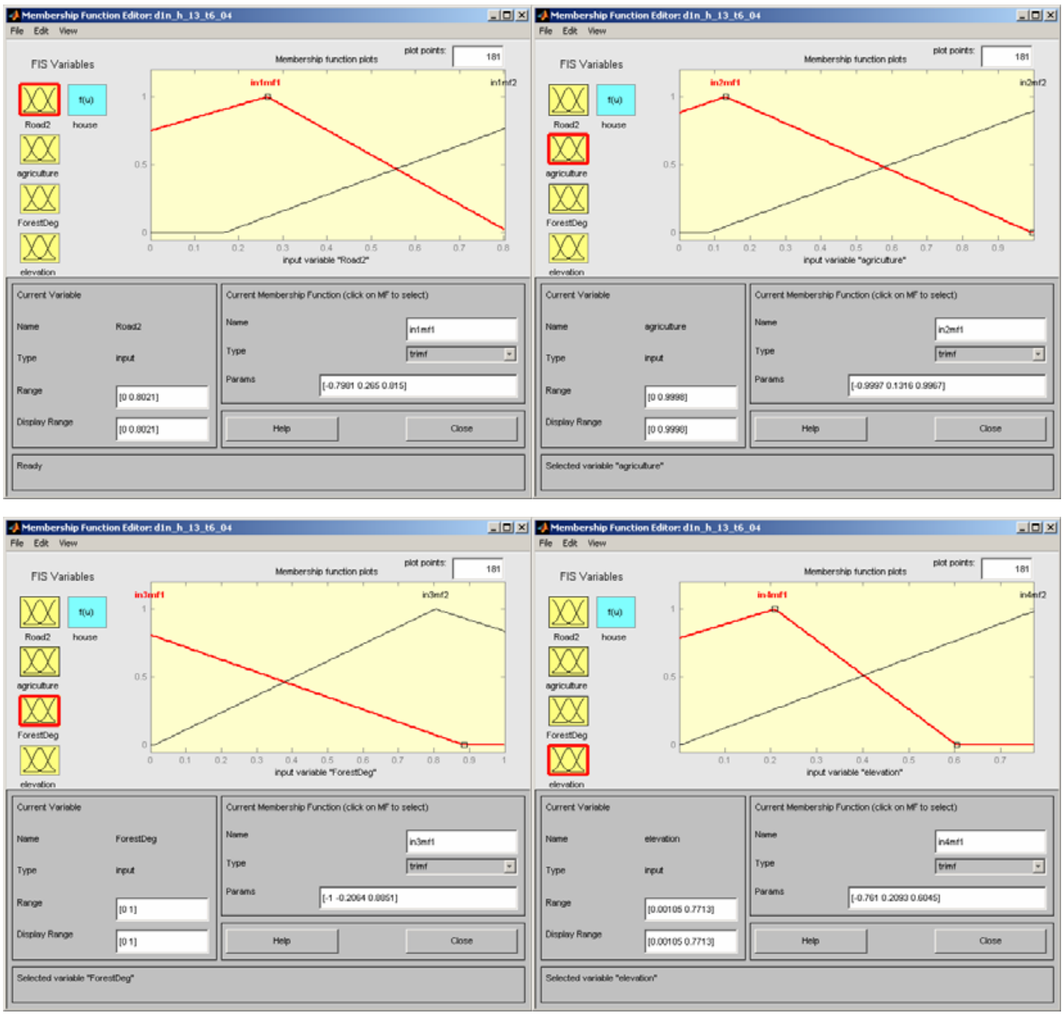
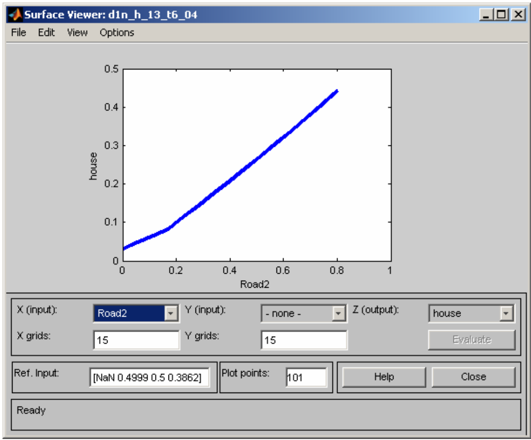
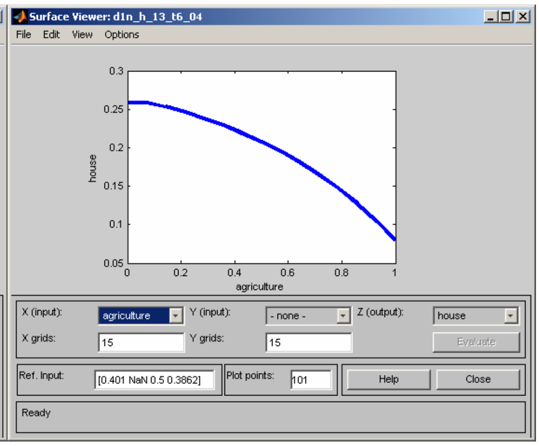


Figure 11.9 Membership functions of unimproved road, agriculture, degraded forest and elevation

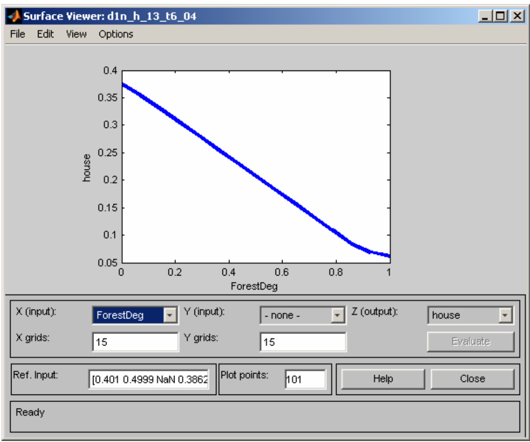
The rules are formed by first order Sugeno fuzzy model. Model interface is given in Figure 11.8. Membership functions of inputs are shown in Figure 11.9 as sample graphical views are given in Figure 11.10 and Figure 6.3.

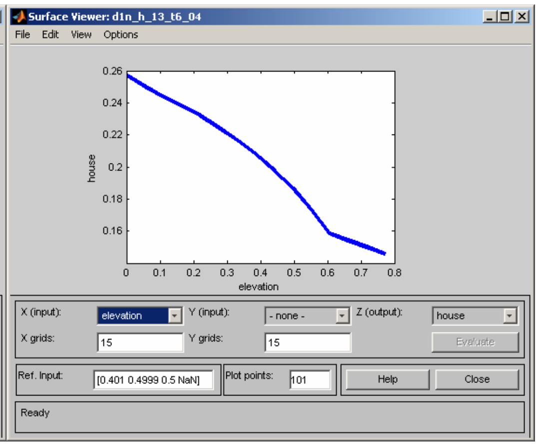
Input and output relations solved by first order Sugeno fuzzy model. The changing laws of input vs. output were represented as a line graph to visualize the relation (Figure 11.10).





(a) (b)





(c) (d)

Figure 11.10 The changing law between house vs. unimproved road (a), agriculture (b), degraded forest (c) and elevation (d)

The ANFIS model, the rules were redefined as an expert view (Abonyi and Feil, 2007; Hui et al.,2004; Salgado P., 2008) and enhanced model surface graphs shown on Figure 6.3.

House counts were assumed as 100 unit for each 500 m land grid equally. By using ANFIS changing laws, the change in settlements houses were forecasted from input grid values and the new unit of housing were calculated. The thematic map of change estimation is given in Figure 6.4.

11.2.3 ANFIS Model For Population Density

On fourth ANFIS model, population density is forecasted. The change of the training error can be shown in Figure 11.11. While training, optimum iteration number was selected for each run to reach a stationary error quantity.

For model development four or three input combinations out of 11 variables are selected and trained on ANFIS considering the computational processor and time requirement. Pop density was selected as an output to develop a model. The model carried out to figure out the response of residence of population to the change in agriculture, elevation, forest area, house, population density, and intermittent river and road types. The model development trials formed of four and three input combinations are given in Table 11.5.

Table 11.5 Trained degraded forest area estimation models for different input combinations

No	Inputs				Output
1	agri	DEM_Median_1	forest	forest_deg	pop_density
2	agri	DEM_Median_1	forest	river_intrmtd	pop_density
3	agri	DEM_Median_1	forest	road_sum	pop_density
4	agri	DEM_Median_1	forest	road1_hghw	pop_density*
5	agri	DEM_Median_1	forest	road2_unpr	pop_density
6	agri	DEM_Median_1	forest_deg	river_intrmtd	pop_density
7	agri	DEM_Median_1	forest_deg	road_sum	pop_density
8	agri	DEM_Median_1	forest_deg	road1_hghw	pop_density
9	agri	DEM_Median_1	forest_deg	road2_unpr	pop_density
10	agri	DEM_Median_1	house	road_sum	pop_density
11	agri	DEM_Median_1	house	road1_hghw	pop_density
12	agri	DEM_Median_1	house	road2_unpr	pop_density
13	agri	DEM_Median_1	river_intrmtd	road_sum	pop_density
14	agri	DEM_Median_1	river_intrmtd	road1_hghw	pop_density
15	agri	DEM_Median_1	river_intrmtd	road2_unpr	pop_density
16	agri	DEM_Median_1	river_intrmtd	road3_trail	pop_density
17	agri	DEM_Median_1	road1_hghw	road2_unpr	pop_density
18	agri	forest	forest_deg	river_intrmtd	pop_density
19	agri	forest	forest_deg	road_sum	pop_density
20	agri	forest	forest_deg	road1_hghw	pop_density
21	agri	forest	forest_deg	road2_unpr	pop_density
22	agri	forest	house	road2_unpr	pop_density
23	agri	forest	river_intrmtd	road_sum	pop_density
24	agri	forest	river_intrmtd	road1_hghw	pop_density
25	agri	forest	river_intrmtd	road2_unpr	pop_density
26	agri	forest	road1_hghw	road2_unpr	pop_density
27	agri	forest_deg	house	road_sum	pop_density
28	agri	forest_deg	river_intrmtd	road_sum	pop_density

