İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

MONITORING AND ANALYSIS OF LANDUSE CHANGES IN HISTORICAL PERIODS FOR THE CITY OF ISTANBUL BY MEANS OF AERIAL PHOTOGRAPHY AND SATELLITE IMAGERY

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İSTANBUL KENTİ'NDE ARAZİ KULLANIMININ HAVA FOTOĞRAFLARI VE UYDU GÖRÜNTÜLERİ YARDIMIYLA TARİHSEL DÖNEMLERDE İNCELENMESİ VE ANALİZİ

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FOREWORD

Detection of landuse has always been one of the most important topics of geoinformatic people all around the world. Some manual, semi-automatic and full-automaitc methods are developed for fitting this aim. All of them has its own target and accuracy. This study gives an example for detection and analysis for the landuse.

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ABBREVATIONS

DEM:	Digital Elevation Model
GPS:	Global Positioning System
ISO:	The International Organisation for Standardization
GIS:	Geographical Information System
GCP:	Ground Control Point
CSE:	Circular Standard Error
CPE:	Circular Probable Error
MSPE:	Mean Square Positional Error
CMAS:	Circular Map Accuracy Standard
CNCE:	Circular Near Certainty Error
RGB:	Red, Green, Blue
NIR:	Near Infrared
WIR:	Wide Infrared
LPOA:	Land principally occupied by agriculture
SANV:	Significant areas of natural Vegetatiton

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İSTANBUL KENTİ'NDE ARAZİ KULLANIMININ HAVA FOTOĞRAFLARI VE UYDU GÖRÜNTÜLERİ YARDIMIYLA TARİHSEL DÖNEMLERDE İNCELENMESİ VE ANALİZİ

ÖZET

İnsanoğlu için nerede yaşadığının belirlenmesi önemli konulardan birisini teşkil etmiştir. Büyük ölçekli olarak dünyanın konumu, şekli ve boyutları ile ilgili birçok araştırmalar yapılmıştır. Bunlara ek olarak, insanoğlu yaşadığı yakın çevre ile ilgili olarak daha fazla bilgi edinmek istemiştir. Bu istek sadece günün mevcut koşulları ile ilgili değil, o bölgenin tarihini de kapsamaktadır.

Yerbilimleri ile ilgili yeni teknolojilerin gelişiminin ardından, bu bilgi eksikliği giderilebilmektedir. Hava fotogrametrisi, uzaktan algılama, GPS gibi teknolojiler kullanılarak yeni yaklaşımlar geliştirilmiştir.

İstanbul gibi büyük metropoller için şehirleşmenin kontrol edilmesi, planlanması ve analizi büyük bir sorun oluşturmaktadır. Şehirleşme ile ilgili bu çalışmalar, yerel otoritelerin görevleri arasında yer almakta olup, bilim adamlarının bu çalışmalara hizmet edecek yeni teknoloji ve metotlar geliştirmesi gerekmektedir.

Bu çalışmada, İstanbul Kentinin 4 farklı döneme ait arazi kullanımına ilişkin bir bilgi sistemi oluşturulmuştur. Bu dönemler 2000, 1987/88, 1965 ve 1940'lar olarak belirlenmiştir. Bu belirlemede özellikle 1965 ve 1940'lar için hava fotoğraflarının elde edilebilirliği belirleyici olmuştur. Dönemler arasındaki değişim incelenmiş olup, geometrik ve tematik sonuçlar doğruluklarıyla ortaya konmuştur. Temel veri olarak IKONOS, IRS 1C/D, KVR ve KFA-1000 uydu görüntülerinin yanısıra hava fotoğrafları ve topoğrafik haritalar kullanılmıştır. Ek veriler ise şehir planları, sayısal arazi modeli, ortofotolar, jeoloji haritası ve şehir ulaşım planlarından oluşmaktadır. Tüm veriler 30° dilim orta meridyeni ve 3° dilim genişliği ile tanımlı UTM sisteminde referanslandırılmıştır. Her bir dönem için detaylar çizgi ve alan tabakaları olarak sayısallaştırılmış ve coğrafi bilgi sistemine aktarılmıştır. Elde edilen sonuçların kalite kontrolu yapılmış olup, sonuçların ölçeğe bağlı olarak yeterli doğruluğa sahip oldukları saptanmıştır.

MONITORING AND ANALYSIS OF LANDUSE CHANGES IN HISTORICAL PERIODS FOR THE CITY OF ISTANBUL BY MEANS OF AERIAL PHOTOGRAPHY AND SATELLITE IMAGERY

SUMMARY

It is always one of the important topics for the human being, where he lives. In a big scale, research about our planet, it's location, it's shape and size. Furthermore, human wants always more information about its environment, i.e. to learn more about the land where it lives. This request was not only about the current conditions, but also about historical conditions of the environment too.

After developing new technologies about geosciences, this lack of information can be fulfilled. Using these technologies such as aerial photogrammetry, remote sensing and GPS, new approaches are generated.

For big cities like Istanbul, it is a big problem to control, plan and analyze the urbanization. All these actions urbanization is the job for local authorities, but scientists have to develop new methods and techniques to serve these actions.

In this study, an information system was established on landuse in 4 different time zones for the city of İstanbul. These time zones were selected as the years 2000, 1987/88, 1965 and 1940'ies. By this selection, especially for 1965 and 1940'ies, the reachability of aerial imagery was the most important parameter. The landuse change has been detected between the time zones with their both geometric and thematic accuracies. As basic data aerial imagery and topographical maps have also been used as well as satellite imagery from IKONOS, IRS 1C/D, KVR and KFA-1000. As an additional data set, city plans, digital elevation models, orthophotos, geological maps and city transportation plan were used. All the data have been georeferenced onto the UTM 3 ° with 30° middle meridian. Details have been digitized on line layer and polygon layer and transported to a geographical information system for every time zones. Data quality for the results has been investigated and it was derived that the results were enough accurate according to the scale of the study.

1. INTRODUCTION AND AIM OF THE STUDY

Landuse detection has been always one of the interesting topics in big cities. For this purpose several techniques and methods have been developed. Some of them are automatic. In order to plan, how to monitor the landuse types, these types of landuse must be derived first. After that, methodology and techniques can be selected.

If the environment is thought, only a few of landuse type can be seen in general. These types are natural surfaces and artificial surfaces. To detect these two types automatically is very easy task. But the result can only serve to very simple aims. The aim is another important topic as any application for landuse detection. The results of landuse detection can be used for other application topics. These topics can be grouped in general as follows.

- Urban planning
- Environmental research and protection
- Transportation planning and management
- Facility planning and management

These areas of study have lots of subgroups related to the aim of landuse detection. The scale of the study must always be selected according to the exact aim. The complexity of the relations between landuse patterns and their spatial determinants causes the scale of analysis to influence the results. Often, focus is on one aspect of this scale effect, the spatial resolution. Scale is defined as "both the limit of resolution where a phenomenon is discernible and the extent that the phenomenon is characterized over space and time". Models that relate landuse, and more specifically landuse patterns, to its determining factors cover a broad range of spatial scales. At spatially detailed scales, the direct actors of land use change can be identified and process-based relationships can be determined. With decreasing resolution and increasing extent, it becomes increasingly harder to identify key processes. **(Kok and Veldkamp, 2001)**

After being selected the scale, technical data must be accessed. All of these steps can be collected in a flowchart (Figure 1.1).

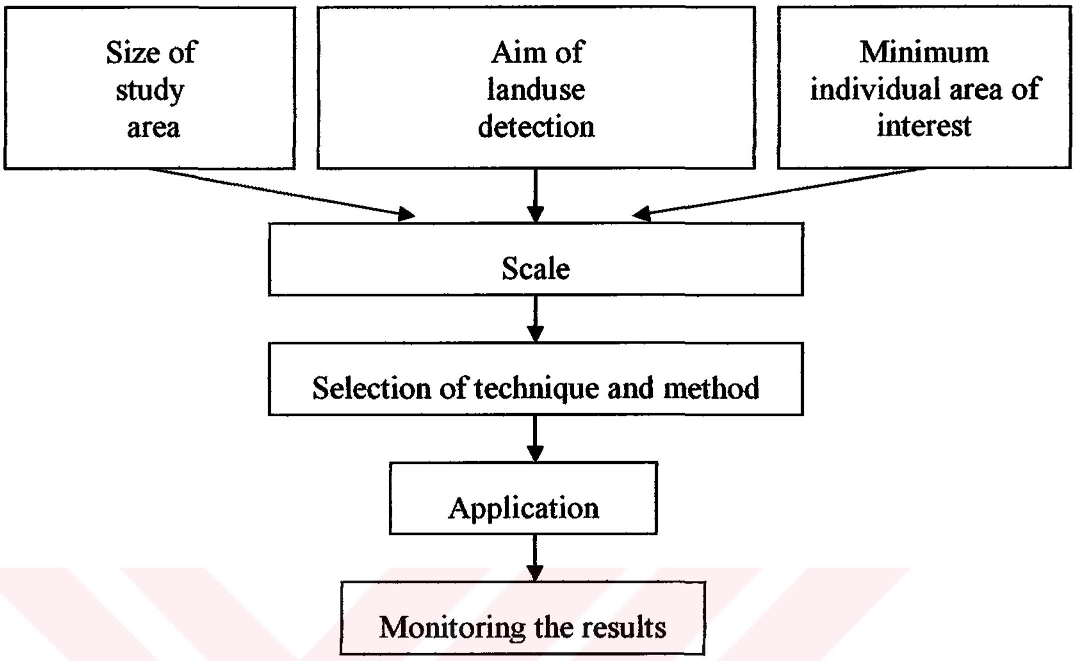


Figure 1.1 Flowchart by landuse detection

Landuse types to detect must be listed in the step of "aims of landuse detection". If the two general types of landuse are extended, several types of landuse can be generated.

1.1 Landuse types

Generally, the first level of landuse types can be listed as below. **(Bossard et al.,2000)**

- Artificial Surfaces
- Agricultural Areas
- Forests and Semi-natural Areas
- Wetland
- Water Bodies

These landuse types will be sub-grouped according to the aim of this study and will be explained in following chapters.

1.2 Aim of the Study

It is always one of the important topics for the human being, where he lives. In a big scale, research about our planet, its location, its shape and size have been done. Furthermore, human always wants more information about its environment. It always wants to learn more about the land where it lives. This request was not only about the current conditions, but also about historical conditions of the environment too.

After developing new technologies about geosciences, this lack of information can be fulfilled. Using these technologies such as aerial photogrammetry, remote sensing and GPS, new approaches are generated.

For big cities like Istanbul, it is a big problem to control, plan and analyze the urbanization. All these actions urbanization is the job for local authorities, but scientists have to develop new methods and techniques to serve these actions.

Actions about urbanization have three main steps. These are **(Kemper et al.,2002)**;

- Change Detection
- Understanding
- Forecasting

Istanbul has an important place in Turkey with its location, economy and history. Located on one of the very import waterways connecting Black Sea and Mediterranean Sea, it always has a big geopolitical importance. Moreover, It has approximately 15% of Turkish population as inhabitant. Very big percentage of Turkish economy depends on the industrial and commercial actions in Istanbul. Another importance of the city is being a bridge between European and Asian cultures. All these properties of the city make it to grow rapidly in both area and population. This growth has always been shown as numbers and statistics but not as geographical and detailed.

The actions about urbanization mentioned above have always been shown in general not in detailed. The aim of this study is to fulfill the first step in detail. Using the current conventional technologies about geosciences, an approach has been generated and applied. In this approach, satellite imagery, aerial photographs, current topographical maps from different scales have been used as main data. Digital elevation models (DEM), orthophotos, some city plans and geological maps are used to as ancillary data.

If term "change detection" is used, a difference between two or more quantitative values of an object must be derived. The term "detection of landuse change" refers to the difference of landuse along a time period. For a big city like Istanbul, this period can be weeks, years or centuries. What this period determines is the usage of the results of a landuse changes.

In this study, it is so planned that the results will give information about the growth along an historical time period. Because of that, this period has been derived according to the existence of the main data usable within the techniques mentioned above. As a result, a evaluation time zones are determined as 1940'ies, 1968, 1987/88 and 2000.

Another aim of this study is to give an accuracy values about the both geometric and thematic results. Some approaches about thematic accuracy will be studied and the most suitable one will be applied to results.

1.3 Overview of International Landuse and Landcover Studies

Landuse and landcover studies are needed at three levels of scale: international, national, and local. At the international level some current applications include **(Young, 1994)**,

- *World agricultural census 2000,* compiled from national censuses over the period 1996-2005.

- *Forest resources assessment 1990* and plans for the next assessment.

- The monitoring of world land resources, cover and use co-ordinated by UNEP through the *Global environment monitoring system (GEMS) and Global resource information database (GRID).*

- The work of the FAO/UNEP *Working group on climatic* change, which seeks to anticipate how human-induced climatic changes may affect production, food security and natural resources.

- A series of internationally-conducted research programmes conducted by the International Geosphere-Biosphere Programme (IGBP), notably that on relating *land use and global land-cover change.*

- A *Land use database,* being prepared by a joint working group co-ordinated by FAO, which provides standardized methods for the collection of detailed data on land use attributes.

- *IGBP Landuse and Landcover Change (LUCC)* aimed at improving the understanding of the landuse and landcover change dynamics and their relationships with the global environmental change.

- *National Aeronautics and Space Administration (NASA) Landsat Pathfinder Project* on the tropical forest cover.

- *FAO land cover map of Africa.*

- *Monitoring Landuse Dynamics (MOLAND)* for European big cities landuse dynamics.

2 LANDUSE CHANGE AND SPATIAL DATA QUALITY

2.1 Techniques for Landuse Detection

For landuse detection, several techniques and methods are used. All of them are meaningful according to the aim. These techniques can be listed as follows

- Photogrammetry
- Remote Sensing
- Terrestrial Geodetic Surveys

2.1.1 Photogrammetry

Photogrammetry is used for landuse detection very commonly. The advantage of selecting flight altitude and camera focal length makes photogrammetry very usable especially in densely urbanized areas. Another advantage of photogrammetry in landuse detection is that information about landscape can be collected as well. According to focal length and flight altitude, a fine geometric resolution can be reached.

New developments in digital aerial cameras let photogrammetry be used for landuse detection and mapping very commonly. These new aerial cameras give the chance of full automatic detection of landuse type.

Another method for landuse detection related with photogrammetry is ortophotos. Using orthophoto for landuse detection is not only very accurate but also meaningful for interpretation.

2.1.2 Remote sensing

In large areas, the effective and cheaper technique for landuse detection is remote sensing. Having all the data in digital form is an advantage of remote sensing. Newly developed sensors are very useful but sometimes not enough for sufficient geometric accuracy.

The availability of remote sensing data applicable for global, regional and local environmental monitoring has greatly increased over recent years. New technologies such as Global Positioning System (GPS), digital photogrammetry and multi-source satellite remote sensing are opening new application fields for remote sensing. With the advent of new (civilian) satellite programs such as IKONOS or Quickbird and, in addition, digital airborne cameras, image data are being acquired at higher spatial, spectral and temporal resolution than have been collected at any other time on Earth. **(Ehlers et al., 2003)**

2.1.3 Terrestrial geodetic surveys

The use of this type of technique individually is not meaningful for the areas of medium and large size. It can only be used for small areas.

Terrestrial geodetic survey for landuse detection is used mostly as geometric data for photogrammetry or remote sensing. Another use of technique is validation of the results reached using other techniques. For that kind of applications, small test areas are selected and mostly GPS and DGPS surveys have been done.