No	Inputs				Output
29	agri	forest_deg	river_intrmtd	road1_hghw	pop_density
30	agri	forest_deg	river_intrmtd	road2_unpr	pop_density
31	agri	forest_deg	road_sum	road3_trail	pop_density
32	agri	forest_deg	road1_hghw	road2_unpr	pop_density
33	agri	house	river_intrmtd	road_sum	pop_density
34	agri	house	river_intrmtd	road2_unpr	pop_density
35	agri	river_intrmtd	road1_hghw	road2_unpr	pop_density
36	agri	road_sum	road1_hghw	road3_trail	pop_density
37	DEM_Median_1	forest	forest_deg	river_intrmtd	pop_density
38	DEM_Median_1	forest	forest_deg	road_sum	pop_density
39	DEM_Median_1	forest	forest_deg	road1_hghw	pop_density
40	DEM_Median_1	forest	forest_deg	road2_unpr	pop_density
41	DEM_Median_1	forest	house	road_sum	pop_density
42	DEM_Median_1	forest	house	road1_hghw	pop_density
43	DEM_Median_1	forest	river_intrmtd	road_sum	pop_density
44	DEM_Median_1	forest	river_intrmtd	road1_hghw	pop_density
45	DEM_Median_1	forest	river_intrmtd	road2_unpr	pop_density
46	DEM_Median_1	forest	river_intrmtd	road3_trail	pop_density
47	DEM_Median_1	forest	road1_hghw	road2_unpr	pop_density
48	DEM_Median_1	forest	road1_hghw	road3_trail	pop_density
49	DEM_Median_1	forest_deg	house	road2_unpr	pop_density
50	DEM_Median_1	forest_deg	river_intrmtd	road_sum	pop_density
51	DEM_Median_1	forest_deg	river_intrmtd	road1_hghw	pop_density
52	DEM_Median_1	forest_deg	river_intrmtd	road2_unpr	pop_density
53	DEM_Median_1	forest_deg	river_intrmtd	road3_trail	pop_density
54	DEM_Median_1	forest_deg	road_sum	road1_hghw	pop_density
55	DEM_Median_1	forest_deg	road1_hghw	road2_unpr	pop_density
56	DEM_Median_1	house	river_intrmtd	road1_hghw	pop_density
57	DEM_Median_1	river_intrmtd	road_sum	road3_trail	pop_density
58	DEM_Median_1	river_intrmtd	road1_hghw	road2_unpr	pop_density
59	forest	forest_deg	house	road2_unpr	pop_density
60	forest	forest_deg	river_intrmtd	road_sum	pop_density
61	forest	forest_deg	river_intrmtd	road1_hghw	pop_density
62	forest	forest_deg	river_intrmtd	road2_unpr	pop_density
63	forest	forest_deg	road1_hghw	road2_unpr	pop_density
64	forest	house	river_intrmtd	road1_hghw	pop_density
65	forest	river_intrmtd	road1_hghw	road2_unpr	pop_density
66	forest_deg	house	river_intrmtd	road_sum	pop_density
67	forest_deg	river_intrmtd	road1_hghw	road2_unpr	pop_density
68	house	river_intrmtd	road1_hghw	road3_trail	pop_density
69	agri	DEM_Median_1	forest		pop_density
70	agri	DEM_Median_1	forest		pop_density
71	agri	DEM_Median_1	forest_deg		pop_density
72	agri	forest	road_sum		pop_density
73	agri	forest	road1_hghw		pop_density
74	DEM_Median_1	forest	road1_hghw		pop_density
75	DEM_Median_1	forest_deg	road2_unpr		pop_density

* Selected model

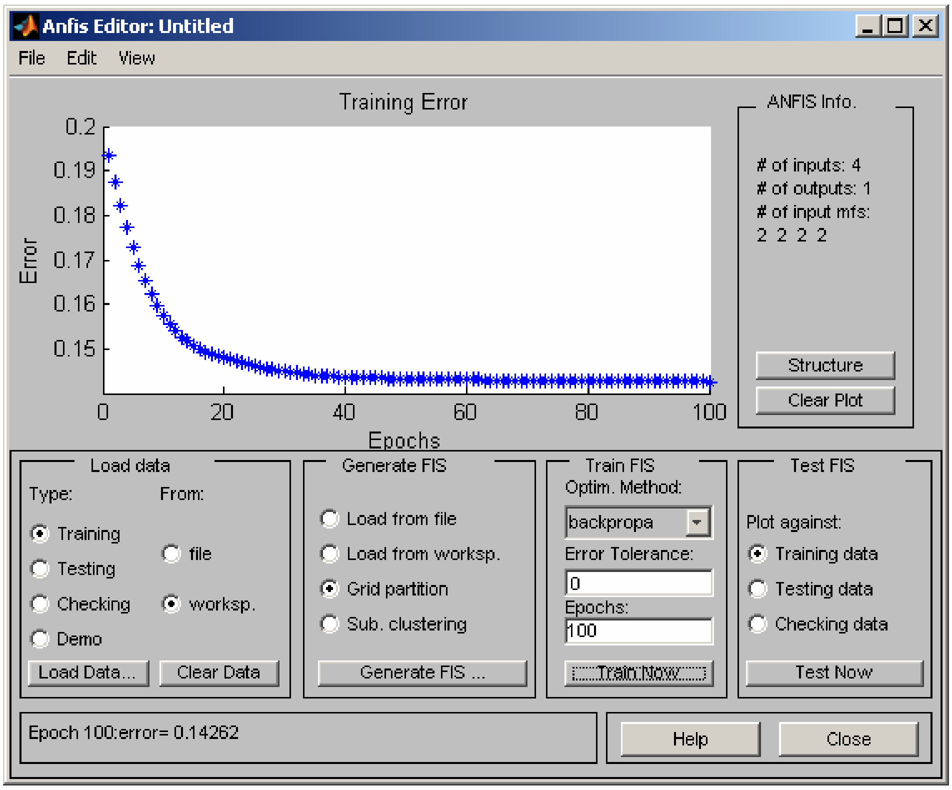


Figure 11.11 Training error of the data

Triangular membership function was selected for this ANFIS model run. Two linguistic term was used for membership functions. ANFIS model structure and membership functions were shown in Figure 11.12 and Figure 11.14.

The rules are formed by first order Sugeno fuzzy model. Model interface is given in Figure 11.13. Membership functions of inputs are shown in Figure 11.14 as sample graphical views are given in Figure 11.15 and Figure 6.5.