2.2 Methods for Landuse Detection

In general, methods for landuse detection can be collected in three groups. These are;

- Manual methods
- Semi-automatic methods
- Full-automatic methods

Landuse detection applications have two main procedures. One of them is determining the land, where the second is defining the use of it and combining to referring land. It can be said that the term “manual method” refers to applications where both of the two main procedures are done manually. In semi-automatic methods, one of them is made by microprocessors automatically and in full-automatic methods both of them automatically.

The main difference between these groups is not only the procedures made by microprocessors and interference of operators to them, and also the limit and scale of results as well as their quality. This quality is not the geometrical accuracy of results. It is the quality of the spatial database, in which the landuse patterns are saved.

Automation has always some advantages in all areas of applications. It is always time consuming and has only few dependencies to manpower. But for automatic landuse detection, the capability of microprocessors is not enough yet. Especially by defining the use of it, only in a few areas of application, automatic methods are usable. These are mainly applications on biotope type mapping, water quality management etc, where the spectral reflectance of interested landuse or landcover types is different from each other. Some applications on landuse detection in urban areas have been done too. In those kind applications, some approaches have been done. These approaches are not enough for accessing high quality for landuse database. As an example, for differing the urban fabric and industrial areas, the roofs with tiles and the flat roofs are used with their spectral reflectance. But this approach is not enough in most cases and must be validated manually.

In this study, manual method has been selected according to richness of legend. Legend of this study contains very complex patterns so that conventional full or semi automatic methods could not be used. As an example, residential and commercial areas differ from each other in the legend and this difference cannot be determined unless using operator's interpretation and knowledge.

2.3 Spatial Data Accuracy Assessment

The term "accuracy" is the degree of conformity with a standard. It relates to a quality of the results and is distinguished from precision, which relates to a quality of the operation by which the result is obtained **(Glossary of Cartographic terms)**. Another definition of accuracy is "closeness of agreement between a test result and the accepted reference value" **(ISO/TC 211 N 1034, 2001)**.

The International Standardization Organization (ISO) explains the quality in ISO 8402 as "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs". Quality is defined as "that which makes or helps to make anything such as it is; a distinguish property, characteristics, or attribute; (in logic) the negative or affirmative character of a proposition **(Buttenfield, 1993)**. Another definitions of quality are "the sum of all the factors that enable ownership satisfaction and bring customers back to buy a product or a service again and again" **(Radwan et al., 2001)** and "the integration of the terms of completeness, consistency and suitability for use, which are statistically measurable" **(Beard and Mackaness, 1993)**. More general definition of quality is "a statistically measurable concept showing the totality of indicators defining the negative and affirmative distinguishing specifications and characteristics in the fields of the satisfaction of the desired conditions for the producer and appropriateness to the aim for the consumer of a product or a service". **(Taştan, 1999)**

2.3.1 Spatial data quality

Data about positions, attributes and relationships of features in space are termed spatial data **(Morrison, 2001)**. Spatial data can be a product or service related with its aim and user. For a GIS provider or producer, it is a product, but for some kind of user such as Internet users etc, it is a service.

Combining the definitions of quality and spatial data, the definition of spatial data quality occurs as "a statistically measurable concept showing the totality of indicators defining the negative and affirmative distinguishing specifications and characteristics in the fields of the satisfaction of the desired conditions for the producer and appropriateness to the aim for the consumer of data about positions, attributes and relationships of features in space".

2.3.2 Quantitative elements

Referring to the definition above, it is clear that the data quality has some indicators or elements. The total quality of a product or service occurs as a combination of them. These elements of data quality are: **(ISO/TC 211 N 1034, 2001)**

- Completeness
- Logical Consistency
- Positional Accuracy
- Temporal Accuracy
- Thematic Accuracy

The elements above address the quantitative elements of data quality and have some subelements as follows: **(ISO/TC 211 N 1034, 2001)**

- Completeness: presence and absence of features, their attributes and their relationships
    - Commission: Excess data present in a dataset
    - Omission: Data absent from a dataset
- Logical Consistency: Degree of adherence to logical rules of data structure, attribution and relationships
    - Conceptual Consistency: Adherence to rules of the conceptual schema
    - Domain Consistency: Adherence of values to the value domains
    - Format Consistency: Degree to which data is stored in accordance with the physical structure of the dataset
    - Topological Consistency: Correctness of the explicitly encoded topological characteristics of a dataset
- Positional Accuracy: Accuracy of the position of features
    - Absolute or External Accuracy: Closeness of reported coordinate values accepted as or being true
    - Relative or Internal Accuracy: Closeness of the relative positions of features in a dataset to their respective relative positions accepted as or being true.
    - Gridded Data Position Accuracy: Closeness of gridded data position values accepted as or being true
- Temporal Accuracy: Accuracy of temporal attributes and temporal relationships of features
    - Accuracy of a Time Measurement: Correctness of the temporal references of an item (reporting of error in time measurement)
    - Temporal Consistency: Correctness of ordered events or sequences, if reported
    - Temporal Validity: Validity of data with respect to time

- Thematic Accuracy: Accuracy of quantitative attributes and correctness of non-quantitative attributes and of the classifications of features and their relationships.
    - Classification Correctness: Comparison of the classes assigned to features or their attributes to a universe of discourse (e.g. ground truth or reference dataset)
    - Non-quantitative Attribute Correctness: Correctness of non-quantitative attributes
    - Quantitative Attribute Correctness: Correctness of quantitative attributes

2.3.3 Non-quantitative elements

Additional to the five data quality elements, data quality overview elements are listed in **(ISO/TC 211 N 1034, 2001)**. They are,

- Purpose
- Usage
- Lineage

For these additional three data quality elements the term "non-quantitative" is used.

Purpose shall describe the rationale for creating a dataset and contain information about its intended use **(ISO/TC 211 N 1034, 2001)**. Moreover, the footnote about the purpose as "a dataset's intended use is not necessarily the same as its actual use. Actual use is described using the data quality overview elements usage" is added by the ISO/TC211 team.

Usage shall describe the application(s) for which a dataset has been used Usage describes uses of the dataset by the data producer or by other, distinct, data users **(ISO/TC 211 N 1034, 2001)**.

The lineage of a database includes reference to source materials, data collection and preprocessing including geometric transformations applied to the data. Whereas positional accuracy, attribute accuracy and logical consistency may be archived as attributes of stored data and completeness may be stored implicitly, lineage archives require access to database pointer **(Buttenfield, 1993)**. As it is described in **ISO/TC**

211 N 1034 (2001), lineage shall describe the history of a dataset and, in as much as is known, recount the life cycle of a dataset from collection and acquisition through compilation and derivation to its current form.

2.3.4 Descriptors of a data quality subelements

Descriptors are one of the important topics in data quality. They have a significant role in establishing the connection between theory and practice.

Quality information shall be recorded for each applicable data quality subelements. The mechanism for completely recording information for a data quality subelement shall be the use of the seven descriptors of a data quality subelement: **(ISO/TC 211 N 1034, 2001)**

- Data quality scope: Extent or characteristic(s) of the data for which quality information is reported.
- Data quality measure: Type of test applied to the data specified by a data quality scope.
- Data quality evaluation procedure: Operation(s) used in applying and reporting quality evaluation methods and their results.
- Data quality result: value or set of values resulting from applying a data quality measure or the outcome of evaluating the obtained value or set of values against a specified acceptable quality level.
- Data quality value type: Value type for reporting a data quality result.
- Data quality value unit: Value unit for reporting a data quality result.
- Data quality date: Date or range of dates on which a data quality measure is applied.

2.3.5 Process for evaluating data quality

A quality evaluation process may be used in different phases of a product cycle, having different objectives in each phase. The process for evaluating data quality is a sequence of steps to produce and report a data quality result. A quality evaluation process consists of the application of quality evaluation procedures to specific dataset-related operations performed by dataset producer and the dataset user **(ISO/TC 211 N 1030, 2000)**.

In the first step of data quality evaluation process, all applicable data quality element, data quality subelement and data quality scope shall be identified. This step must be repeated for as many times as required by the product specification or user requirements **(ISO/TC 211 N 1030, 2000)**.

In the second step, a data quality measure, data quality value type and if applicable, a data quality value unit shall be identified for each test to be performed **(ISO/TC 211 N 1030, 2000)**.

In the next step, evaluation method for data quality shall be selected and applied. This evaluation method can be either a direct evaluation method or an indirect evaluation method **(ISO/TC 211 N 1030, 2000)**.

As the output of the selected and applied data quality evaluation method, a quantitative data quality result, a data quality value or set of data values, a data quality value unit and a date shall be determined in the fifth step of data equality evaluation process **(ISO/TC 211 N 1030, 2000)**.

In the last step, conformance shall be determined according to conformance quality level, which is specified by product specification or user requirements. A conformance data quality result is the comparison of the quantitative data quality results with a conformance quality level and shall be given as either pass or fail.

All these steps and their relationships are illustrated in Figure 2.1.

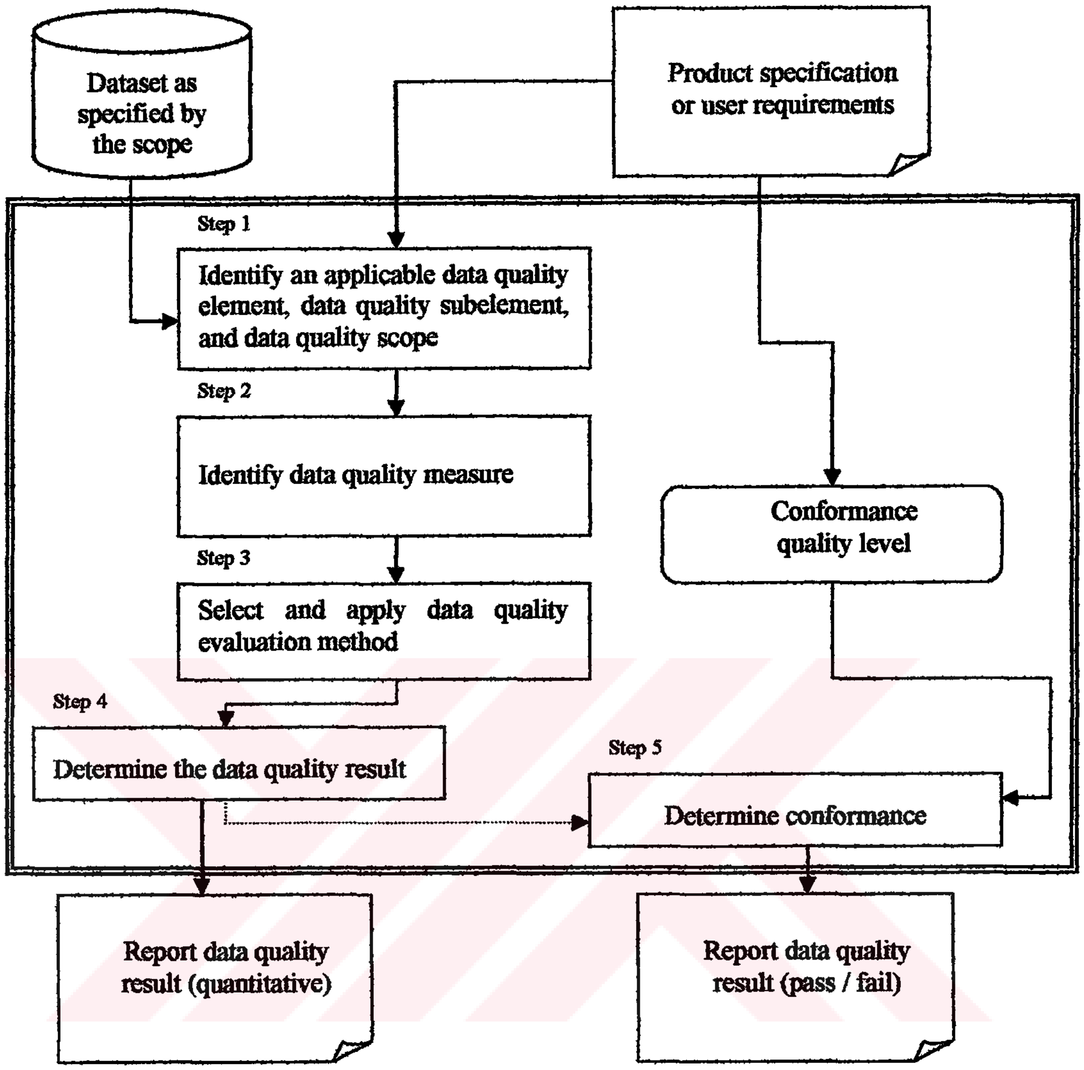


Figure 2.1 Process flow for evaluating and reporting data quality results
(ISO/TC 211 N 1030, 2000)

2.4 Data Quality Evaluation Methods

Data quality evaluation methods are divided in two groups called as direct and indirect evaluation methods.

Direct evaluation methods have two subgroups as internal and external. In internal method, data quality process shall be done using some internal data or dataset used in the study. By external method, the same process shall be done via some external references such as additional measurements or data.

By indirect methods, there must be some additional (external) knowledge. This type of method is used only if direct methods are not applicable **(ISO/TC 211 N 1030, 2000)**.

2.5 Methodology on Geometric Accuracy

In a geographical information system (GIS), the geometric components are point, line and area. Point is a place in the space without a dimension. Line is a combination of places between predefined two points. An area is the geometric place, which is bounded with three or more lines intersecting each other.

As it can be understand from the explanations above, geometric accuracy of an area depends on the geometric accuracy of lines bounding it and the geometric accuracy of a line depends on the geometric accuracy of the start- and endpoints of it. That causes the geometric accuracy assessment to begin with the geometric accuracy of a point.

2.5.1 Geometric accuracy of a point

Geometric accuracy of a point has two components. The first one is the planimetric accuracy where the second is vertical accuracy. In this study, digitalization has been done on plane. Thus, only planimetric accuracy will be discussed.

Let x_i and y_i be the coordinates of a digitized and also to GIS transported point and X_i and Y_i be the true coordinates of the same point. True error of this point is;

$$\varepsilon_{x_i} = x_i - X_i \qquad (2.1)$$

$$\varepsilon_{y_i} = y_i - Y_i \qquad (2.2)$$

the differences of positions can be calculated as

$$\varepsilon_{si} = \sqrt{\varepsilon_{x_i}^2 + \varepsilon_{y_i}^2} \qquad (2.3)$$

If the sampling group for geometric accuracy assessment contains n points, then the standard deviations occurs as follows; **(Taştan, 1999)**

$$\sigma_{\varepsilon_x} = \sqrt{\frac{\varepsilon_{x_i}^2}{n}} \qquad (2.4)$$

$$\sigma_{\varepsilon_y} = \sqrt{\frac{\varepsilon_{y_i}^2}{n}} \tag{2.5}$$

The theoretic circular standard error can be calculated as follows; **(Taştan, 1999)**

$$\sigma_c = \sqrt{\frac{\sigma_{\varepsilon_x}^2 + \sigma_{\varepsilon_y}^2}{2}} \tag{2.6}$$

Some statistical approaches have been done for geometric accuracy. These approaches are summarized in **Taştan (1999)**.