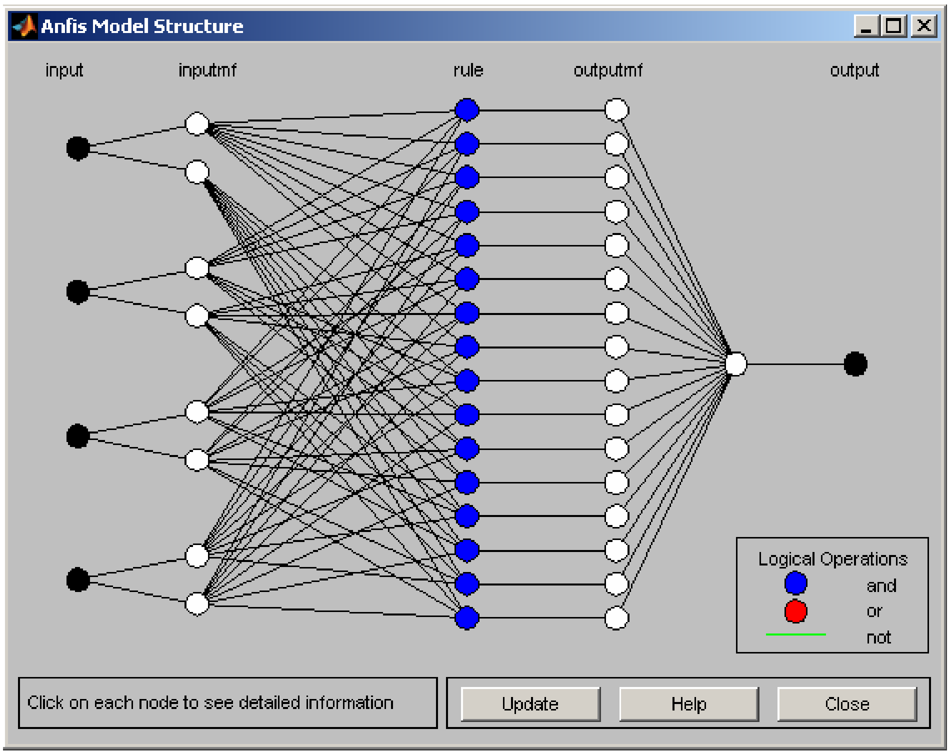


Figure 11.12 Model structure

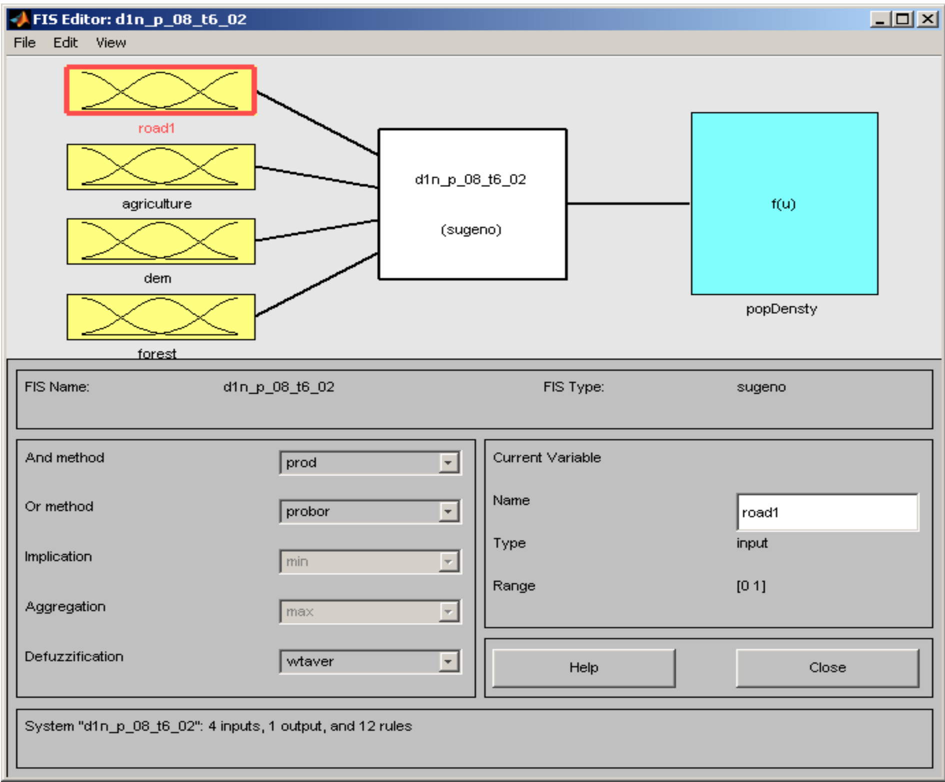


Figure 11.13 Input and output of the analysis

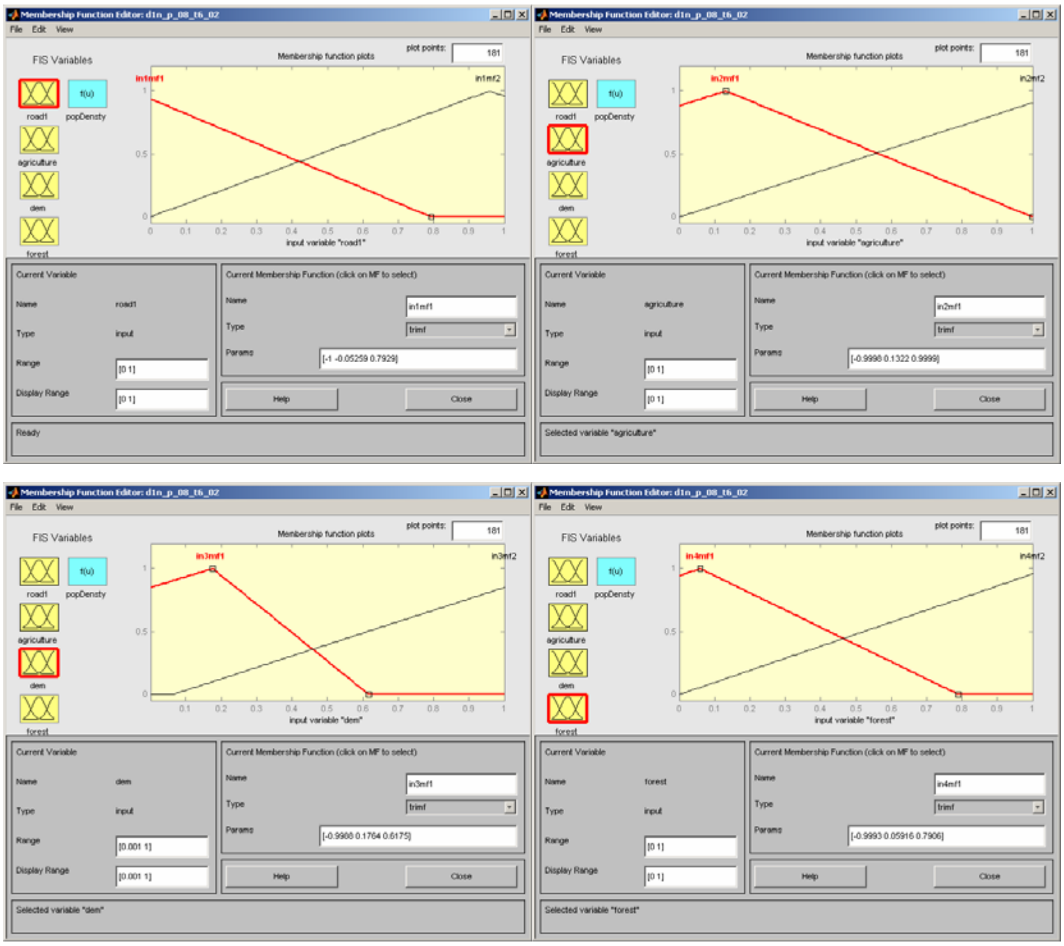
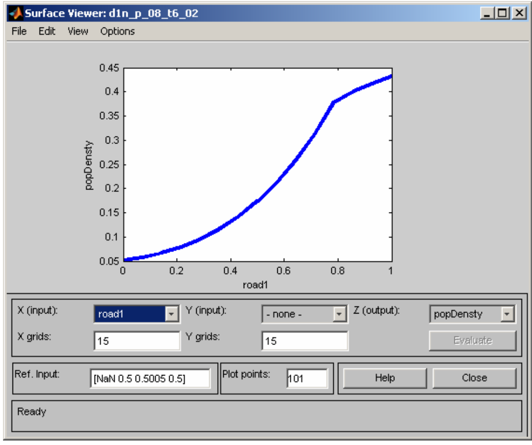


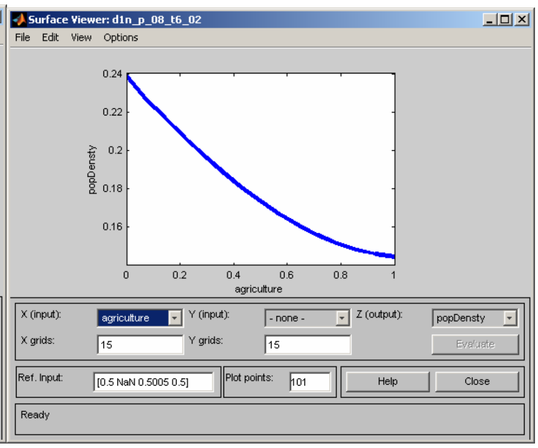
Figure 11.14 Membership functions of highway, agriculture, elevation and forest

Input and output relations solved by first order Sugeno fuzzy model. The changing laws of input vs. output were represented as a line graph to visualize the relation (Figure 11.15).

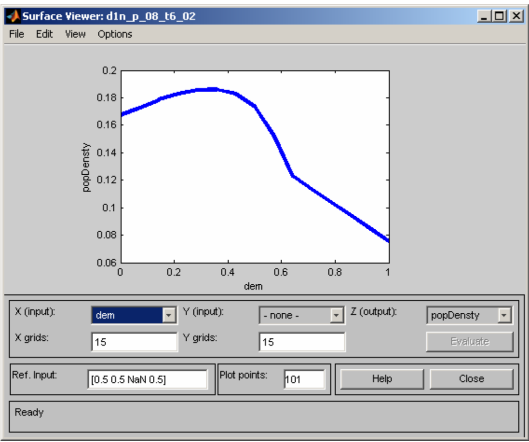
The ANFIS model, the rules were redefined as an expert view (Abonyi and Feil, 2007; Hui et al.,2004; Salgado P., 2008) and enhanced model surface graphs shown in Figure 6.5.



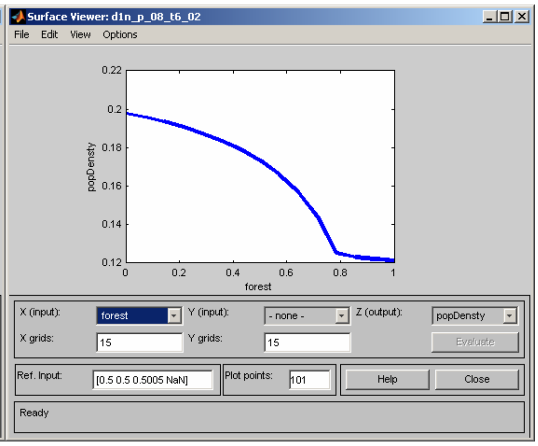
(a)



(b)



(c)



(d)

Figure 11.15 The changing law between population density vs. highway (a), agriculture (b), elevation (c) and forest (d)

Population density was assumed as 100 unit for each 500 m land grid equally. By using ANFIS changing laws, the population density was forecasted from input grid values and the new unit of population density was calculated. The thematic map of the population density estimation is given in Figure 6.6.

11.3 Sea Data Principal Component Analysis

Sea data that consist of anthropogenic stresses and endangered or internationally protected species was taken from Marine Biological Diversity assessment of Gökova Specially Protected Area Project (OCEANOS Project) report (EPASA, 2006). Diving survey data of the project was used in this sea analysis. There were 246 diving surveys in this study (Figure 4.11). Diving survey data was integrated into GIS and used as 500 m sea grids (Figure 4.15).

The data was analyzed for outlier case determination and deletion of statistically meaningless parameters; data was thereby refined for further analysis.

Species belonging to Porifera, Mollusca, Echinodermata and Arthropoda phylums, which have no or limited mobility, were selected for the PCA in the first step. Variable importance (Table 11.6 and Figure 11.16) and loadings of each parameter was examined for defining relationships.

Table 11.6 Variable importance

	Variable number	Power	Importance
SpongiaO	5	0.929	2
Scyllarus	7	0.929	2
PinnaNobilis	12	0.458	3
AxinellaP	3	0.332	4
AxinellaC	2	0.274	5
AplysinaA	1	0.253	6
Centrostephanus	13	0.106	7
Echinaster	14	0.091	8
SpongiaA	4	0.084	9
Strombuspersicus	15	0.083	10
Scyllarides	8	0.059	11
Lithophaga	11	0.056	12
Tethya	6	0.028	13
Charonia	10	0.019	14
Haliotis	9	0.018	15

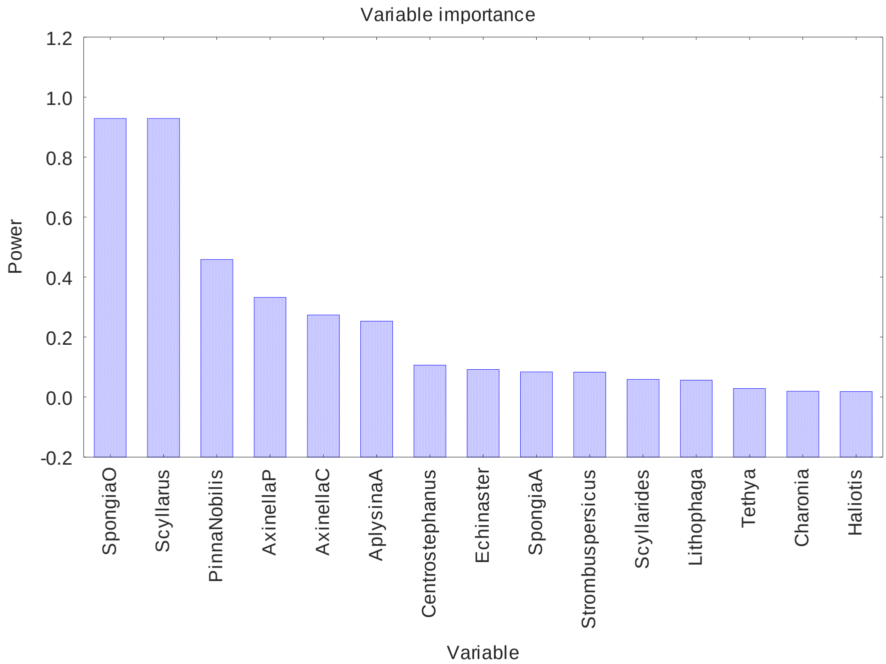


Figure 11.16 Variable importance histogram

As shown in Table 11.6 *Spongia officinalis* and *Scyllarus arctus* show similar characteristics and affect principal components in the same way (Figure 11.16 and Figure 11.17). *Pinna nobilis* having wide distribution in Gökova Bay has high importance.

It is possible to define four groups from parameters where they are substantially correlated as shown in Figure 11.17, such as:

- *Spongia officinalis* and *Scyllarus arctus*
- *Axinella cannabina* and *Axinella polypoides*
- *Spongia agaricina* and *Scyllarides latus*
- *Tethya aurantium*, *Lithophaga lithophaga* and *Haliotis tuberculata*

In the second step of data exploration, PCA was applied to anthropogenic stresses and exotic specie counts ,which also cause stress in native habitats. In this analysis, yacht tourism and fisheries sector display grouping in which one of the parameters can represent the grouped ones. (Figure 11.18 and Figure 11.19).