Here, σ_c is conforming Chi-square distribution from second degree of freedom, as it is a sum of squares of two variables, conforming standardized normal distribution **(Taştan, 1999)**

$$\frac{\varepsilon_s^2}{\sigma_c^2} \approx \chi_{(2)}^2 \tag{2.7}$$

For the different fractal values of Chi-square distribution, different accuracy criteria have been defined. For example, circular standard error is defined for a fractal value of $\chi^2_{(2,\alpha)} = 1$

$$P\left(\frac{\varepsilon_s^2}{\sigma_c^2} \leq 1\right) = 0.3935 \tag{2.8}$$

$$P\left(\varepsilon_s^2 \leq \sigma_c^2\right) = 0.3935 \tag{2.9}$$

$$P\left(\varepsilon_s \leq \sigma_c\right) = 0.3935 \tag{2.10}$$

This equation means that the probability of a being equal or less than circular standard error for any positional error (ε_s) is 39.35 %.

As it is mentioned above, in **Taştan (1999)**, several accuracy approaches are summarized. These approaches are differing from each other because their fractal values in Chi-square table.

A criterion for a probability value of 50 % in Chi-square distribution is named as circular probable error (CPE). The fractal value for this probability is 1.39. Thus;

$$P\left(\frac{\varepsilon_s^2}{\sigma_c^2} \le 1.39\right) = 0.5 \tag{2.11}$$

$$P\left(\varepsilon_s^2 \le 1.39\sigma_c^2\right) = 0.5 \tag{2.12}$$

$$P\left(\varepsilon_s^2 \le (CPE)^2\right) = 0.5 \tag{2.13}$$

$$P\left(\varepsilon_s \le CPE\right) = 0.5 \tag{2.14}$$

$$CPE = \sqrt{1.39\sigma_c^2} \tag{2.15}$$

can be formulated.

Another criterion is the mean square positional error (MSPE). It is defined for a probability value for $\chi^2_{(2,\alpha)} = 2$ fractal value. The probability for the fractal value mentioned here is 63.21%. This is formulated as follows;

$$P\left(\frac{\varepsilon_s^2}{\sigma_c^2} \le 2\right) = 0.6321 \tag{2.16}$$

$$P\left(\varepsilon_s^2 \le 2\sigma_c^2\right) = 0.6321 \tag{2.17}$$

$$P\left(\varepsilon_s^2 \le (MSPE)^2\right) = 0.6321 \tag{2.18}$$

$$MSPE = \sqrt{2\sigma_c^2} \tag{2.19}$$

For the probability of 90% in Chi-square distribution, a criterion has defined as circular map accuracy standard (CMAS). The fractal value for the probability of 90 % is 4.61. The formulation is as follows;

$$P\left(\frac{\varepsilon_s^2}{\sigma_c^2} \le 4.61\right) = 0.90 \tag{2.20}$$

$$P\left(\varepsilon_s^2 \le 4.61\sigma_c^2\right) = 0.90 \tag{2.21}$$

$$P\left(\varepsilon_s^2 \le (CMAS)^2\right) = 0.90 \tag{2.22}$$

$$CMAS = \sqrt{4.61\sigma_c^2} \tag{2.23}$$

The last criterion is the circular near certainty error (CNCE). It is defined for the fractal value of $\sqrt{\chi^2_{(2,1-\alpha)}} = 3,5$ in Chi-square distribution. The probability for this fractal value is 99.78 %.

$$P\left(\frac{\varepsilon_s^2}{\sigma_c^2} \leq 3.5^2\right) = 0.9978 \tag{2.24}$$

$$P\left(\varepsilon_s^2 \leq 3.5^2 \sigma_c^2\right) = 0.9978 \tag{2.25}$$

$$P\left(\varepsilon_s^2 \leq (CNCE)^2\right) = 0.9978 \tag{2.26}$$

$$CNCE = 3.5\sigma_c \tag{2.27}$$

2.5.2 Geometric accuracy of a line

As it is mentioned above, geometric accuracy of a line depends on the geometric accuracies of start- and endpoint of itself. The geometry of a line is illustrated in Figure 2.2.

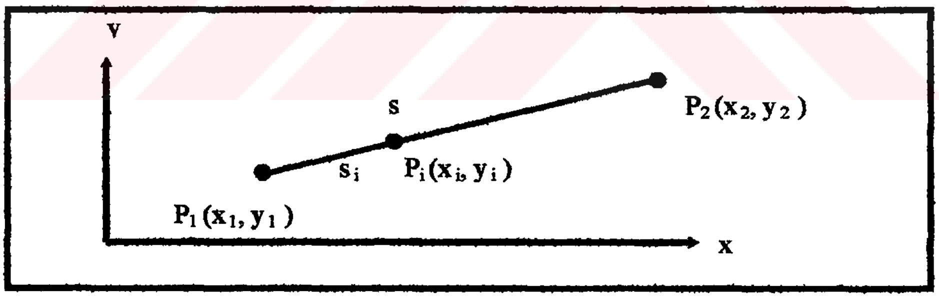


Figure 2.2 Position of a point on a layer

The accuracy result of a line is the error band. Using the deviations of beginning and endpoint of a line, two error ellipses can be drawn on the two tails of a line. These ellipses can be drawn using the deviations on the predetermined portions of the line. **(Taştan, 1999)**

$$\frac{s_i}{s} = p_i \tag{2.28}$$

$$x_i = x_1 + p_i(x_2 - x_1) \tag{2.29}$$

$$x_i = (1 - p_i)x_1 + p_i x_2 \tag{2.30}$$

$$dx_i = (1-p_i)dx_1 + p_i dx_2 \tag{2.31}$$

$$\sigma_{x_i}^2 = (1-p_i)^2\sigma_{x_1}^2 + p_i^2\sigma_{x_2}^2 + 2p_i(1-p_i)\sigma_{x_1x_2} \tag{2.32}$$

If the formula is used for σ_y the result appears as;

$$\sigma_{y_i}^2 = (1-p_i)^2\sigma_{y_1}^2 + p_i^2\sigma_{y_2}^2 + 2p_i(1-p_i)\sigma_{y_1y_2} \tag{2.33}$$

Supposing that the beginning- and endpoint have no correlation between them,

$$\sigma_{x_1x_2} = 0 \tag{2.34}$$

$$\sigma_{x_i}^2 = (1-p_i)^2\sigma_{x_1}^2 + p_i^2\sigma_{x_2}^2 \tag{2.35}$$

$$\sigma_{y_i}^2 = (1-p_i)^2\sigma_{y_1}^2 + p_i^2\sigma_{y_2}^2 \tag{2.36}$$

Combining the extreme points of these ellipses, the above mentioned error band can be drawn (Figure 2.3).

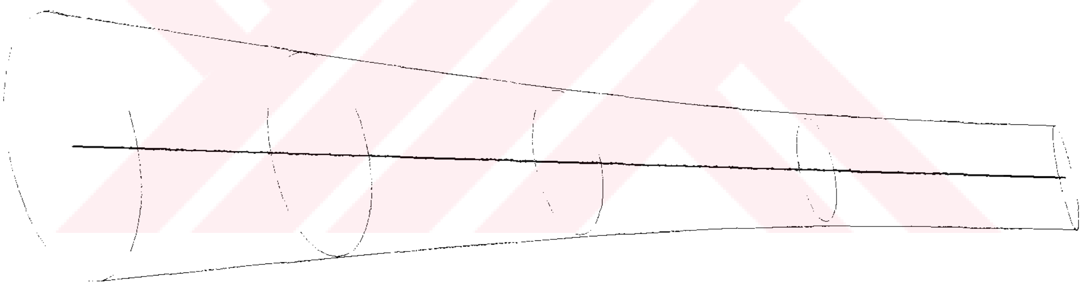


Figure 2.3 Error ellipses(red) and error band (blue) of a line (black)

2.5.3 Geometric accuracy of an area

The geometric accuracy of an area depends on the geometric accuracies of the lines bounding it. For calculation of an area, the following formula is used **(Taştan, 1999)**.

$$F = \frac{1}{2}\sum_{1=1}^{n}(y_{i+1} - y_{i-1})x_i \tag{2.37}$$

Using this formula, accuracy of this area will be as follows.

$$\sigma_F^2 = \frac{1}{4}\sum_{i=1}^{n}\left((y_{i+1} - y_{i-1})^2\sigma_{x_i}^2 + (x_{i-1} - x_{i+1})^2\sigma_{y_i}^2\right) \tag{2.38}$$

Another generated accuracy criterion is given in **Taştan (1999)** as follows.

$$\sigma_F = \sigma\sqrt{2F\sin\left(\frac{360}{n}\right)} \tag{2.39}$$

where σ denotes an accuracy for both x- and y directions.

2.6 Methodology for Thematic Accuracy

By thematic accuracy assessment, a test group of records from database will be selected as sampling group. This group will be compared with an internal or external data. The proportion of correctly defined areas to the sampling group is calculated as a thematic accuracy.

By sampling of records, some approaches can be done. The first approach is to derive a sampling size for the whole objects in database where the other one is to derive this sampling size for individual groups in database according to their attributes. The second approach is more accurate than other one is since it will give accuracy for all the groups in database.

3 APPLICATION

3.1 Data Used Within the Study

In this study, several types of data were used. In order to get considered precision, these data have been processed precisely. The data types can be grouped as follows;

- Reference maps
- Reference imagery
- Historical satellite based and airborne photographs
- Ancillary data

3.1.1 Reference maps

As geodetic reference base, digital maps in vector and raster format; mainly scanned and geo-referenced topographical maps in scale of 1:25.000 were used. For the whole study area, 22 maps have been processed. In some parts of study area, topographical maps from a scale 1:5000 were used. These areas are mainly the areas closed to study border. The coverage of maps from 1:25000 is illustrated in Figure 3.1.

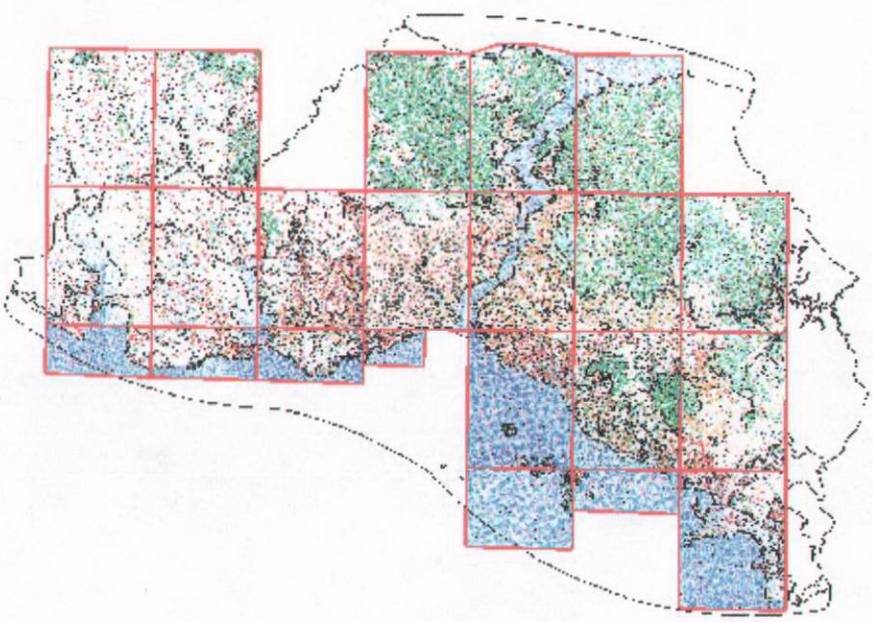


Figure 3.1 The topographical maps in scale of 1:25.000 used in the study

Since the dimensions of a map from a scale of 1:25000 were about 55.5x42.5 cm, they couldn't be scanned in conventional scanners. Therefore first all the 1:25000 maps have been partially scanned in DIN A4 flatbed scanner, than all parts have been georeferenced individually. In georeferencing of these partial maps, grids on the maps were used. The whole map was created by merging of these georeferenced parts. Details of georeferencing process for maps in scale of 1:25000 are as follows:

All maps have been scanned with 600x600 dpi geometric and 24-bit radiometric resolution. The coordinate system is selected as UTM 3° with middle meridian 30° east. Georeferencing was done by using TopoL-GIS software, coordinate transformations by an Excel calculation. With the method of partial transformation most accurate georeferenced maps were obtained. Standardized operating procedures were defined with 3 steps: The first step was a normal Affine-transformation to place the scanned maps to the position of the maps origin coordinate system to enable a good orientation and to detect more easily the displacement in the next step. That was only the first and approximate transformation and done by using the map corners. Afterwards, all the maps are transformed exactly to the corresponding coordinate system using all the grid points on them. With this partial transformation, the maps are not only georeferenced but also the errors were reduced. With this transformation, suitable neighborhoods between maps and a mistake minimization of scanning and paper sheets (and sometimes also of the print) effects have been got. Then a third Affine-transformation, to move the image to the other coordinate system (from one to another strip or ellipsoid), were taken place. The correct coordinates have been calculated by the map-corner coordinates or by the grid on the map-sheets.

3.1.1.1 Example for the standardised operating procedure

- Creating out of the coordinates of the map corners as a txt-file, where in first column is the number; second the value in meters for Y and as third the value for X in meters.
- Importing this file into a vector-layer (TopoL-Block) by import-reading points.
- Creating lines between the corners by using snap mode. The vertices of the lines have to fit perfectly to the points.

- Picking up the map corners on the TopoL-Block and the corners of the map and transform it by using Affine-transformation algorithm. By this procedure, the residuals should be smaller than 5 m.
- Loading the new raster automatically.
- Very useful is to enable the display of the grid, which should be set to the value of the co-ordinate-crosses, for the maps from a scale of 1:25000, it is 1000x1000 m
- Starting special transformation and chose the pre-georeferenced file.
- Georeferencing of the corners. Setting snapping mode to a distance of 0.3 m and only snapping to points. First the correct coordinates must be entered to the system, so it can either be put manually or the point can be selected with the pointer. After this, the source point, which will be transformed, must be selected.
- Georeferencing the frame coordinates. Leaving snapping-mode at a distance of 0.3 m and only snapping to line-bodies. After this, same procedure as georeferencing of the corners must be fulfilled.
- Georeferencing the coordinate crosses. Set the snapping-mode to a distance of 0.5 m and only snap to Grid-points. Following procedure is the same as by georeferencing of the corners and frame coordinates.
- Correcting coordinates. Coordinates must be checked and manipulated. The first 4 coordinates are the frames. These coordinates should be clearly done. The next perhaps 32 points are the grid coordinates, where one should have whole coordinate value. Correct this to a whole amount, usually in steps of 1000 m. The coordinates of the crosses also should be correct and both coordinates have whole value.
- Setting of Affine-transformations and controlling the distortion, which should be less than 10 m for a 25.000 map. If there are some strange mistakes, referring point must be checked. Otherwise running of partial transformation is the next step. As shown in Figure 3.2, the system will chose the TIN automatically and try to set the minimum and maximum co-ordinates.

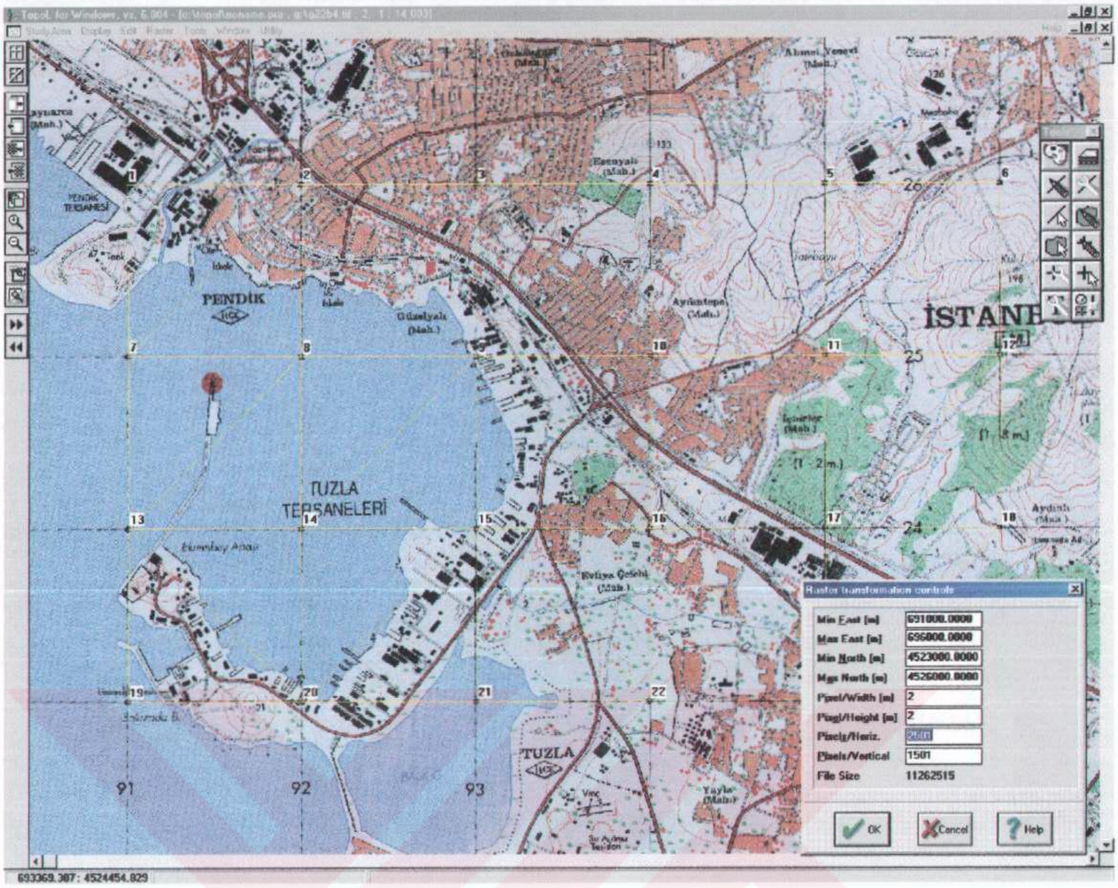


Figure 3.2 Screenshot of the partial transformation of the topographical maps 1:25.000

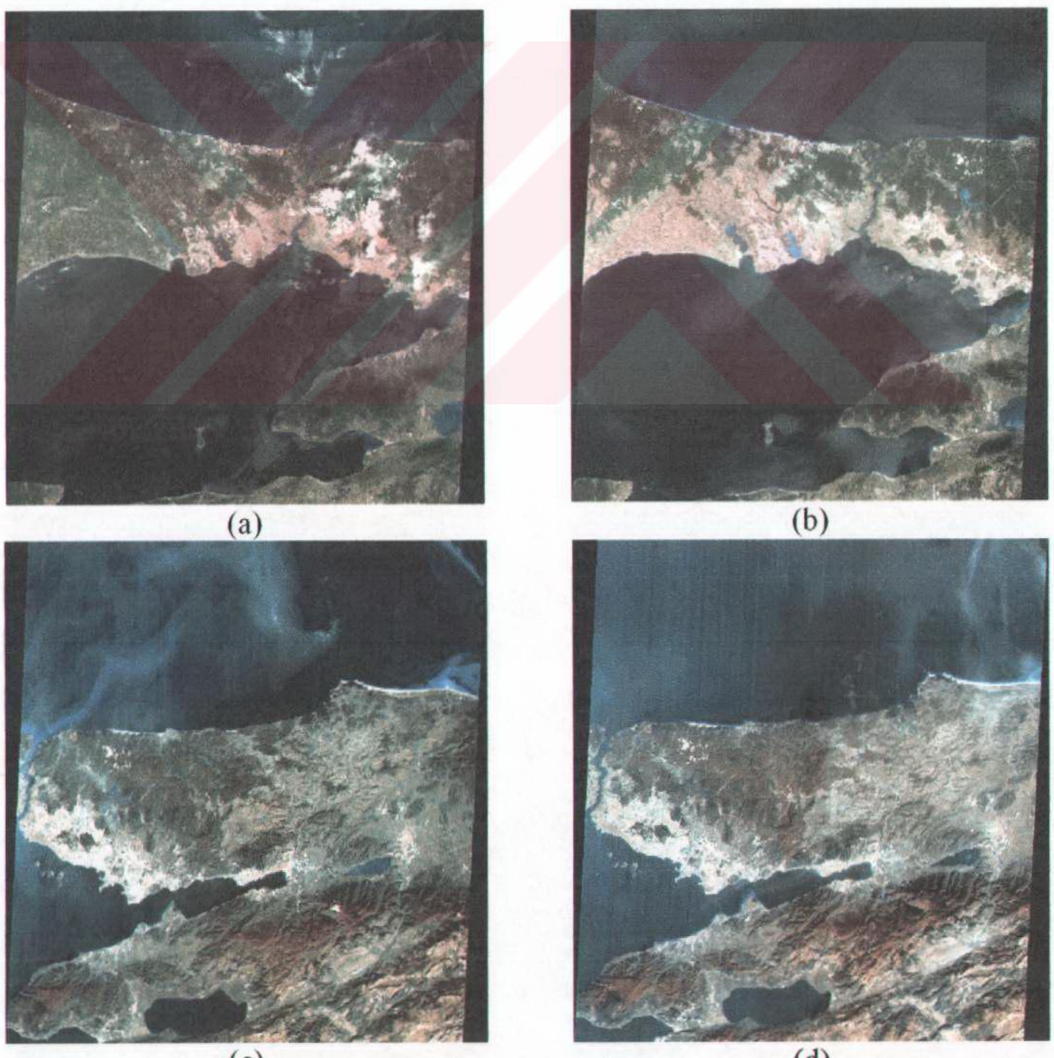
3.1.2 Reference imagery

The reference land use database has been derived from "reference imagery". The reference imagery is first IRS-1C/1D with 5 m. spatial resolution in panchromatic and 25 m. in multi-spectral. The image was delivered as an IMG file on CD, which was imported into TopoL-GIS by setting rows and columns. Merging technologies produced colored 5 m. imageries out of this. Big structures are good visible in the imagery, the smaller once can be interpreted only by using additional information from maps, city plans and field-checks. For the area of the Bosphorus, the IKONOS imagery with 1 m. spatial resolution in panchromatic and 4 m. in multi-spectral have been available. They have already been delivered as in Tiff format with a pre-georeferencing in a tfw-file (but it did not fit to the local geodetic system in any case). Also here merged imageries have been prepared for the interpretation. The visibility of the terrain was clear on the images.

3.1.2.1 IRS imagery

Imageries of the Indian Satellite IRS for this study were consisted of 4 scenes, both in panchromatic and multispectral mode. The reference imagery IRS-1D in panchromatic (5 m spatial resolution) and multi-spectral mode (25 m spatial resolution) have been imported into TopoL-GIS by IMG import and then converted to Tiff format.

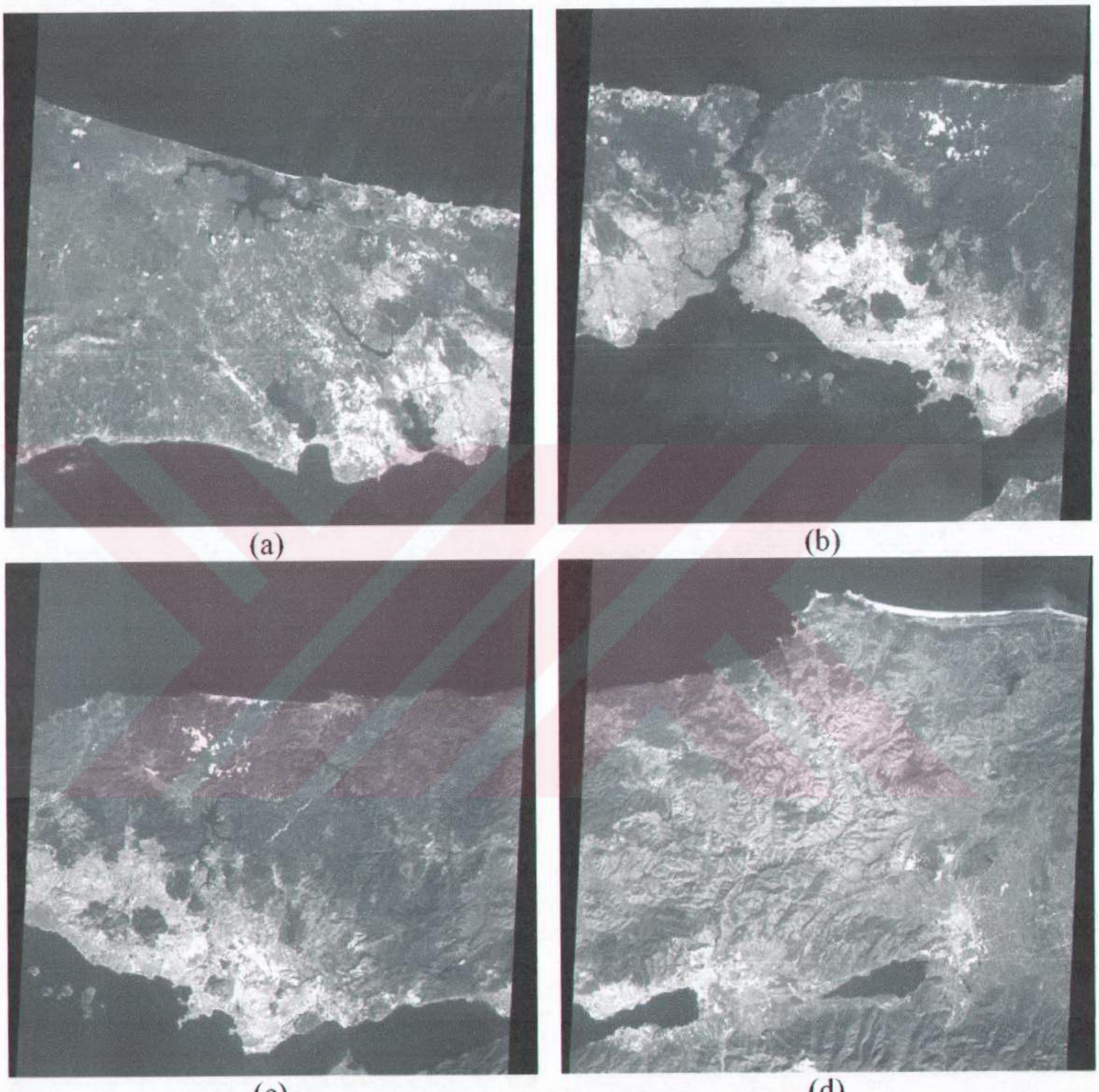
For the 4 multispectral scenes, the channels 3 (red), 2 (green) and synblue have been combined to a coloured image as shown in Figure 3.3. The channel 4 (NIR) was not used as well as the channel 5 (WIR), which exists for 2 MS-Scenes. 2 scenes cover the entire study area; the other two were mostly belonging to the Asian part and the eastern part of Istanbul. The dates of image acquisition were different.



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

Figure 3.3 IRS-1D MS taken at (a) 12.05.2000; (b) 26.07.2000; (c) 31.10.2000 and (d) 25.11.2000 (RGB: 1/2/3)

The 4 panchromatic IRS-1D imagery cover the entire area as a strip west-east (Figure 3.4). They have been imported as IMG-File into TopoL and then converted to Tiff format. The spatial resolution was 5.8 m. Two images were covering the study area, therefore the third and fourth were not used in the study.



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

Figure 3.4 IRS-1D panchromatic images taken at (a) 12.05.2000; (b) 26.07.2000; (c) 25.11.2000 and (d) 31.10.2000

The two images, shown in Figure 3.4(a) and Figure 3.4(b), were the IRS-1D imagery used. By georeferencing of them, 71 and 109 points were used as GCP respectively. The coordinates of them and their deviations as well as their distributions are given in Appendix A.

3.1.2.2 IKONOS imagery

Since the IKONOS imagery used were produced as 11-bit greyscale, they had to be converted into 8-bit greyscale. This was done in Adobe-Photoshop, which supports also 16-bit greyscale. The IKONOS imageries had already some georeference information (tfw-file) that enabled to mosaic these 3 IKONOS-scenes together. The information on georeferencing of the IKONOS scenes were not enough since the coordinate system used by georeferencing of the IKONOS scenes did not fit the coordinate system used in the study. The images have been delivered as multispectral set (blue, green, red and NIR) with 4 m spatial resolution, and as panchromatic with 1 m spatial resolution. The multi-spectral once have been combined to an RGB-File (without NIR) and as well matched with the 1 m panchromatic imageries. Unfortunately these 3 scenes only show the Bosphorus area as shown in Figure 3.5.

Figure 3.5 The three IKONOS imagery in sequence covering the Bosphorus Region (RGB: 1/2/3). (a) northern, (b) central, (c) southern

As shown above, reference imagery consists of multiple images. These images were taken by different sensors. A comparison between the sensors and platforms for the reference imagery is given in Table 3.1. By georeferencing of IKONOS imagery, 43 GCPs for northern image, 52 GCPs for central image and 50 GCPs for southern image were used. The coordinates of them and their deviations as well as their distributions are given in Appendix A.

Table 3.1 Comparison of technical specifications for sensors used in the study **(Sadeghian S. et al. 2001, IKONOS Products and Product Guide 2002, Satellite Constellation)**

	IRS 1C		IRS 1D		IKONOS	
Sensor	LISS III	PAN	LISS III	PAN	MS	PAN
Spatial Resolution	23.5 m (visible and near IR region) 70.5 m (shortwave IR region)	5.8 m.	23.7 m	5.2 m	3.2 m.	0.8 m.
Swath	141 km (visible and near IR region) 148 km (shortwave IR region)	70 km	127 km (bands 2, 3, 4) 134 km (band 5 -MIR)	65 -80 km	11 km.	11 km.
Temporal Resolution	24 days	5 days	25 days	3 days	3 days	
Spectral Resolution	0.52 - 0.59 microns (B2) 0.62 - 0.68 microns (B3) 0.77 - 0.86 microns (B4) 1.55 - 1.70 microns (B5)	0.50 - 0.75 microns	0.52 - 059 microns (B2) 0.62 - 0.68 microns (B3) 0.77 - 0.86 microns (B4) 1.55 - 1.70 microns (B5)	0.50 - 0.75 microns	0.45 - 0.52 microns (B1) 0.52 - 0.60 microns (B2) 0.63 - 0.69 microns (B3) 0.76 - 0.90 microns (B4)	0.45 - 0.90 microns
Altitute	817 km		780 km		681 km.	
Radiometric Resolution	6 bit		6 bit		11 bit	

3.1.3 Historical satellite based and airborne photographs

For the historical years 1988, satellite photographs from Russian Satellite KFA and KVR were used. For this type of imagery generally, term of "satellite photograph" is used, because these images are taken analogously and then they are digitised by using high-resolution scanners.

For other two historical years (1965 and 1940s), airborne photographs were used. This causes very long work for evaluation of these two historical years. Especially, creating orthophotos has taken very long time.

3.1.3.1 Satellite photographs for the year 1987/88

The historical satellite imagery for the year has been processed out of KVR-1000 photos with 2 m resolution and KFA-1000 photos with 5 m spatial resolution for the year 1988. These data were of Russian origin and belonged to the satellite-based spycampaign of the 80ies. They were produced as satellite-photographs, not scanned imagery. The data are available only after the development of the film. Technical specifications on KFA-1000 and KVR-1000 satellite images are given in Table 3.2. The process of scanning has to take place before the processing in digital form. The pictures have been bought already scanned with high resolution (8 μm) in digital form on CD. Therefore, the processing was partly difficult.