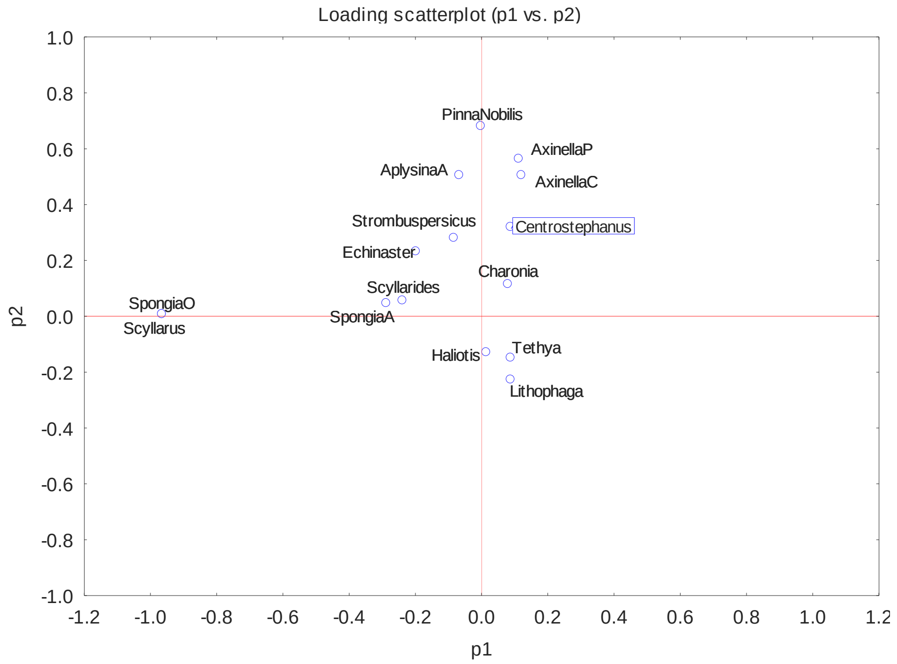


Figure 11.17 Loading Scatterplot

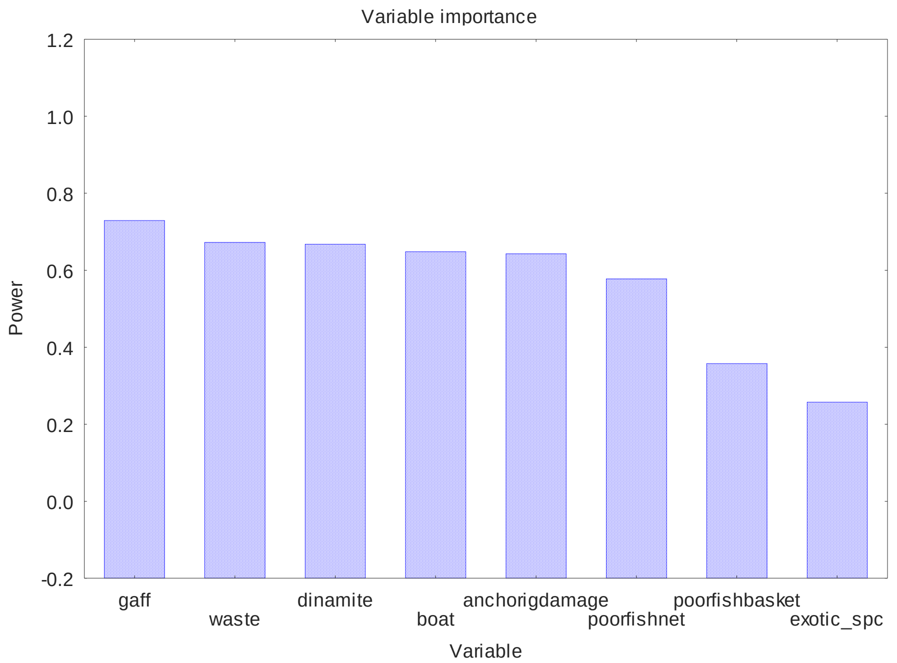


Figure 11.18 Variable importance histogram

Same analysis conducted changing exotic species count with protected species (which is the impacted by also exotic species due to competition). However the result show the same characteristic (Figure 11.20 and Figure 11.21). Only the variable importance ranking of stresses changed between these two analyses.

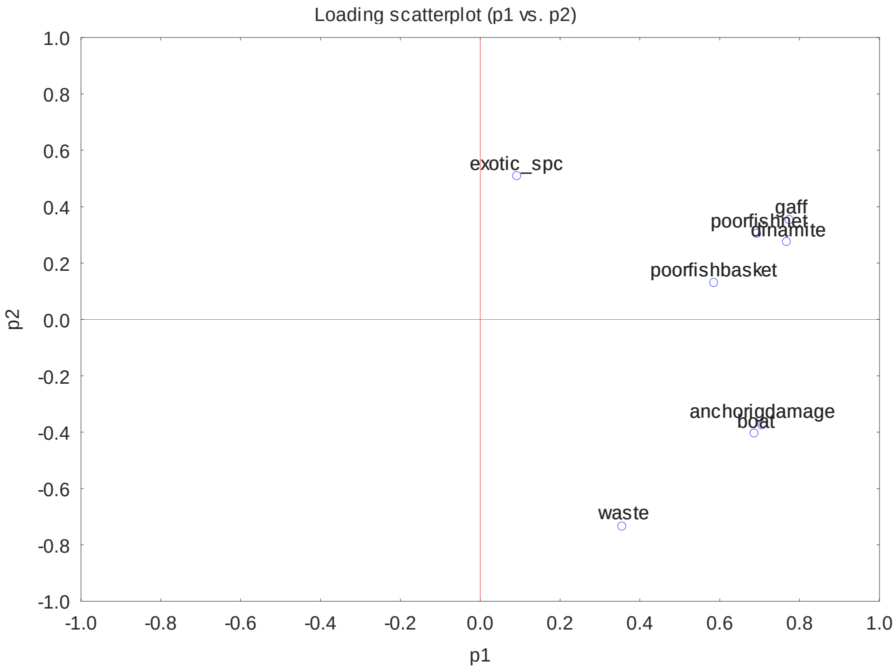


Figure 11.19 Loading Scatterplot

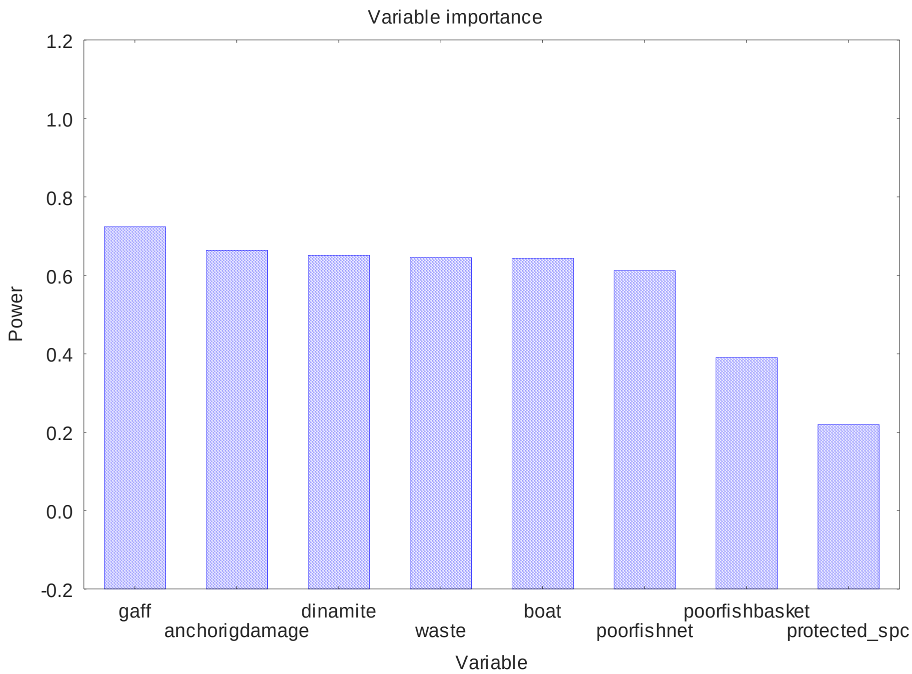


Figure 11.20 Variable importance histogram

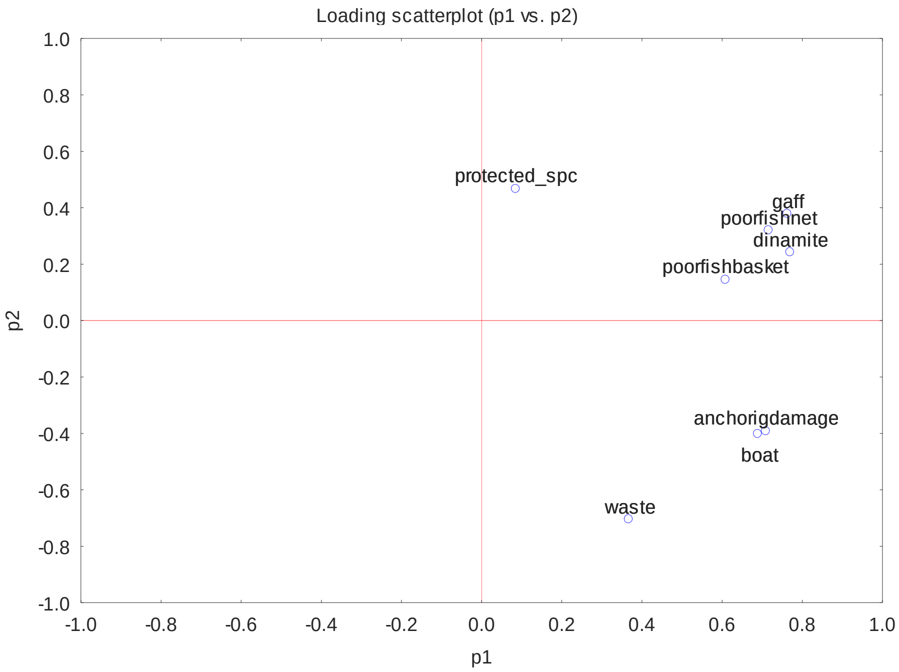


Figure 11.21 Loading Scatterplot

As a result, exotic and protected species counts were used together with anthropogenic stresses to figure out the overall relation. This analysis also expresses the similar grouping between variables belonging to tourism and fisheries stress. On the contrary, the importance of the parameters shifted

As shown in Figure 11.23, exotic species can be used instead of protected species counts in an analysis where stresses examined. The results can be explained as impact of anthropogenic stresses on species, whether native or alien, is the same and unfavorable.

In the third step, PCA was carried out with the plant biota species, which are sea grasses *Posidonia oceanica, Cymodocea nodosa, Flabellia petiolata*, and alien species, *Halophila stipulacea* and *Caulerpa racemosa* (DAISIE, 2009). Each species showed a different structure in principal components and the most important species; Posidonia oceanica was at the top of the variable importance list of the PCA model (Table 11.7).