Table 3.2 Technical Specifications of KFA-1000 and KVR-1000 Satellites **(Russian high-data resolution)**

Satellite	**KFA-1000**	**KVR-1000**
Spatial Resolution	5 m.	2 m.
Scene Size	120 x 120 km	40 x 40 km.
Proposed Maximum Scale	1:15000	1:5000
Spectral Information	1 panchromatic channel 2 spectral channels	1 panchromatic channel

The data have been georeferenced like the images of the reference year, by a normal affine-transformation first, and then a second global transformation for the entire area. Georeferencing was done with TopoL-GIS. The KVR-1000 imageries covered the inner part of the centre zone and the Bosphorus area. They were similar to the IKONOS images but the coverage was about 3 times bigger. These images are in panchromatic and taken by the Russian satellite. The KFA-1000 imageries are also Russian and they have some colour, which are like pseudo-coloured. The channels are not separated but the spatial resolution compatibility with the IRS-1D was sufficient. As seen from Figure 3.6 and 3.7., the coverages of both KFA-1000 and KVR-1000 images used were adequate for the analysis.

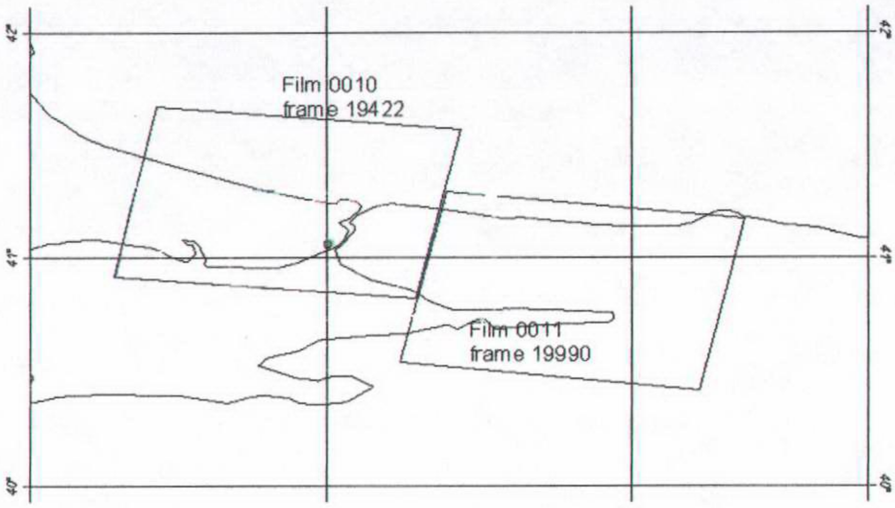


Figure 3.6 Coverage of KFA-1000 imagery used.

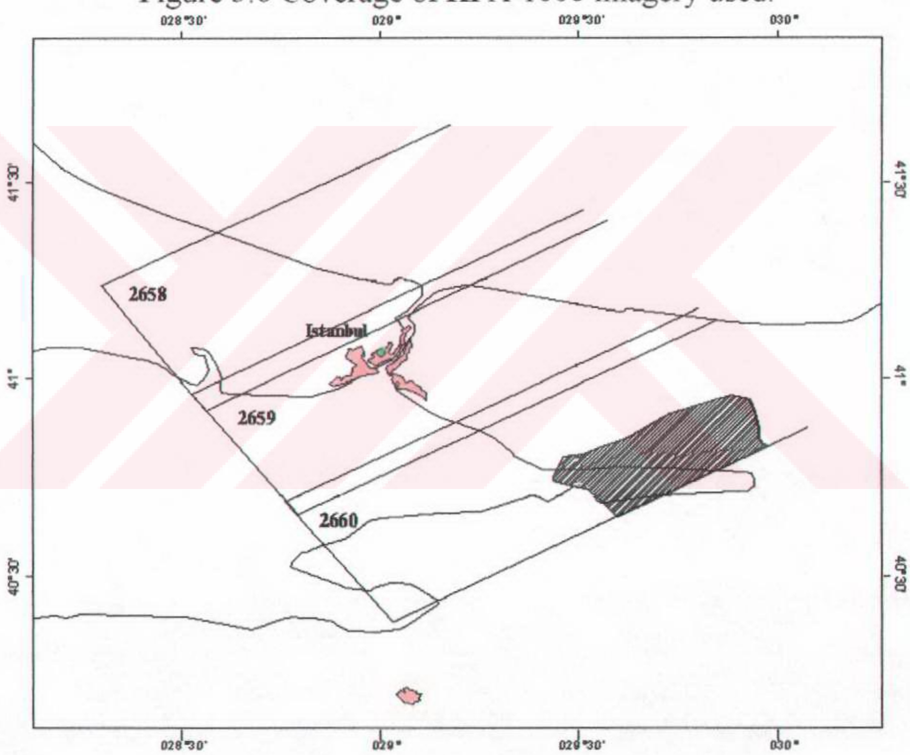


Figure 3.7 Coverage of KVR-1000 imagery used.

By georeferencing of two KFA images used, 111 GCPs for the first one and 36 GCPs for the second one were used. The coordinates of them and their deviations as well as their distributions are given in Appendix A.

3.1.3.2 Airborne photographs for the year 1968 and 1940s

The historical imageries for the years 1968 and 1940s have been created out using aerial photographs. The acquisition wasn't very easy because such old flight campaigns were not very good. Every year had different flight-campaigns (blocks) with different camera and sometimes also different flight-altitude (scale). The camera calibration protocol was delivered from the General Command of Mapping together with the photos and partly taken out of the literature or measured out of the sets of the images. The photos had an overlap of about 80%, so far only every second photo had been acquired. The photos often have been rotated, shifted and tilted which made the processing not easy. The coverage of the orthophotos for the year 1940ies is given in Figure 3.8.

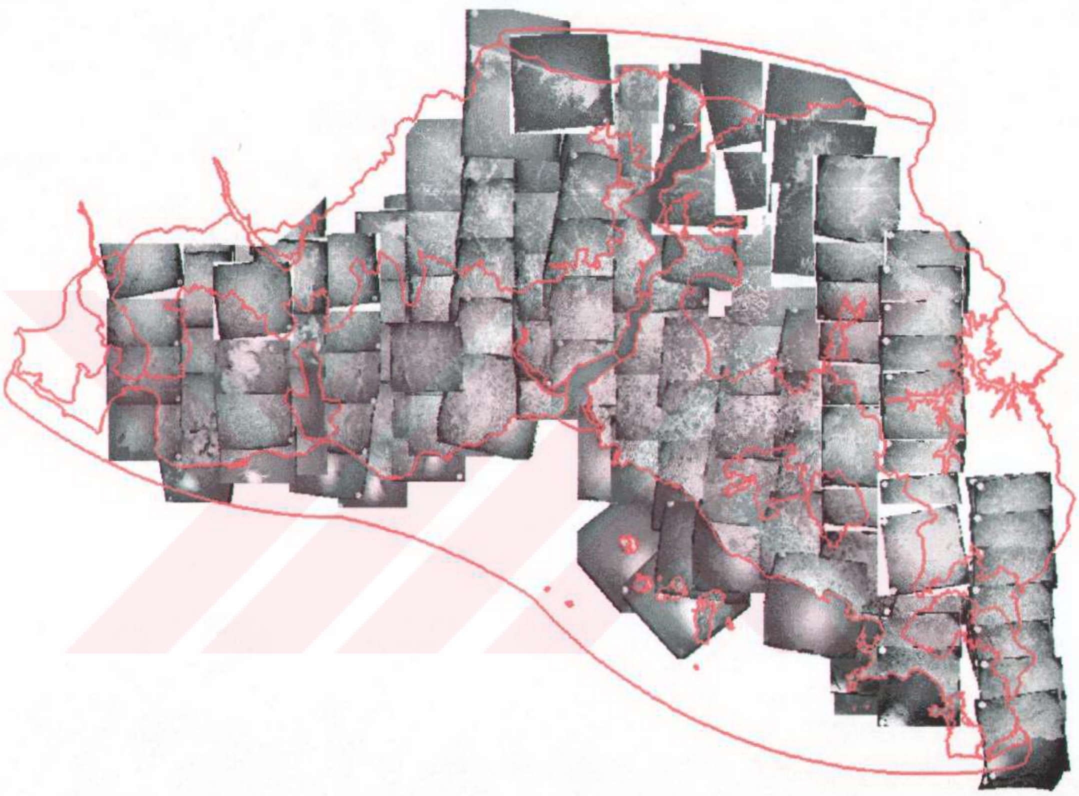


Figure 3.8 Created orthophotos for the year 1940ies

Since a DTM was missing near the border of the study area, photos were processed using georeferencing tools.

In year 1968 there are three blocks with numbers 1968, 1907, and 1914 (Table 3.3). They were taken by the same camera with focus length 99.40 mm in 1:42.000 scale. All photos, a total of 94, have 18x18 cm size. Flying altitude was calculated from focus length and scale. The airborne photos were scanned with 600 dpi. Other required information especially about the fiducial marks coordinates and the radial distortion of the lens were not supplied.

Table 3.3 The aerial photographs used for the year 1968

Year	Number of Blocks	Number of Photos	Approximated Scale	Approximated Flying Altitude	Focus length
1968	1968	9	1: 42.000	4.200 m	99.40 mm
1968	1907	50	1: 42.000	4.200 m	99.40 mm
1968	1914	35	1: 42.000	4.200 m	99.40 mm
Sum	-	94	-	-	-

Historical photos for the 40s are not taken in the same year. It was only possibility to get data from different years but it was not exactly known if the date was correct. According to the rough information about the photos the years were approximately 1940, 1942 and 1949. Since the differences between the landuse on the photos were rather small, to make the correct dating of the photos was difficult. Different cameras have been used. But the size was the same – 18x18 cm. Details on the photos for 1940s are given in Table 3.4.

Table 3.4 The aerial photographs used for the 40s

Year	Number of Block	Number of Photos	Approximated Scale	Approximated Flying Altitude	Focus length
~1940	48-b	33	1: 35.000	3.500 m	99.48 mm
~1942	55	36	1: 35.000	3.500 m	99.50 mm
~1949	518	45	1: 42.000	4.200 m	99.68 mm
Sum	-	114	-	-	-

3.1.4 Other types of data

The data types are not only satellite or airborne images but also some additional data for helping to detect land cover changes. These types of data can be grouped as follows:

- Topographical Maps
- Old city plans
- Geological Maps
- Digital Terrain Model
- Public Transport Data

3.1.4.1 Topographical Maps

Mostly in the areas, where maps from scale 1:25000 do not exist, some topographical maps from scale 1:5000 were used. These maps were used for georeferencing of satellite images. Another use of this type of data was to control the georeferenced satellite images. After georeferencing of satellite images, randomly selected areas were overlaid onto actual topographical maps from scale 1:5000 (Figure 3.9). This was another visual control of georeferencing.

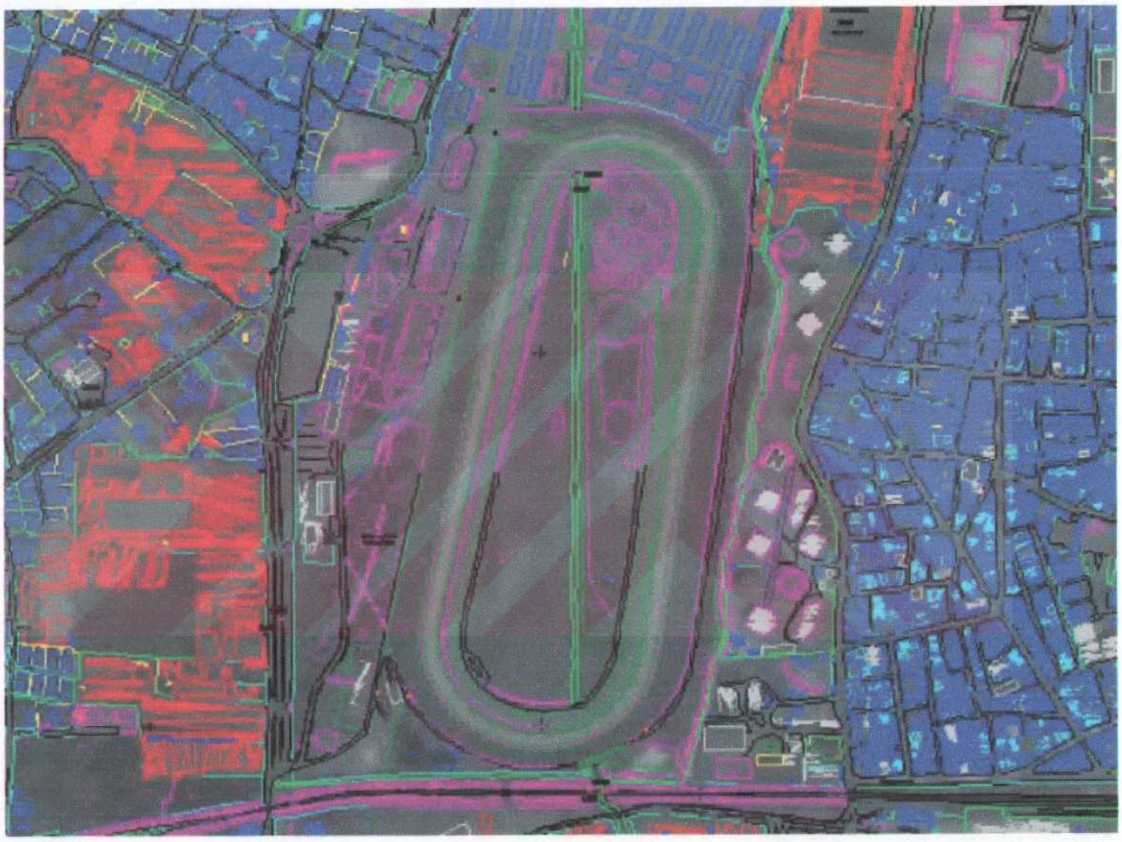


Figure 3.9 Comparison of an IRS-1D imagery with already existing digital vector map from scale of 1:5000

3.1.4.2 Old city plans

In additional to the maps from scale 1:25.000, 6 topographic city-plans in scale 1:16.000 have been acquired. They were printed 1978. The city plans cover only the central part of the study area, mainly the historical city and some part of the Bosphorus (Figure 3.10). They have been scanned as well but not georeferenced to the coordinate system of the study. Since they were belonging to late 70ies, they haven't contained any information related to the terrain. Even they were generalised in relation to the maps from scale 1:25.000, they have been used mainly for interpretation of old satellite and airborne photography.