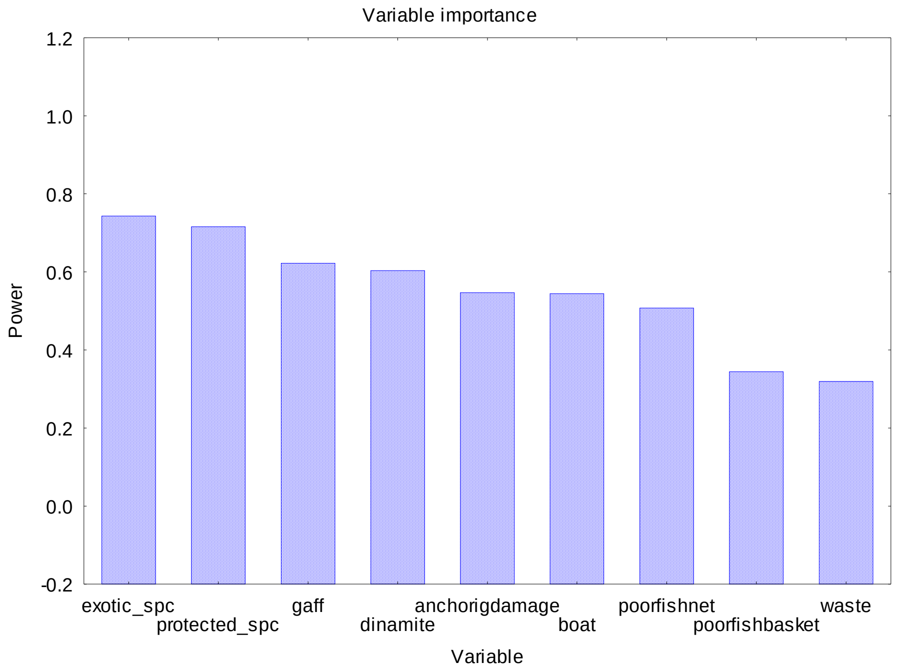


Figure 11.22 Variable importance histogram

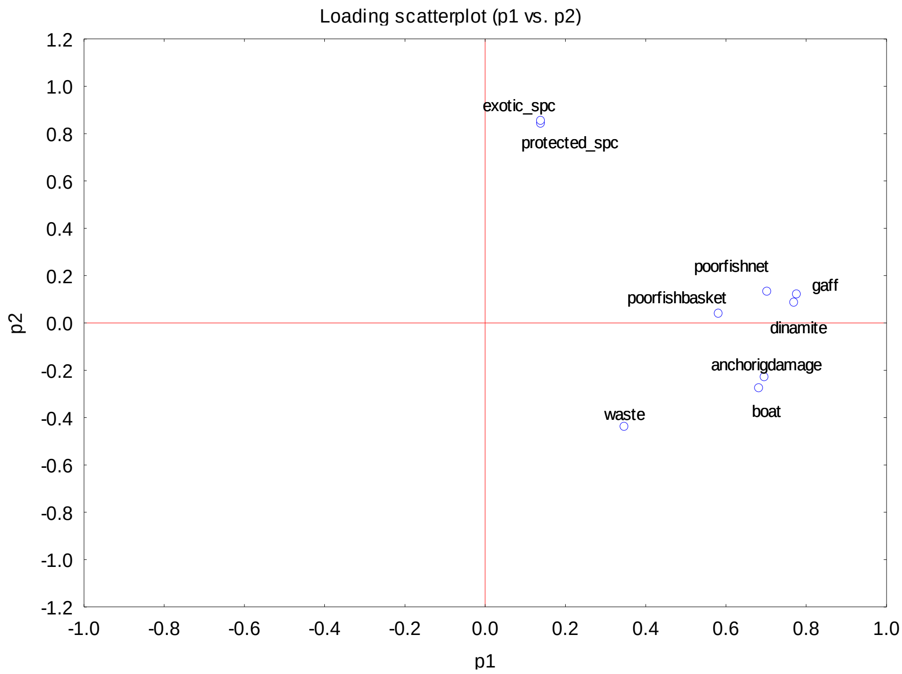


Figure 11.23 Loading Scatterplot

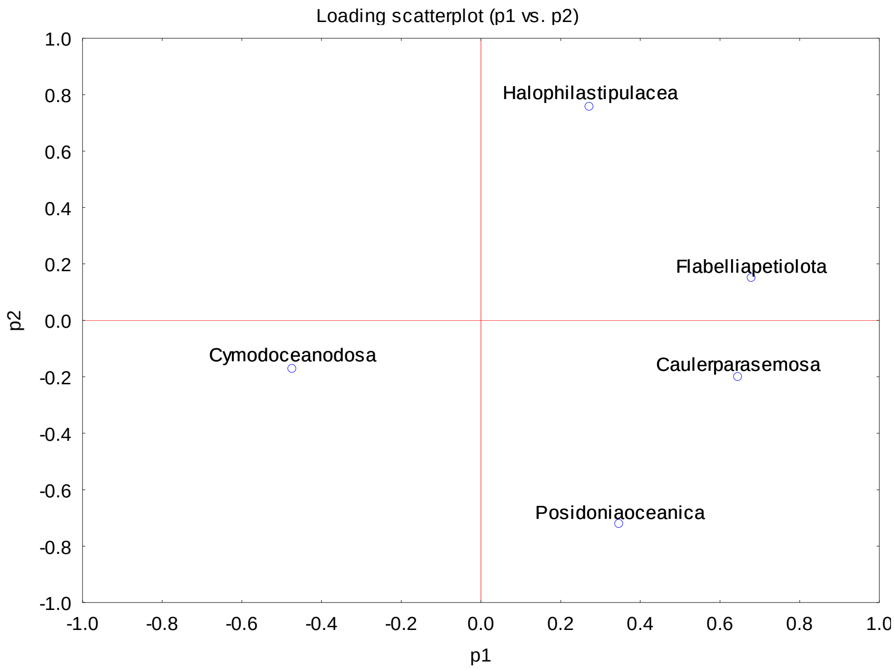


Figure 11.24 Loading Scatterplot

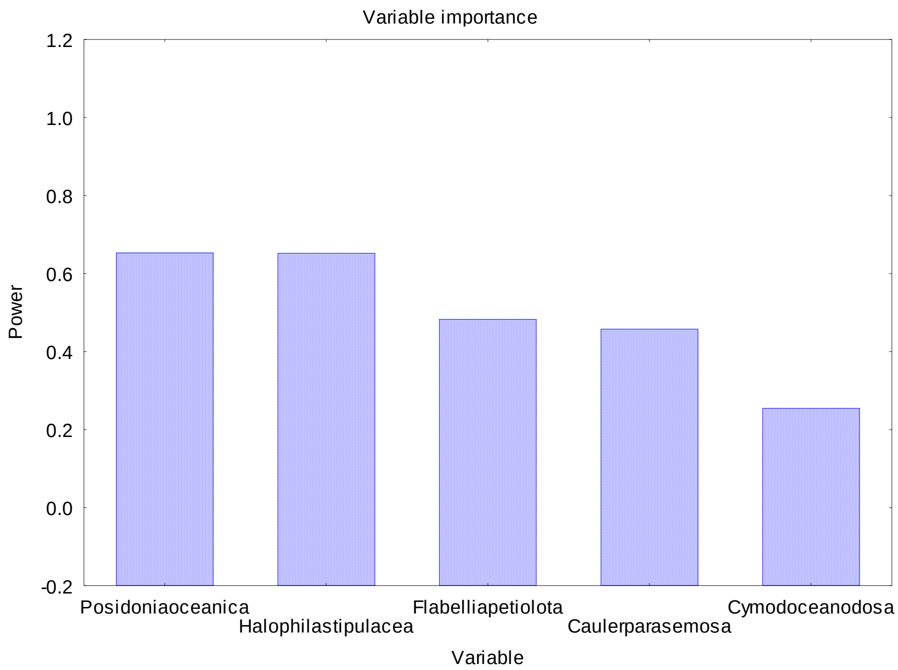


Figure 11.25 Variable importance histogram

Table 11.7 Variable importance

Variables	Power	Importance
Posidoniaoceanica	0.652	1
Halophilastipulacea	0.651	2
Flabelliapetiolota	0.482	3
Caulerparasemosa	0.457	4
Cymodoceanodosa	0.254	5

In order to figure out the whole relation between marine biodiversity data and anthropogenic stresses, PCA was applied to all the former parameters. Results show that most of the anthropogenic stresses took place at the top of the importance list (Table 11.8 and Figure 11.26).

Table 11.8 Variable importance

Variable	Power	Importance
protected_spc	0.675	1
exotic_spc	0.598	2
gaff	0.587	3
dynamite	0.539	4
poorfishnet	0.500	5
anchordamage	0.468	6
boat	0.467	7
PinnaNobilis	0.453	8
specie_count	0.422	9
poorfishbasket	0.361	10
Strombuspersicus	0.230	11
waste	0.203	12
EpinephelusM	0.200	13
EphinephelusCostae	0.165	14
AxinellaC	0.157	15
Caulerparasemosa	0.128	16
AplysinaA	0.117	17
Posidoniaoceanica	0.105	18
Halophilastipulacea	0.077	19
Tethya	0.071	20
AxinellaP	0.069	21
Echinaster	0.062	22
Paracentrotus	0.060	23
SpongiaO	0.048	25
Scyllarus	0.048	25
Centrostephanus	0.048	26
Lithophaga	0.042	27
Charonia	0.038	28
Haliotis	0.031	29
SpongiaA	0.022	30
Scyllarides	0.017	31
Flabelliapetiolota	0.009	32
Cymodoceanodosa	0.007	33

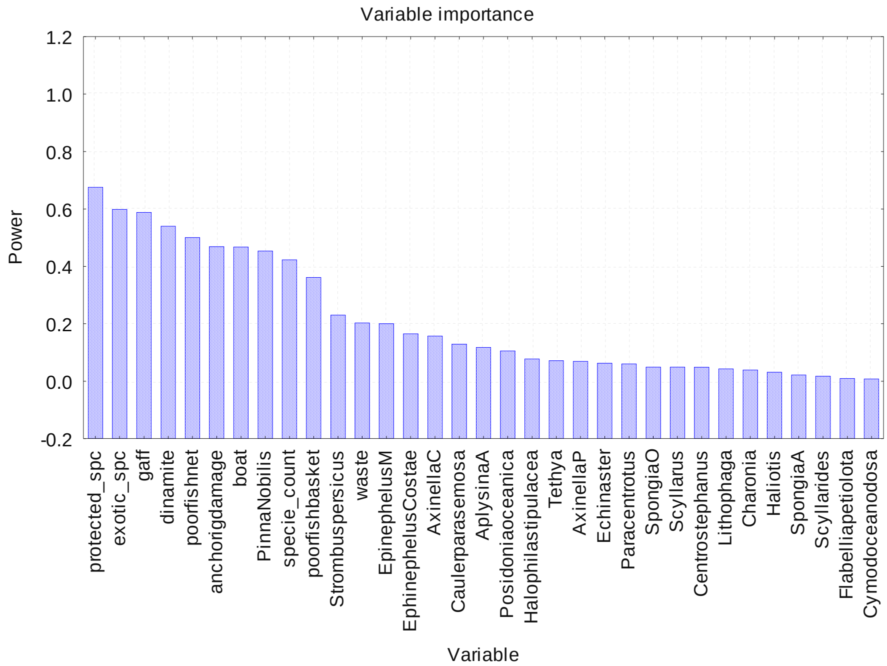


Figure 11.26 Variable importance histogram

In Figure 11.27, the loading scatter plot of all data, shows the correlation between parameters. As shown here, the anthropogenic stresses are grouped together. The parameter waste (solid wastes detected on the seabed) behaves in a different manner as an anthropogenic effect. Moreover, two important seagrass meadows species, *Posidonia oceanica* and *Cymodocea nodosa*, which are protected habitats for the Mediterranean, behave oddly among other parameters. Furthermore, the grouping of exotic and protected species with *Pinna nobilis* species can be seen on the bottom-right. Hence, as a result of these PCA, one of the grouped parameters, in which the data is used as an input, can substantially be used for further analysis .