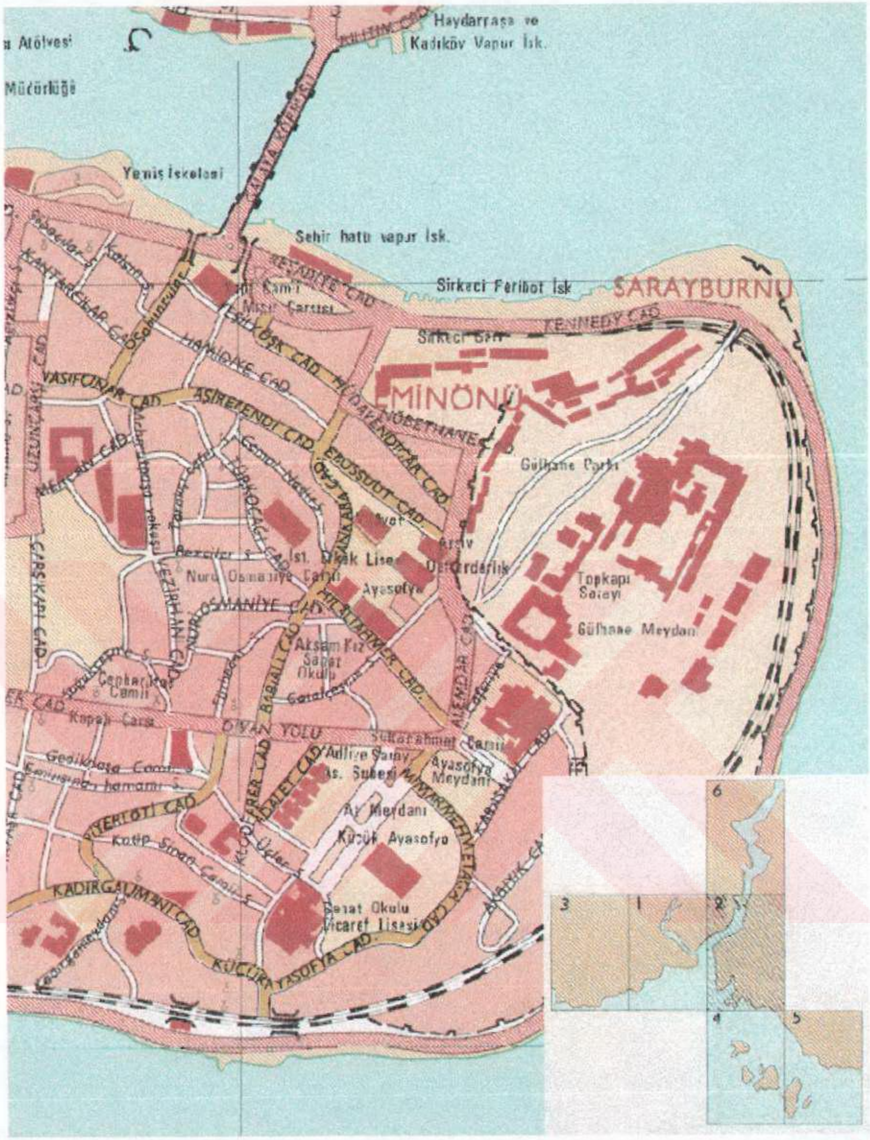


Figure 3.10 City map from scale of 1:16.000 with the overview-legend

3.1.4.3 Geological Maps

Different sets of geological maps covering the study area in different scale and quality and have been scanned and georeferenced. Especially one geological map from a scale 1:50000 covering the Bosphorus (Figure 3.11), properly georeferenced and digitised in vector form with a polygon-database of the geological formations. This map was containing quite more detailed information about the situation around the Bosphorus area than the other maps acquired. Other geological or geo-tectonic maps were acquired in raster format, but they had rather coarse resolution. Some of them have information about tectonically ruptures and a brief zonation of the earthquake risk.

Figure 3.11 Geological map covering Bosphorus from a scale of 1:50000 **(Ketin, 1990)**

3.1.4.4 Digital terrain model

For all the 1:25000 topographical maps, contour lines in vector format have been acquired. They are in DGN-format and been converted to DXF (3d) via AutoCAD.

They have been pre-processed in Atlas-DMT and in TopoL-GIS as well. This terrain model was already used for the orthorectification of the aerial photos. The contour lines have been completed by manual digitisation in some parts, especially on the Black Sea coast of the European side of Istanbul. In the case that this data are vectors, the quality is well and the resolution of contour lines is about 5 m. Contour lines and vertices of them have been used as break lines and points respectively by creating of DEM using Atlas-DMT. A new triangulated network was built with 1.1 million points, 2.2 million edges and 3.3 million triangles (Figure 3.12)

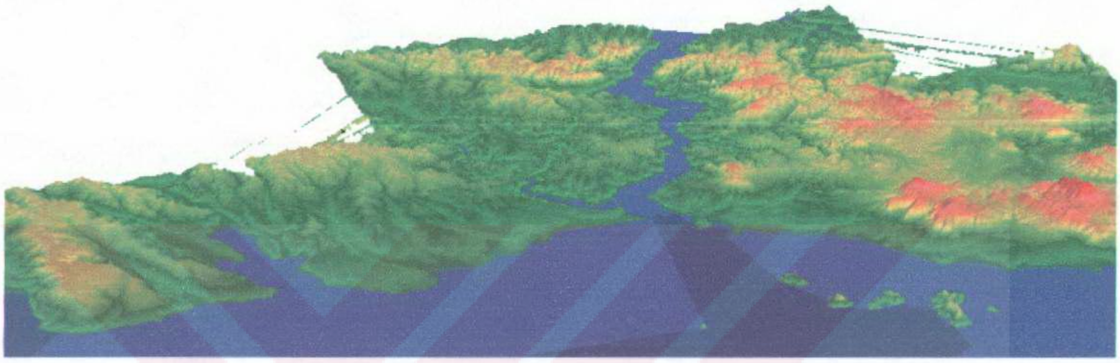


Figure 3.12 3D view of the terrain-model created.

3.1.4.5 Public transport data

A map of the public transport structures in scale 1:38.000 has been delivered and scanned and then georeferenced to the coordinate system of the study. The map was strongly generalised but all bus-stations were painted. The publishing date of this map is 2001.

On this map, the bus-lines with the bus-stations, the ferries of the Bosphorus and Marmara Sea with their harbours, railroads and railway stations, trams and their stops, the short but existing subways with entrance-points and the garages of the busses and trams were stored.

The bus stations have been mapped into a vector layer as points with an attached database. An example of this with the marked points can bee seen on the Figure 3.13.

During digitisation, the transportation network layer, already digitised from the reference imagery, was opened and been used to snap the bus-station to the vector-lines. Mostly it was possible to do so and in this way, the problem caused by the generalisation of public transportation map was solved partly.

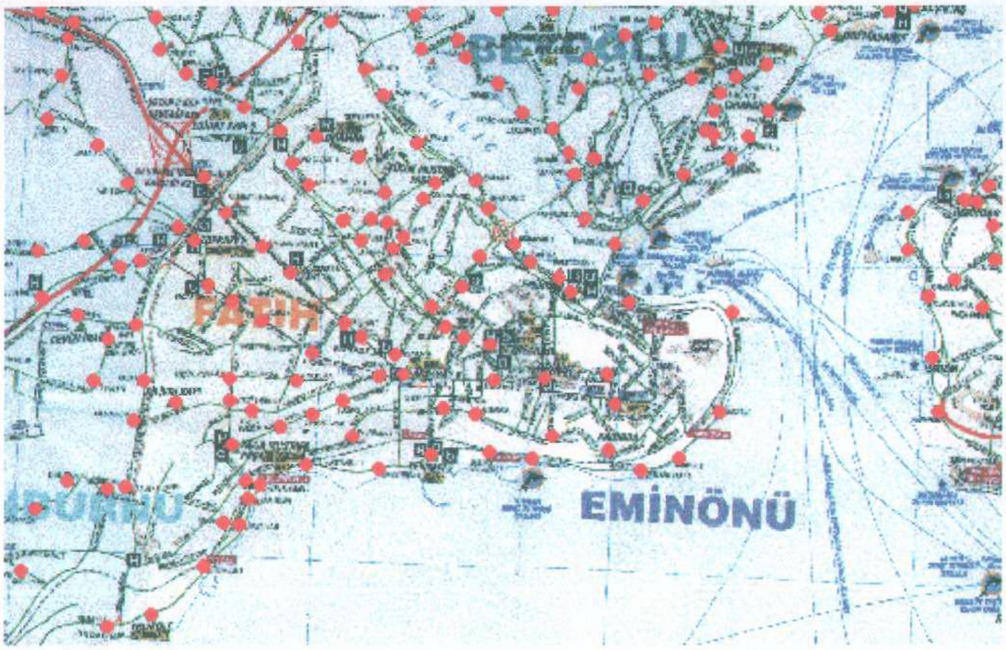


Figure 3.13 The map of public transport with the digitised bus stops

3.2 Techniques Used Within the Study

Line-Layer: First the linear elements (lines and polylines), such as transportation (road and rail) and river/sea-canal network, have been mapped according the legend, which is given in chapter 3.3., by using TopoL GIS system. Topological data-structure has been required. A middle line has been digitised for wide linear features such as boulevards or highways and as far as they have a bigger width than 25 m, they were also mapped in the area-layer as well. During digitisation each line-feature has been mapped first as a solo line up to the acceptance by the operator. After the line-object has been drawn, the database opened automatically and the dialogue-box for capturing the attributes appeared. When this step was done, the line was connected with the others to a topological structure by creation of nod-points and single-units between them. These lines are usually also boundaries for area-objects with the exception of wide road-features. An example for digitising of linear objects is given in Figure 3.14.

Area-Layer: The lines and polylines of the line-layer have been used as basement for the area-layer (polygon with label-point), only the middle line of linear-objects with bigger width than 25 m have been erased. All other areas with a homogeneous use according to the legendary have been defined by the boundary-line and the labelling-point with the attached database in its middle. The minimum recommended size is 1 ha. Smaller areas have been digitised as far as they are important. Also here topological mapping was required to reduce the work and the risk, which can appear, by redundant lines. Also the snap-mode has been set to lines and vertex points in a suitable radius to fill entire study area without macro rest polygons. The database was filled during defining the label-point inside the boundary. All lines, which have been digitised after the built up of areas, did cut this areas and divided them because of the topological structure. An example for digitising of areas is given in Figure 3.15.

3d Area-Layer: An additional area-layer was added in this study to take area objects into account, which would cover other area objects. These are namely big bridges (like the Bosphorus-bridges) and highway tunnels. These elements are on one side connected correctly by the middle-line in the line layer and further on by a direct neighbourhood to a related object in the area layer. In the case that only a few objects have been digitised into this layer, the snap mode has been enabled to snap to other, non-active layers as well to keep a semi-topological structure.

Temporal analysis has done by upgrading the changes of the 3 layers by going backwards in 1988, 1968 and 1940ies. Finally 4 line layers, 4 area layers and about 4 3D area layers have been developed. By using database-analyses and GIS-intersections the changes can be detected and quantified. First of the entire line layer had to be updated by the older images. Additional line-objects had to be added and others to be erased. The database had to be checked if the object attributes still fit to the legend. Then the updated lines and the lines of the newer area layer have been imported into a new empty layer. To import the database just for information, only the label points with attached area database have been read. Then also here the lines have been corrected as boundary lines. As far as the area and the use is the same, the area has been created automatically and the attributes taken from the point database.

However, all the streets, ways, railways, canals and rivers were digitised. There are only a few of them left, because they were not detectable from the images clearly. These polylines would be the basic data for the areas, which is the most important topic of the study.

Figure 3.14 Digitising of linear objects. Red: Fast transit roads and associated land (Legend code: 1.2.2.1), Lila: Other roads and associated roads (Legend code: 1.2.2.2)

Figure 3.15 Digitising of polygons. Red: Urban fabric (Legend code: 1.1.*.*), Lila: Industrial, commercial, public and private units (Legend code: 1.2.1.*), Green: Artificial non-agricultural vegetated areas (Legend code: 1.4.*.*), Yellow: Fast transit roads and associated land (Legend code: 1.2.2.1)

3.3 Legend

In order to make a good classification, legend must be suitable for the aim. Since the study area is the city of Istanbul, the minimum area of interest must be not so large. For this purpose, legends and classification strategies from relevant projects are examined. Projects on landuse change are mainly dealt with vegetation changes. In that kind of applications, legends contain very detailed information on vegetation but poor or no classes about artificial surfaces. Other kind of applications is about land cover analysis in both urbanized and non-urbanized surfaces. In much of these studies, minimum area of interest is about 25 ha such as Corine land cover projects.

Another point of view is that, in most of land use/cover studies classification is done by using image processing. In this situation, legend is mainly depends on the capability of sensors used.

In this study, manual digitisation method as well as manual classification was applied. That has an advantage of using the image interpretation and additional data such as maps by the step of classification. This causes the legend be more detailed for urbanised surfaces.

As it mentioned in chapter 1, the landuse types can be collected in following groups in the first step.

- Artificial surfaces
- Agricultural areas
- Forests and semi-natural areas
- Wetlands
- Water bodies

This grouping is a suitable start point but not enough for detailed classification. Based on this level 1 grouping, legend of Moland project of European Commission has taken as a reference.

This legend is a level-4 legend and contains detailed information about landuse classes in metropolitan areas and covering zones. This specification makes it suitable for the aim of this study.

Another advantage is that, using a standard legend will make the results of this study more realistic and gives an opportunity to combine them with other studies results.

Classes of this legend are outlined in Table 3.5 and detailed information of classes is given in Appendix B.

Table 3.5 Level-4 legend **(Kemper et al, 2002)**

1. Artificial surfaces	1.1 Urban fabric	1.1.1 Continuous urban fabric	1.1.1.1 Residential continuous dense urban fabric
			1.1.1.2 Residential continuous medium dense urban fabric
			1.1.1.3 Informal settlements
		1.1.2 Discontinuous urban fabric	1.1.2.1 Residential discontinuous urban fabric
			1.1.2.2 Residential discontinuous sparse urban fabric
			1.1.2.3 Residential urban blocks
			1.1.2.4 Informal discontinuous residential structures
	1.2 Industrial, commercial and transport units	1.2.1 Industrial, commercial, public and private units	1.2.1.1 Industrial areas
			1.2.1.2 Commercial areas
			1.2.1.3 Public and private services not related to the transport system
			1.2.1.4 Technological infrastructures for public service
			1.2.1.5 Archaeological sites
			1.2.1.6 Places of worship
			1.2.1.7 Non-vegetated cemeteries
			1.2.1.8 Hospitals
			1.2.1.9 Restricted access services
			1.2.1.10 Agro-industrial complexes
		1.2.2 Road and rail networks and associated land	1.2.2.1 Fast transit roads and associated land
			1.2.2.2 Other roads and associated land
			1.2.2.3 Railways and associated land
			1.2.2.4 Other rails
			1.2.2.5 Additional transport structures
			1.2.2.6 Parking sites for private vehicles
			1.2.2.7 Parking sites for public vehicles
		1.2.3 Port areas	
		1.2.4 Airports	
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites	
		1.3.2 Dump sites	
		1.3.3 Construction sites	
		1.3.4 Abandoned land	
	1.4 Artificial non-agricultural vegetated areas	1.4.1 Green urban areas	1.4.1.1 Vegetated cemeteries
		1.4.2 Sport and leisure facilities	

Table 3.5(Continued)

2. Agricultural areas	2.1 Arable land	2.1.1 Non-irrigated arable land	2.1.1.1 Arable land without dispersed vegetation
			2.1.1.2 Arable land with scattered vegetation
			2.1.1.3 Greenhouses
		2.1.2 Permanently irrigated land	
	2.3 Pastures	2.3.1 Pastures	2.3.1.1 Pastures without tree and shrubs
			2.3.1.2 Pastures with trees and shrubs
	2.4 Heterogeneous agricultural areas	2.4.2 Complex cultivation patterns	2.4.2.1 Complex cultivation patterns without settlement
			2.4.2.2 Complex cultivation patterns with scattered settlement
		2.4.3 Land principally occupied by agriculture (LPOA), with significant areas of natural vegetation (SANV)	2.4.3.1 Prevalence of arable land and SANV
			2.4.3.2 Prevalence of pastures and SANV
		2.4.4 Agro-forestry areas	
3. Forests and semi-natural areas	3.1 Forests	3.1.1 Broad-leaved forests	
		3.1.2 Coniferous forests	3.1.2.1 Coniferous forest with continuous canopy
		3.1.3 Mixed forests	3.1.3.1 Forest mixed by alternation of single trees with continuous canopy
	3.2 Shrub and/or herbaceous vegetation associations	3.2.1 Natural grassland	3.2.1.1 Coarse permanent grassland / Tall Herbs without trees and shrubs
			3.2.1.2 Coarse permanent grassland / Tall Herbs with trees and shrubs
			3.2.1.3 Coastal and floodplain meadow
		3.2.4 Transitional woodland / shrub	3.2.4.3 Natural young coniferous stands
			3.2.4.4 Wooded fens, bog and wooded transitional bog
	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes, sands	3.3.1.1 Dunes
			3.3.1.2 Beaches
		3.3.2 Bare rock	3.3.2.2 Coastal cliffs
		3.3.3 Sparsely vegetated areas	3.3.3.1 Sparse vegetation on sands
			3.3.3.2 Sparse vegetation on bare rock
4. Wetlands	4.1 Inland wetlands	4.1.2 Peat bog	
5. Water bodies	5.1 Inland waters	5.1.1 Water courses	5.1.1.1 Canals
			5.1.1.2 Rivers
		5.1.2 Water bodies	5.1.2.1 Natural standing water
			5.1.2.2 Artificial reservoirs
	5.2 Marine waters	5.2.3 Sea and oceans	

4 RESULTS AND ANALYSIS

The results can be divided into two groups, where the first group contains the results related to the landuse changes and the second contains the results related to the accuracy. The first group can rather be related to social results. In this group, the changes of landuse in Istanbul between the years taken into consideration were given with their examples and some reasons. In the second group of results, the main topic was considered as accuracy of the results in the first group.