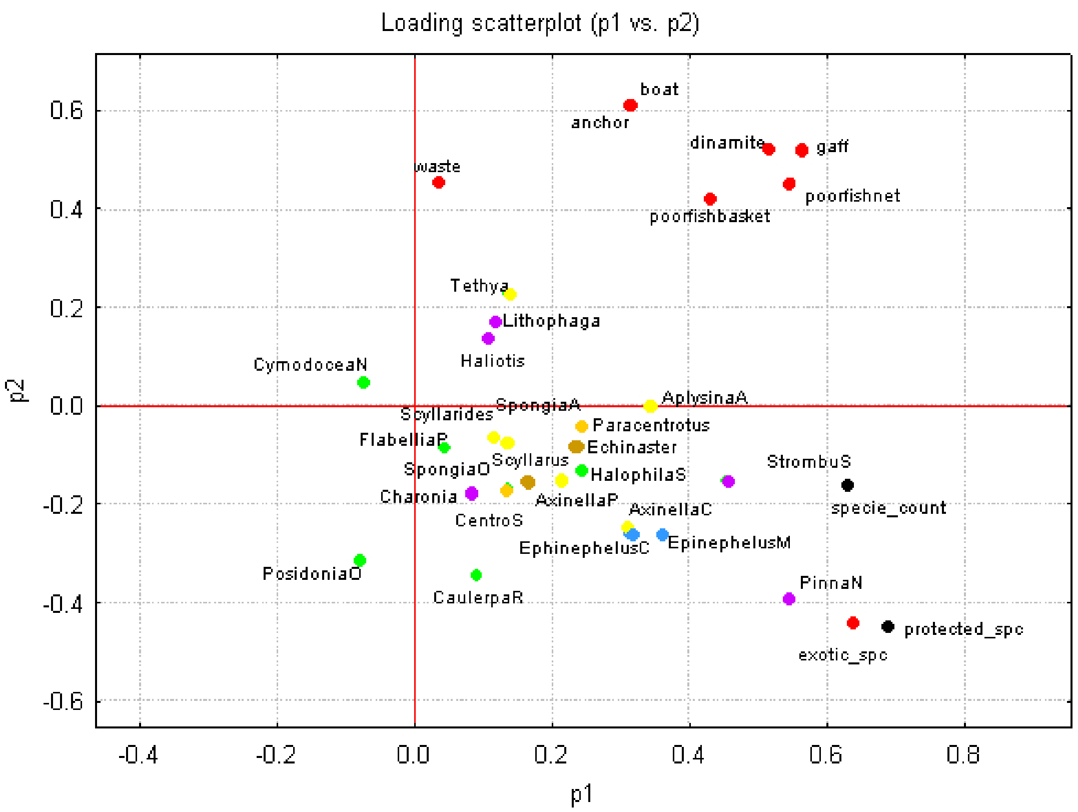


Figure 11.27 Loading Scatterplot marine species PCA

11.4 Sea Data ANFIS Model Development

The variables of sea 500 m grid data consist of layers poorfishnet, poorfishbasket, dynamite, gaff, anchordamage, waste, boat, exotic species and protected species counts. These layers are used for ANFIS model after normalization in order to overcome the problems arising from range differences.

For developing a reliable ANFIS model, input and output variable selection is very important (Jang, 1996) and model outputs and training errors are all sensitive to both model and case input changes. During case, input and output selection, the PCA analyses are used as a guide. Combination of cases and inputs tried many times to decrease the error while setting up ANFIS model. A sample data is given in Table 11.9 for sea data.

Table 11.9 Sample of sea data for ANFIS training (153x6)

poorfishnet	poorfishbasket	dynamite	anchordamage	boat	protected_spc
0.00000	0.00000	0.00000	0.00000	0.00000	0.13043
0.10000	0.00000	0.00000	0.00000	0.00000	0.39130
0.00000	0.10000	0.00000	0.00000	0.00000	0.39130
0.10000	1.00000	0.00000	0.00000	0.00000	0.30435
0.00000	0.00000	0.00000	0.00000	0.00000	0.13043
0.00000	0.00000	0.00000	0.50000	0.05000	0.60870
0.00000	0.00000	0.00000	0.00000	0.00000	0.30435
0.10000	0.00000	0.00000	0.00000	0.10000	0.47826
0.10000	1.00000	0.00000	0.00000	0.10000	0.39130
0.05000	0.00000	0.00000	0.00000	0.00000	0.60870
0.00000	0.10000	0.00000	0.10000	0.00000	0.30435
1.00000	1.00000	1.00000	1.00000	1.00000	0.13043
0.00000	0.00000	0.00000	0.00000	0.00000	0.04348
0.00000	0.00000	0.00000	0.00000	0.00000	0.30435
1.00000	1.00000	1.00000	0.10000	0.00000	0.47826
0.00000	0.00000	0.00000	0.10000	0.00000	0.30435
0.10000	0.00000	0.00000	0.00000	0.00000	0.30435
0.00000	0.00000	0.00000	0.05000	0.00000	0.60870
0.00000	0.00000	0.00000	0.00000	0.00000	0.13043
0.00000	0.00000	0.00000	0.00000	0.00000	0.30435
. . .	. . .	. . .	. . .	. . .	. . .
0.00000	0.00000	0.00000	0.00000	0.00000	0.13043

During model development trials, some of the cases cause abnormalities in model outputs (Jang, 1996). These meaningless cases and outliers are determined by help of the statistical analysis. The deleted rows are selected from the input data (N) to obtain new ANFIS sets (Q). (Table 11.10).

On ANFIS model, protected species counts are forecasted. The change of the training error can be shown in Figure 11.28. While training, optimum iteration number was selected for each run to reach a stationary error quantity.

Table 11.10 Trained anthropogenic effects on protected species models for different input combinations

	Inputs						Output
N series			net	dynamite	waste	boat	protected_spc
		net	basket	dynamite	gaff	anchor	protected_spc
		dynamite	gaff	anchor	waste	boat	protected_spc
		net	basket	dynamite	gaff	exotic	protected_spc
		net	dynamite	anchor	boat	exotic	protected_spc
			net	dynamite	anchor	boat	protected_spc
		net	basket	dynamite	gaff	anchor	protected_spc
		dynamite	gaff	anchor	waste	boat	protected_spc
		net	basket	dynamite	gaff	exotic	protected_spc
		net	dynamite	anchor	boat	exotic	protected_spc
			net	dynamite	anchor	boat	protected_spc
Q series			net	dynamite	waste	boat	protected_spc
		net	basket	dynamite	gaff	anchor	protected_spc
		dynamite	gaff	anchor	waste	boat	protected_spc
		net	basket	dynamite	gaff	exotic	protected_spc
		net	dynamite	anchor	boat	exotic	protected_spc
			net	dynamite	anchor	boat	protected_spc
	net	basket	dynamite	anchor	waste	boat	protected_spc
		net	basket	dynamite	anchor	boat	protected_spc*
* Selected model							

For model development six to four input combinations out of 8 variables are selected and trained on ANFIS considering the computational processor and time requirement. Protected species counts were selected as an output to develop a model. The model gives the response of species to the anthropogenic stresses poorfishnet, poorfishbasket, dynamite, gaff, anchordamage, waste, boat and exotic species. The model development trials formed of four, five and six input combinations are given in Table 11.10.

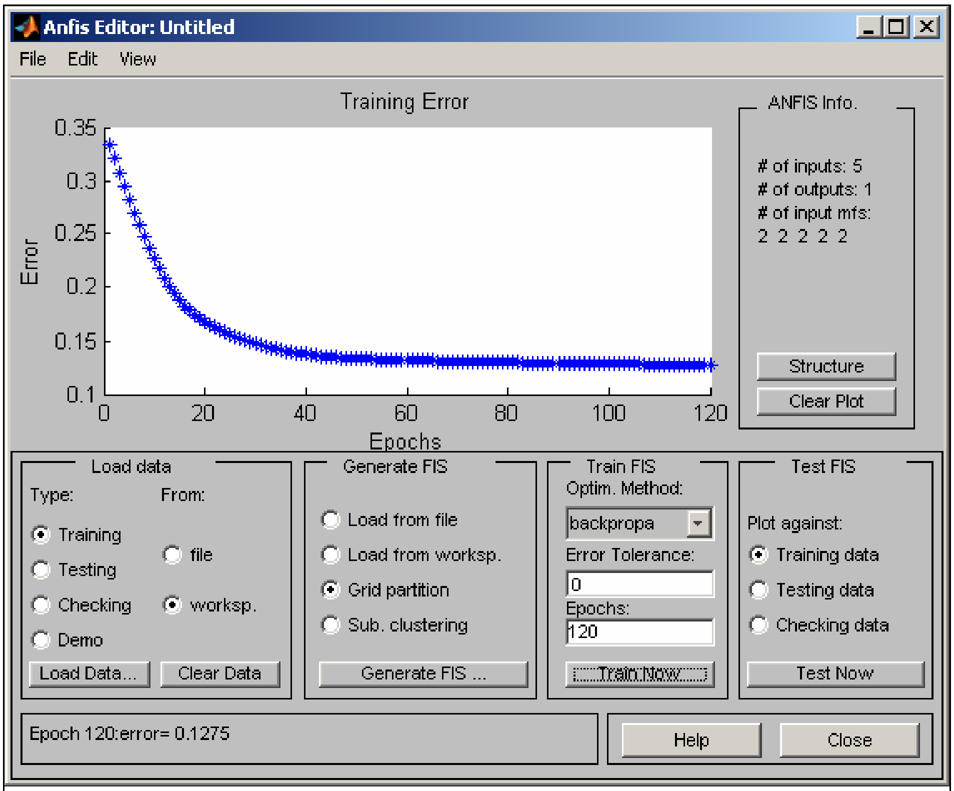


Figure 11.28 Training error of the data

Triangular membership function was selected for this ANFIS model run. Two linguistic term was used for membership functions. ANFIS model structure and membership functions were shown in Figure 11.29 and Figure 11.31.

The rules are formed by first order Sugeno fuzzy model. Model interface is given in Figure 11.30. Membership functions of inputs are shown in Figure 11.31 as sample graphical views are given in Figure 11.32, Figure 6.7 and Figure 6.8.

Input and output relations solved by first order Sugeno fuzzy model. The changing laws of input vs. output were represented as a line graph to visualize the relation (Figure 11.32).

The ANFIS model, the rules were redefined as an expert view (Abonyi and Feil, 2007; Hui et al.,2004; Salgado P., 2008) and enhanced model surface graphs shown on Figure 6.7 and Figure 6.8.