4.1 Results Related to the Landuse

First part of results relevant to the landuse contains the landuse in reference year. This part of evaluation was very important for detection and monitoring of landuse changes. If the reference year was not evaluated as exactly as possible, the results about the landuse changes were not accurate. Some examples on the landuse in reference year are given in Appendix C.

As being the most important city of Turkey, Istanbul has growth rapidly. This rapid grow causes a big amount of landuse changes in city center and surrounding. Some examples on the landuse changes are given in following chapters.

4.1.1 Examples of the landuse classes

This part contains some examples of the classes and how they look as vector information, and on the different imageries. It should also be noted that not for all classes could be seen on IKONOS images or on the orthophotos, therefore examples relevant to all examples couldn't shown. The old ones were not shown here because most of the classes have changed too much and the number of examples would have been too small. However, it is thought that these examples give a good overview about the visibility of the different land-use classes on the different kind of imageries.

Here are commonly used classes according to legend. The shown examples are based on the reference year. Some classes have been detected very often through all years; others are only in some years valid.

- Residential continuous dense urban fabric (1.1.1.1):

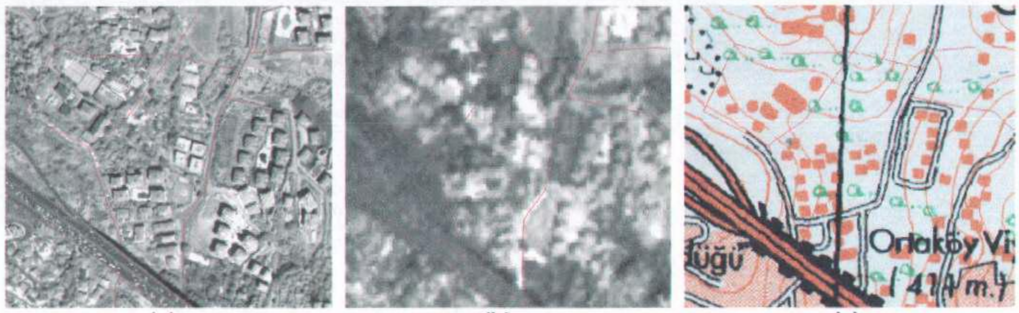
In this class, especially urban fabrics where buildings are closed together and which have several floors have been shown. It is not easy to say that this kind of structures is only available in the center of the city. It is well known, that Istanbul has not only one center according to its topography and urban density. This class is mainly used in center zone of the study. But there are some exceptions in buffer zone. The main use is residential but usually there are also small shops in the ground floor. There are also offices in upper floors. If it is clear that the buildings are both in commercial and residential use, the word “mixed” is added to attribute table. The purpose was to detect the main use. Figure 4.1 shows an example from the European part of Istanbul.

(a) (b) (c)

Figure 4.1 Residential continuous dense urban fabric on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Residential continuous medium dense urban fabric (1.1.1.2)

This class insists of buildings likely in class 1.1.1.1. But buildings in this class have either fewer stories than 1.1.1.1 or they are not in high density like 1.1.1.1. This class is used mainly used in centre zone. But likely class 1.1.1.1, there are some exceptions. Sometimes small gardens belong to such buildings but do not influence the density as much, as to put them in class 1.1.2.1. Figure 4.2 shows an example for this landuse class.

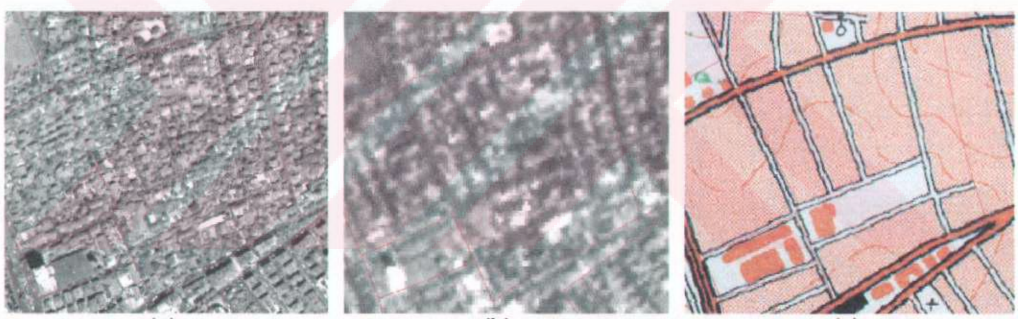


(a) (b) (c)

Figure 4.2 Residential continuous medium dense urban fabric on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Residential discontinuous urban fabric (1.1.2.1)

This class contains mainly the suburban buildings. But there are some parts in the centre of the city, where buildings are in this class. In these parts of the city, mainly rich people are living. That kind of class is mostly available around Bosphorus and suburban zone. These houses are not built up in connected style; they have space between, mostly used for garden, green area or others (Figure 4.3).



(a) (b) (c)

Figure 4.3 Residential discontinuous urban fabric (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Industrial areas (1.2.1.1)

As being the biggest metropolis and the economic centre of Turkey, Istanbul has of coarse lots of this kind of land use. The newer industrial areas are mostly in buffer zone. But also some of them are in centre zone. Figure 4.4 shows an example from center zone for this type of landuse class.

(a) (b) (c)

Figure 4.4 Industrial areas on (a) IKONOS pan; (b) IRS-1D pan; (b) Map 1:25000

- Commercial areas (1.2.1.2)

One of the common classes beside the industrial one is commercial area. It is not only shops, which you usually can find everywhere but not as the dominant use, it is also lots of skyscrapers, which are used commercial as well like for offices, banks etc. Modern commercial sites are located mostly in the new developing city regions, or on important trade place especially Historical Peninsula, which is mostly covered by that kind of land use. An example for this type of landuse class with tall buildings is given in Figure 4.5.

(a) (b) (c)

Figure 4.5 Commercial areas on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Public and private services not related to transport system (1.2.1.3)

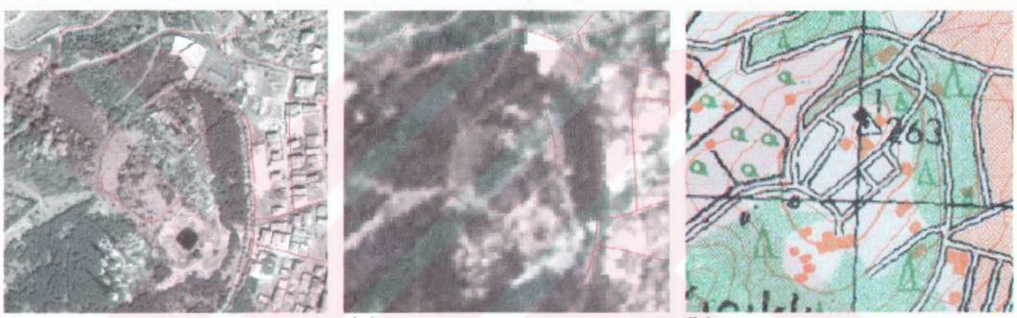
With 10 Million citizens, there is a need in having a big amount of public and private services for Istanbul. These ones are not only in centre zone. Schools, universities, public building etc. are collected in this group. Figure 4.6 shows an example for hospitals, classified in this group.

(a) (b) (c)

Figure 4.6 Public and private services not related to transport system on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Technological Infrastructures for public use (1.2.1.4)

In this class, there are radio and TV towers (If they are together and clearly visible), electric infrastructures etc. A TV tower and its associated land is given in Figure 4.7.

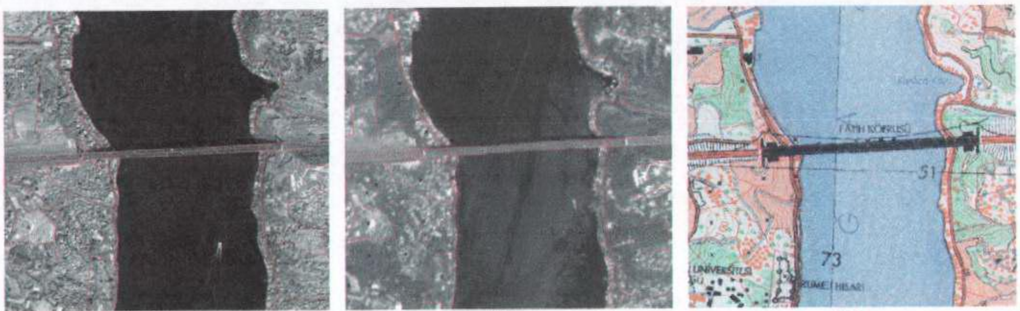


(a) (b) (c)

Figure 4.7 Technological infrastructure (radio-transmitter) on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Fast transit roads and associated land (1.2.2.1)

In this class there are main bypass roads and one part of motorway. On the line layer, bridges on the Bosphorus were defined in this class. The main difference of this class from the class "other ways" is that the roads in this class are that the pedestrians cannot reach them and they have minimum 4 strips. In case of bridges, there has to be paid a road-tax as well. Highways in Turkey do not need vignette or tax; so far this argument cannot be used. Fatih Sultan Mehmet Bridge is given as an example for this class of landuse in Figure 4.8.

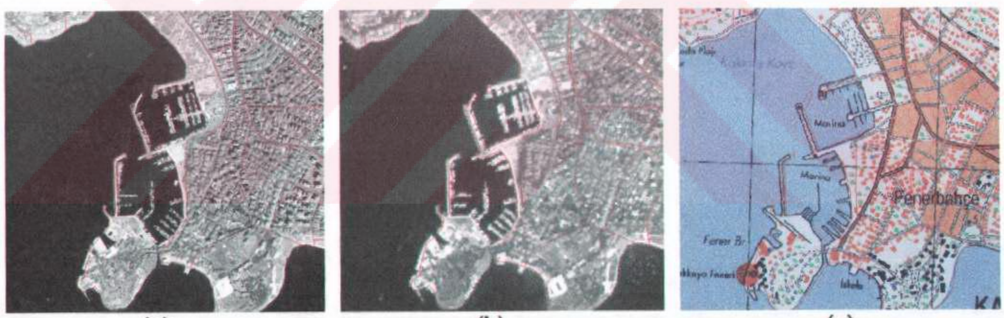


(a) (b) (c)

Figure 4.8 Fast transit roads (Fatih Sultan Mehmet Bridge) on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Port areas (1.2.3)

Being surrounded with the Bosphorus, the Golden Horn and two seas causes Istanbul to have several ports. Also traditional Istanbul is an important port-site. These ports are used for public inner-city transport, public inter-city transport, public international transport, commercial transport and private use. Several ports, which are used for public city transport, are less then 1 ha. The ports are often connected to sporting and industry. Figure 4.9 shows an example for private yacht ports.



(a) (b) (c)

Figure 4.9 Port areas on (a) IKONOS pan; (b) IRS-1D pan; (b) Map 1:25000

- Abandoned land (1.3.4)

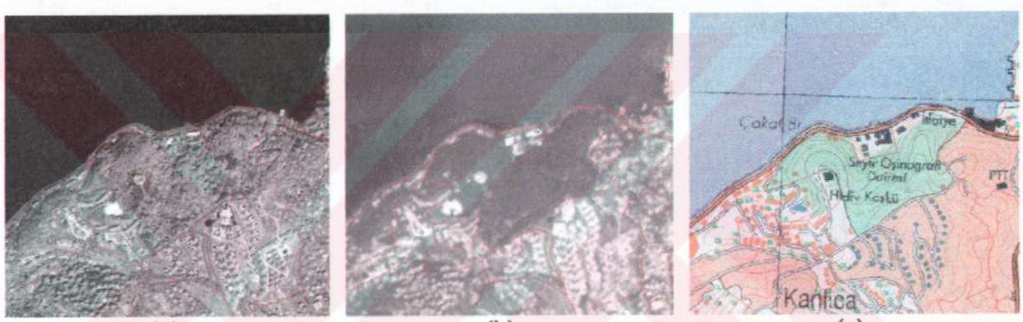
In both centre and buffer zone, there are lots of areas, on which a particular use cannot be seen (Figure 4.10). That kind of areas is defined in this group. Such areas seem to be free of planning but they have big potential for development either for residential, commercial or industrial, or for green urban areas.

(a) (b) (c)

Figure 4.10 Abandoned land on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Green urban areas (1.4.1)

There are lots of city parks and green urban areas in Istanbul. They are mostly around the Bosphorus and the Golden Horn. Figure 4.11 shows an example for this landuse class from the Bosphorus area.

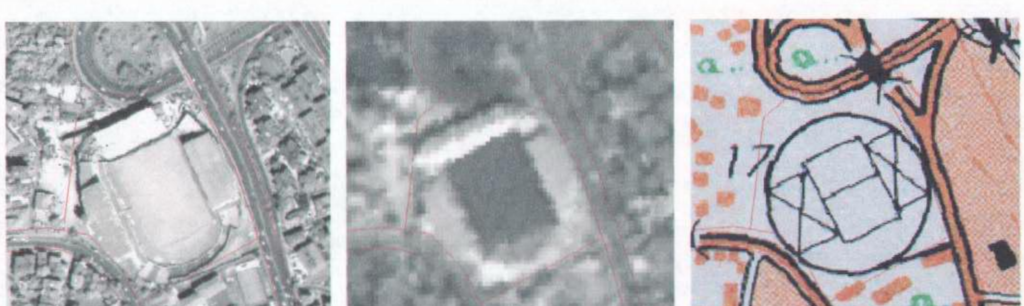


(a) (b) (c)

Figure 4.11 Green urban areas on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

- Sport and leisure facilities (1.4.2)

In this class, there are mainly public sport complexes, stadiums and some private sport centers. A stadium can be seen in Figure 4.12 as an example for Sport and leisure facilities.