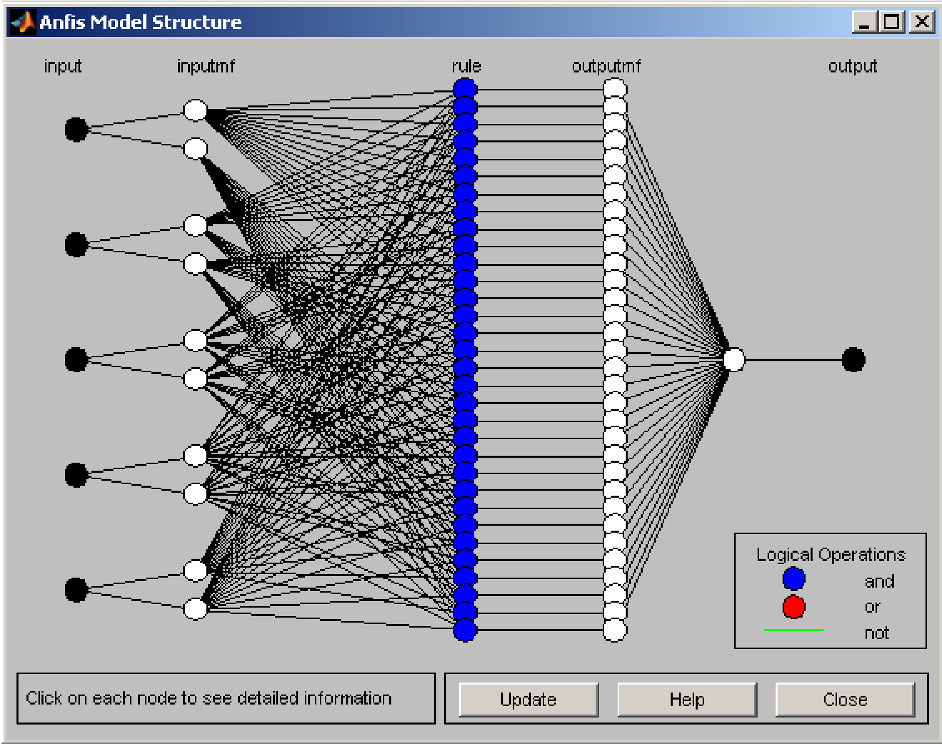


Figure 11.29 Model structure

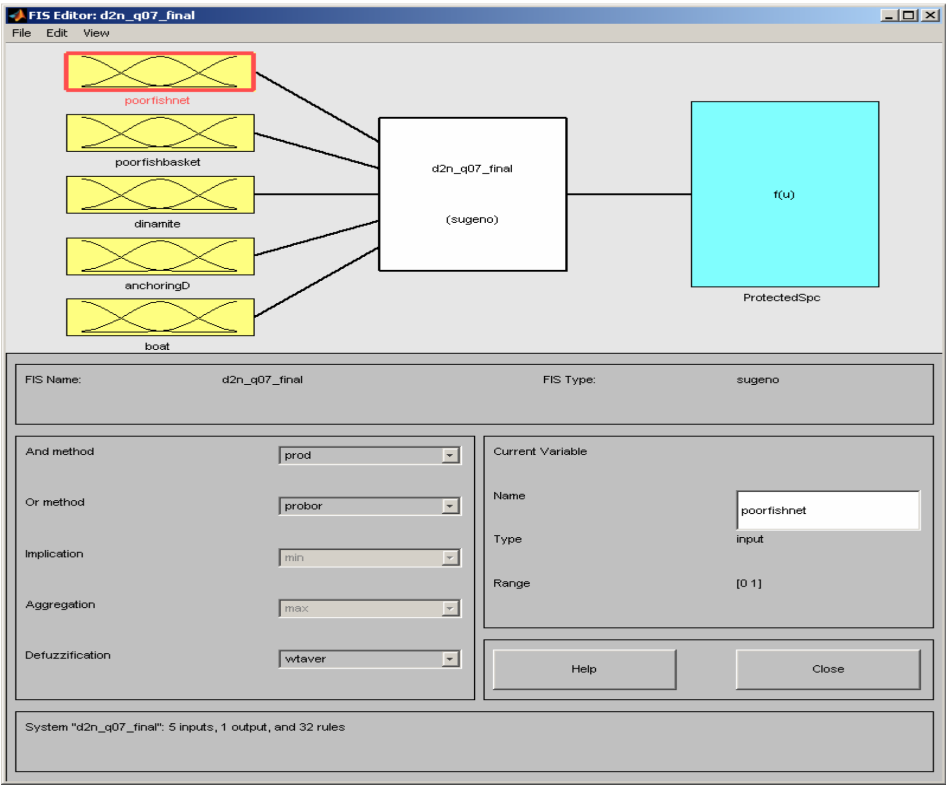
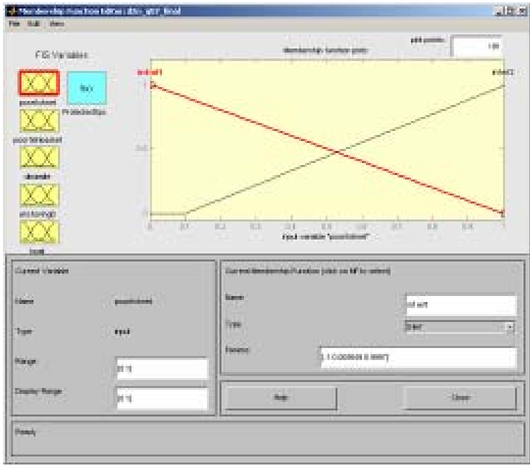
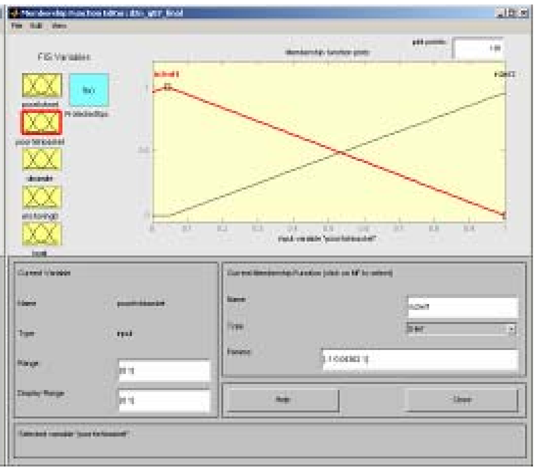
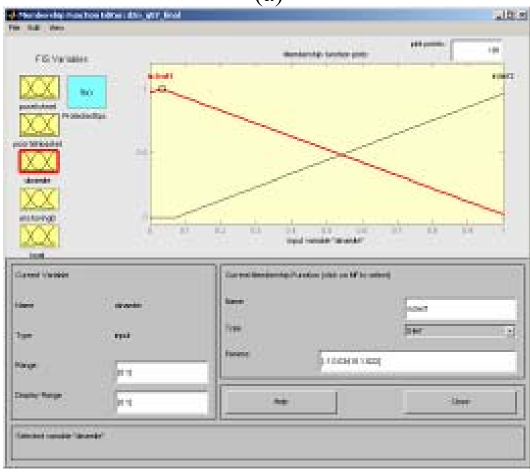
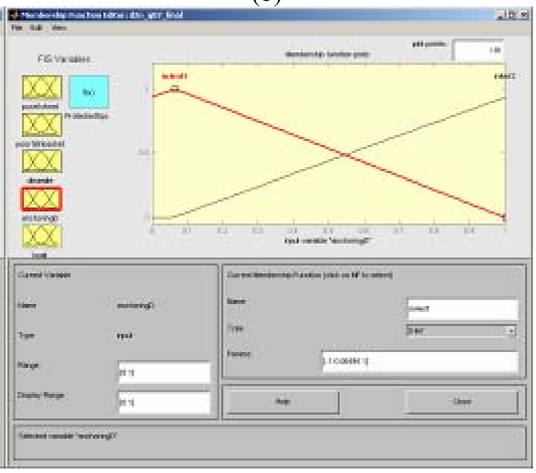


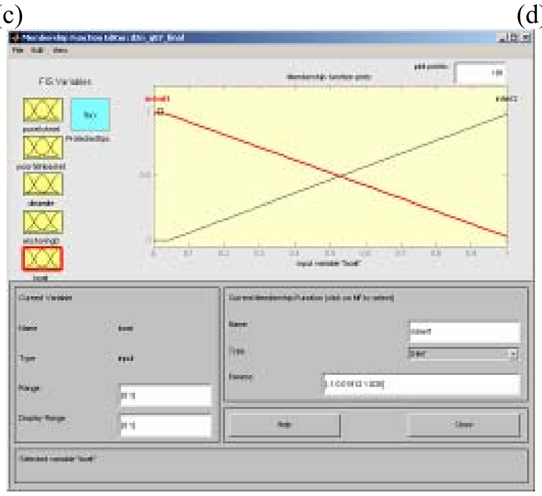
Figure 11.30 Input and output of the analysis

(a) (b)

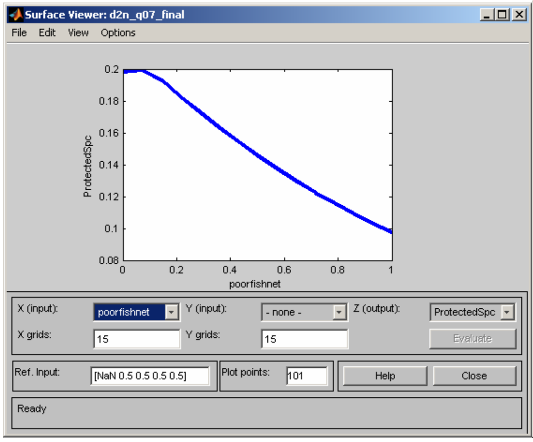



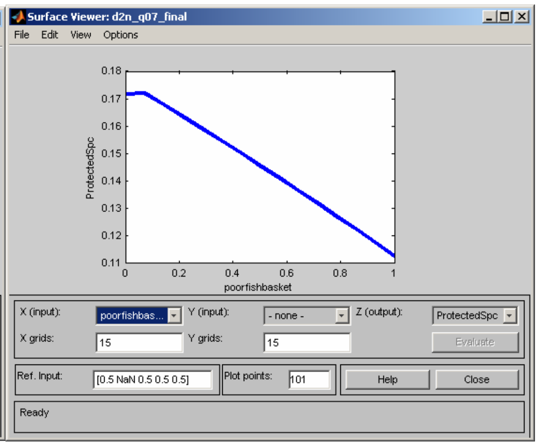
(c) (d)



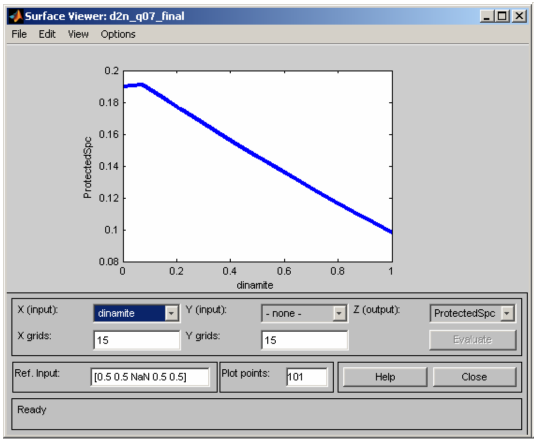
(e)

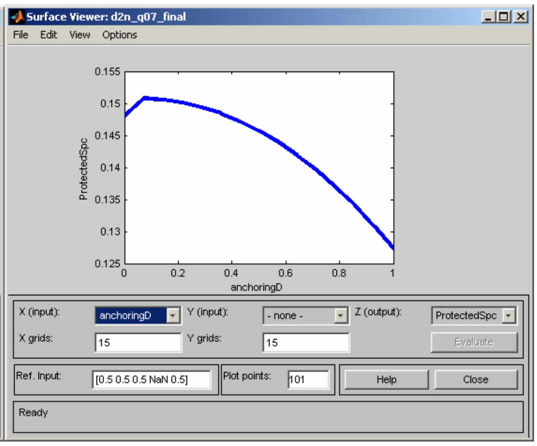
Figure 11.31 Membership functions of poorfishnet (a), poorfishbasket (b), dynamite (c), anchoring (d) and boat (e)



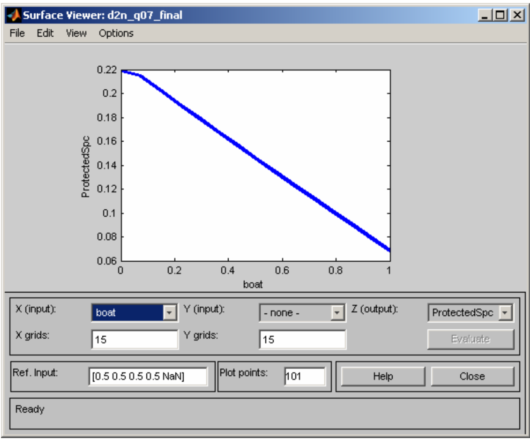


(a) (b)





(c) (d)



(e)

Figure 11.32 The changing law between protected species vs. poorfishnet (a), poorfishbasket (b), dynamite (c), anchoring (d) and boat (e)

Protected species counts was assumed as 100 for each 500 m sea grid equally. By using ANFIS changing laws, the decrease was forecasted from input grid values and the new count of protected species was calculated. The thematic map of the degraded biodiversity estimation in terms of protected species is given in Figure 6.9.

APPENDIX C
DATA LIST

Table 12.1 Data used in land analysis obtained or calculated from layers

Land Analysis	Source Layer	Source Data	Explanation
house	Settlements	GCM	Building counts in the grid
pier	Piers	GCM	Pier counts in the grid
river	River	GCM & DGF	River segment in the grid
river_all_eqv	All river layers	GCM & DGF	Sum of river and equivalent intermittent stream length per grid
river_intrmtd	Intermittent Streams	GCM & DGF	Intermittent stream length in the grid
river_intrmtd_eqv	Intermittent Streams	GCM & DGF	Equivalent intermittent stream length in the grid
road all	All road layers	GCM	Sum of length of all road types in the grid
road all (area)	All road layers	GCM	Sum of area of all road types in the grid
road1_hghw	Highways (joined)	GCM	Highways road legth in the grid
road1_hghw(area)	Highways (joined)	GCM	Highways road area in the grid
road2_unpr	Roads Unimproved	GCM	Roads Unimproved legth in the grid
road2_unpr(area)	Roads Unimproved	GCM	Roads Unimproved area in the grid
road3_trail	Roads Trail	GCM & DGF	Roads Trail legth in the grid
road3_trail(area)	Roads Trail	GCM & DGF	Roads Trail area in the grid
waterresrc	Waterresources	GCM	Waterresources count in the grid
wetland	Swamp & Rushes	GCM	Wetland area in the grid
pop_density	Villages	TurkStat & GCM	Population density in the grid
population	Villages	TurkStat & GCM	Population in the grid
agri	Forest Border	DGF	Agricultural area in the grid
f_deg_fraction	Forest Border	DGF	Degradation fraction of the forest in the grid
forest	Forest Border	DGF	Forest area in the grid
forest_burnt	Forest Border	DGF	Burnt forest area in the grid
forest_deg	Forest Border	DGF	Degraded forest area in the grid
Slope_Max_1	Land DEM	GCM	Maximum slope in the grid
Slope_Mean_1	Land DEM	GCM	Mean slope in the grid
Slope_Median_1	Land DEM	GCM	Median slope in the grid
Slope_Min_1	Land DEM	GCM	Minimum slope in the grid
DEM_Max_1	Land DEM	GCM	Maximum elevation of the grid
DEM_Mean_1	Land DEM	GCM	Mean elevation of the grid
DEM_Median_1	Land DEM	GCM	Median elevation of the grid
DEM_Min_1	Land DEM	GCM	Minimum elevation of the grid

Table 12.1 Data used in land analysis obtained or calculated from layers (cont.)

Land Analysis	Source Layer	Source Data	Explanation
aspect_ENE	Land DEM	GCM	Grid aspect
aspect_ESE	Land DEM	GCM	Grid aspect
aspect_NNE	Land DEM	GCM	Grid aspect
aspect_NNW	Land DEM	GCM	Grid aspect
aspect_SSE	Land DEM	GCM	Grid aspect
aspect_SSW	Land DEM	GCM	Grid aspect
aspect_WNW	Land DEM	GCM	Grid aspect
aspect_WSW	Land DEM	GCM	Grid aspect

Table 12.2 Data used in sea analysis obtained or calculated from layers

Sea Analysis	Source Layer	Source Data	Explanation
Min_depth	Sea DEM	SHOD Data	Min depth in the grid
Max_depth	Sea DEM	SHOD Data	Max depth in the grid
Mean_depth	Sea DEM	SHOD Data	Mean depth in the grid
Median_depth	Sea DEM	SHOD Data	Median depth in the grid
CoeffOfVar_depth	Sea DEM	SHOD Data	Coefficient of Varriation of depth in the grid
StdDev_depth	Sea DEM	SHOD Data	Standart deviation of depth in the grid
specie_count	Biodiversity Data	OCEANOS	All species counts
Cystoseira	Biodiversity Data	OCEANOS	Cystoseira amentacea var. Stricta
Lithophyllum	Biodiversity Data	OCEANOS	Lithophyllum byssoides
AplysinaA	Biodiversity Data	OCEANOS	Aplysina aerophoba
AxinellaC	Biodiversity Data	OCEANOS	Axinella cannabia
AxinellaP	Biodiversity Data	OCEANOS	Axinella polypoides
SpongiaA	Biodiversity Data	OCEANOS	Spongia agaricina
SpongiaO	Biodiversity Data	OCEANOS	Spongia officinalis
Tethya	Biodiversity Data	OCEANOS	Tethya aurantium
Palinurus	Biodiversity Data	OCEANOS	Palinurus elephas
Scyllarus	Biodiversity Data	OCEANOS	Scyllarus arctus
Scyllarides	Biodiversity Data	OCEANOS	Scyllarides latus
Haliotis	Biodiversity Data	OCEANOS	Haliotis tuberculata lamellosa
Charonia	Biodiversity Data	OCEANOS	Charonia variegata
Luria	Biodiversity Data	OCEANOS	Luria lurida
Lamellaria	Biodiversity Data	OCEANOS	Lamellaria latens
Tonna	Biodiversity Data	OCEANOS	Tonna galea
Lithophaga	Biodiversity Data	OCEANOS	Lithophaga lithophaga
PinnaNobilis	Biodiversity Data	OCEANOS	Pinna nobilis
HorneraCf	Biodiversity Data	OCEANOS	Hornera cf. lichenoides
Centrostephanus	Biodiversity Data	OCEANOS	Centrostephanus longispinus
Paracentrotus	Biodiversity Data	OCEANOS	Paracentrotus lividus
Echinaster	Biodiversity Data	OCEANOS	Echinaster sepositus sepositus
EpinephelusM	Biodiversity Data	OCEANOS	Epinephelus marginatus

Table 12.2 Data used in sea analysis obtained or calculated from layers (cont.)

Sea Analysis	**Source Layer**	**Source Data**	**Explanation**
Sciaena	Biodiversity Data	OCEANOS	Sciaena umbra
Pagrus	Biodiversity Data	OCEANOS	Pagrus pagrus
Caretta	Biodiversity Data	OCEANOS	Caretta caretta
Chelonia	Biodiversity Data	OCEANOS	Chelonia mydas
Strombuspersicus	Biodiversity Data	OCEANOS	Strombus persicus
protected_spc	Biodiversity Data	OCEANOS	Protected species counts
exotic_spc	Biodiversity Data	OCEANOS	Exotic species counts
Posidoniaoceanica	Biodiversity Data	OCEANOS	Posidonia oceanica
Cymodoceanodosa	Biodiversity Data	OCEANOS	Cymodocea nodosa
Caulerparasemosa	Biodiversity Data	OCEANOS	Caulerpa racemosa
waste	Diving Places	OCEANOS	Solid waste
anchorigdamage	Diving Places	OCEANOS	Anchorig damage
boat	Diving Places	OCEANOS	Boat counts
Flabelliapetiolota	Biodiversity Data	OCEANOS	Flabellia petiolota
Halophilastipulacea	Biodiversity Data	OCEANOS	Halophila stipulacea
Aplysinaaerophoba	Biodiversity Data	OCEANOS	Aplysina aerophoba
EphinephelusCostae	Biodiversity Data	OCEANOS	Ephinephelus costae
poorfishnet	Diving Places	OCEANOS	Poor fishnet
gaff	Diving Places	OCEANOS	Gaff usage
dinamite	Diving Places	OCEANOS	Dinamate usage
poorfishbasket	Diving Places	OCEANOS	Poor fishbasket

LIST OF ABBREVIATIONS

ANFIS	Adaptive Neuro-Fuzzy Inference System
ANN	Artificial Neural Networks
CORINE	Coordinated Information on the Environment
DEM	Digital Elevation Model
DGF	General Directorate of Forestry
DSS	Decision Support System
EPASA	Environmental Protection Agency for Special Areas
GCM	General Command of Mapping
GIS	Geographic Information System
GOOS	Global Ocean Observing System
ICM	Integrated Coastal Management
ICZM	Integrated Coastal Zone Management
INA-GOOS	Indonesia Global Ocean Observing System
IUCN	International Union for Conservation of Nature
NGOs	Non Governmental Organizations
NIPALS	Nonlinear Iterative Partial Least Squares
PCA	Principal Component Analysis
SEPA	Special Environmental Protection Area
SHOD	Office Navigation, Hydrography and Oceanography
TSMS	Turkish State of Meteorological Service
TurkStat	Turkish Statistical Institute
UN	United Nations
UNCED	United Nations Conference on Environment and Development
WCC	World Coast Conference
WWF	World Wildlife Fund