(a) (b) (c)

Figure 4.12 Sport and leisure facilities on (a) IKONOS pan; (b) IRS-1D pan; (c) Map 1:25000

4.1.2 Examples of landuse changes

Because of being the most important city of Turkey, Istanbul has growth rapidly since the foundation of Turkish Republic. Especially after the 40ies, this growing and related to it, the change of land use is enormous. The landuse change is directly visible on the imagery, which will be shown on the following figures.

4.1.2.1 Change from agriculture to residential surface

All the agricultural surfaces in 1940ies have a total size of 950 km²; the residential surface counts 65 km². In 2000 it is only 388 km² under agricultural use but 485 km² under residential fabric. This shows the typical change of agricultural areas to urban settlements. Figure 4.13 outlines the change from agriculture to residential surfaces with the imageries and the borders of detected landuse classes.

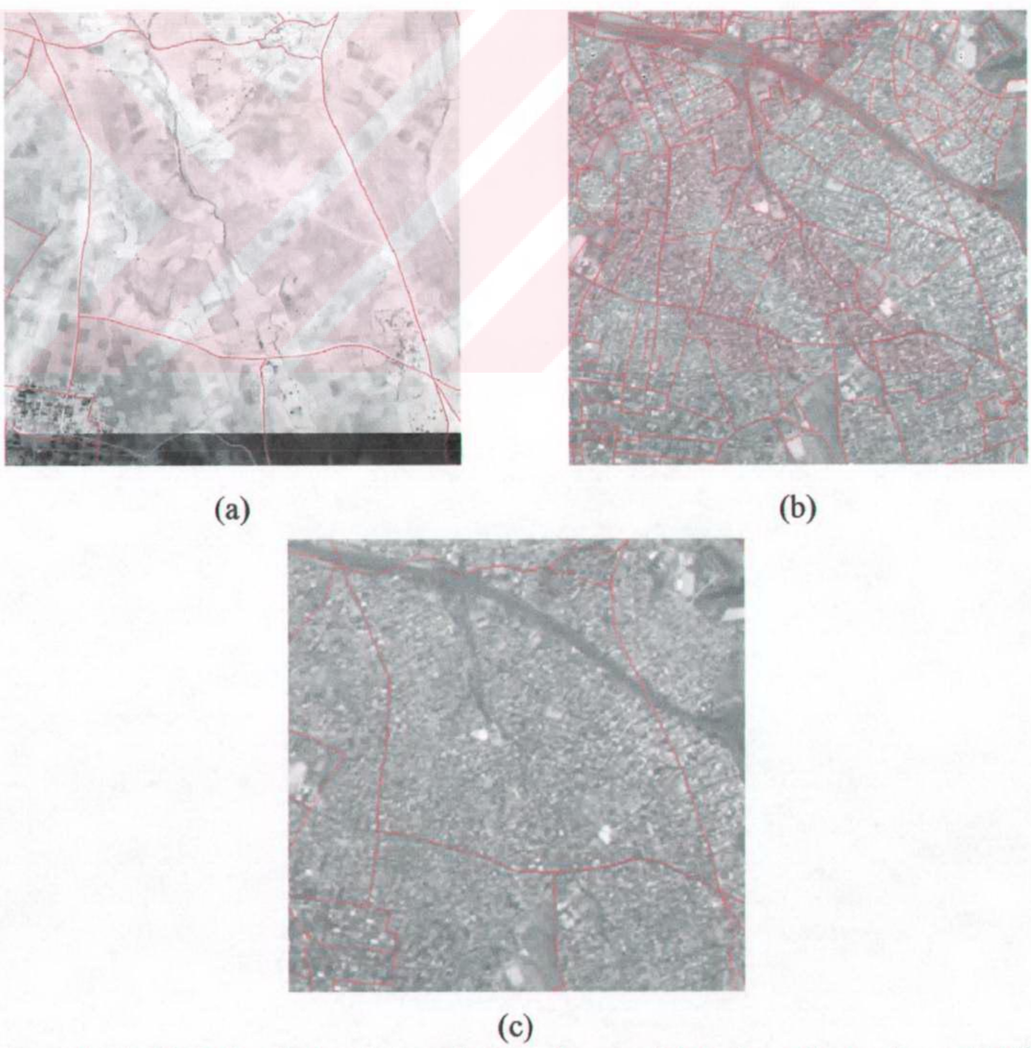
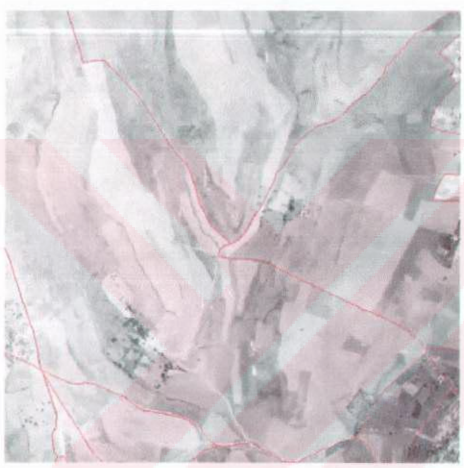


Figure 4.13 (a) Orthophoto of an agricultural area with its boundaries from 1940ies (b) IRS-1D image of the same are in residential usage with its boundaries from 2000 (c) IRS-1D image and the landuse boundaries from 1940ies overlapped.

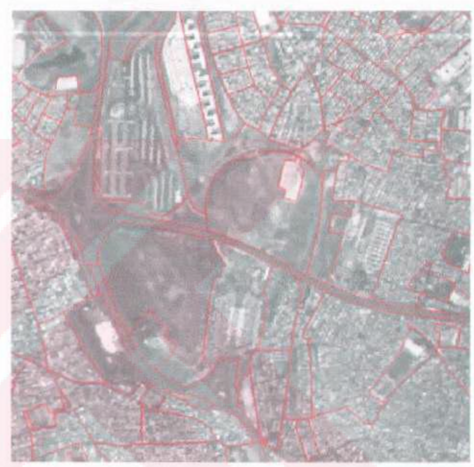
Only a small amount of old geomorphologic structures have been kept. The old rivulet still can be seen, the village-structure right up is still alive and some of the old roads are used inside of the residential area. All other structures have been removed totally; especially the highway cuts the former landscape without recognition of the former structure.

4.1.2.2 Change from agriculture to industrial, commercial and transport units

Other big changes are detectable in agriculture to industrial, commercial and transport units. In 1940ies, only 55 km² have been covered by business areas, in the year 2000 it was grown to 370 km². This kind of change is illustrated in Figure 4.14.



(a)



(b)

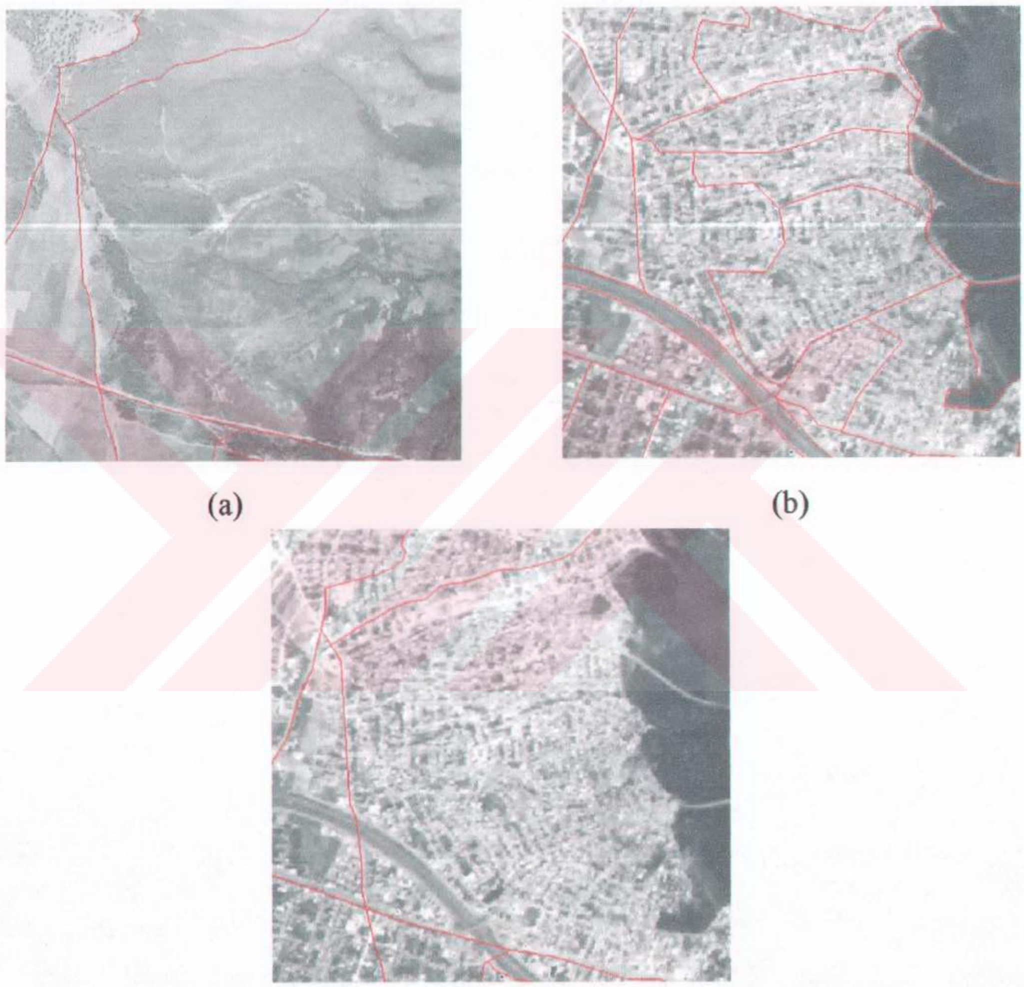
(c)

Figure 4.14 (a) Orthophoto of an agricultural area with its boundaries from 1940ies (b) IRS-1D image of the same are in industrial, commercial and transport usage with its boundaries from 2000 (c) IRS-1D image and the landuse boundaries from 1940ies overlapped.

As can be seen from this example, the structure has been changed totally. Only some former roads are much the same as the reference ones.

4.1.2.3 Change from forestry to urban surface

The amount of the loss of forests is big between the old time periods but later relatively small, moreover there is some growth between 1988 and 2000 according to land-use change from agriculture to forestry. Nevertheless forestry areas have changed to urban fabric. One example related to this kind of change is given in Figure 4.15.



(a) (b) (c)

Figure 4.15 (a) Orthophoto of a forest with its boundaries from 1940ies (b) IRS-1D image of the same are in residential usage with its boundaries from 2000 (c) IRS-1D image and the landuse boundaries from 1940ies overlapped.

The landscape has changed totally; only in the east part of the forest area is the same but with more closed structure than in 1940ies, where an open spaced forest can be seen.

4.1.2.4 Change at the coastline

Another detectable land use dynamics in Istanbul is at the coastline. Constructions for land winning or filling the sea to gain land can be seen. But this was not done like artificial marches, it was directly connected with constructive activities. Because of some infrastructure needs such as roads, ports etc. lots of hectares are filled in order to gain usable land (Figure 4.16). Examples for this property can be detected especially in the Marmara Region, both Asian and European sides.

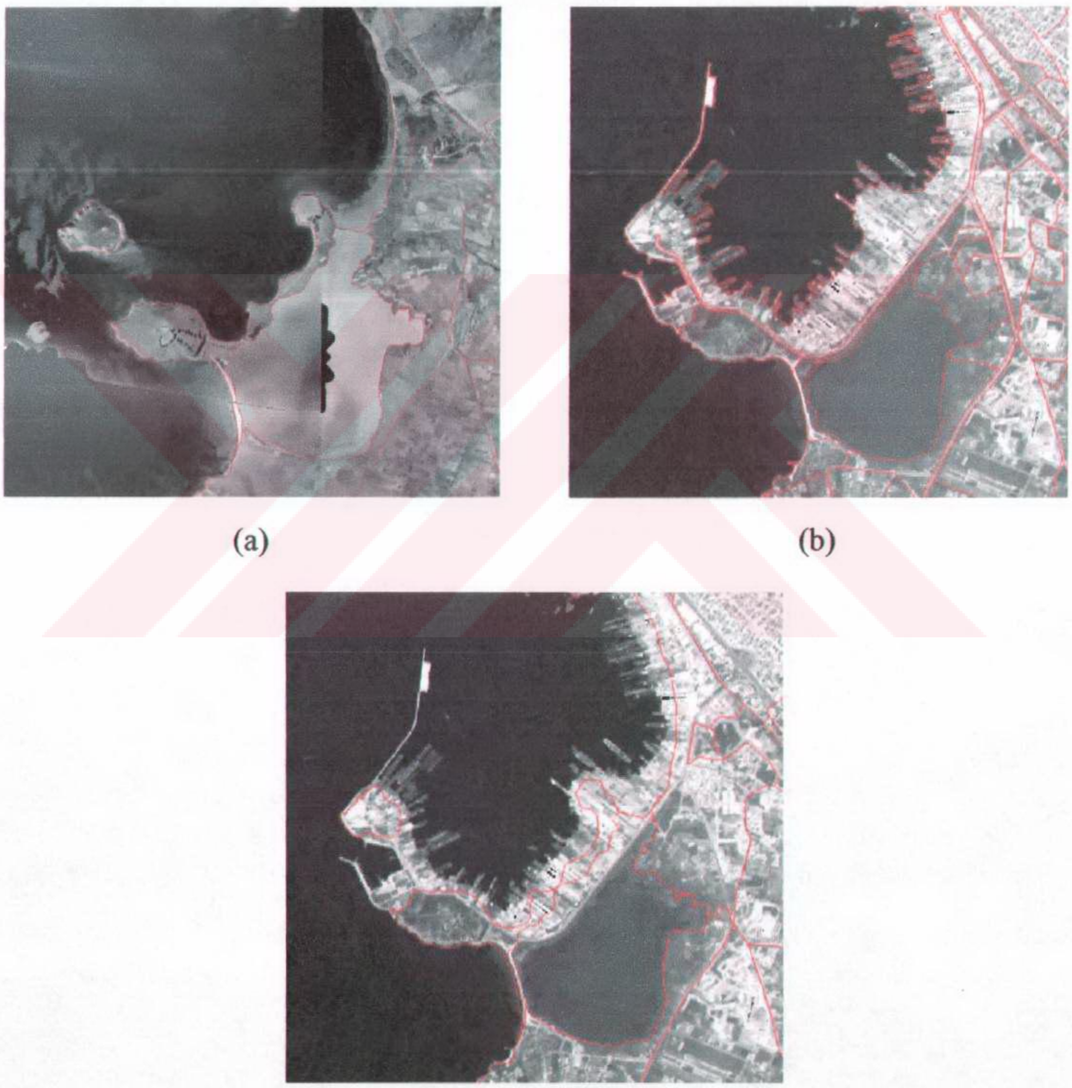


Figure 4.16 (a) Orthophoto of an area and the coastline of Marmara Sea in the south-eastern part of Istanbul from 1940ies (b) IRS-1D image of the same area and coastline from 2000 (c) IRS-1D image and the landuse boundaries as well as coastline from 1940ies overlapped.

In this example, natural basement is clearly visible under the actual surface, which seems completely artificial. The coastal cliffs and beaches have been used for the establishment of port areas with related industry.

4.1.2.5 Change in the transport-features; Bosphorus Bridge

The Bosphorus Bridge initiated a big change in the landuse. The northern bridge, the Fatih Sultan Mehmet Bridge, was constructed in the 80ies and opened in 1988. The photos below show the growth of it. Figure 4.17 shows the development stages of the bridge.

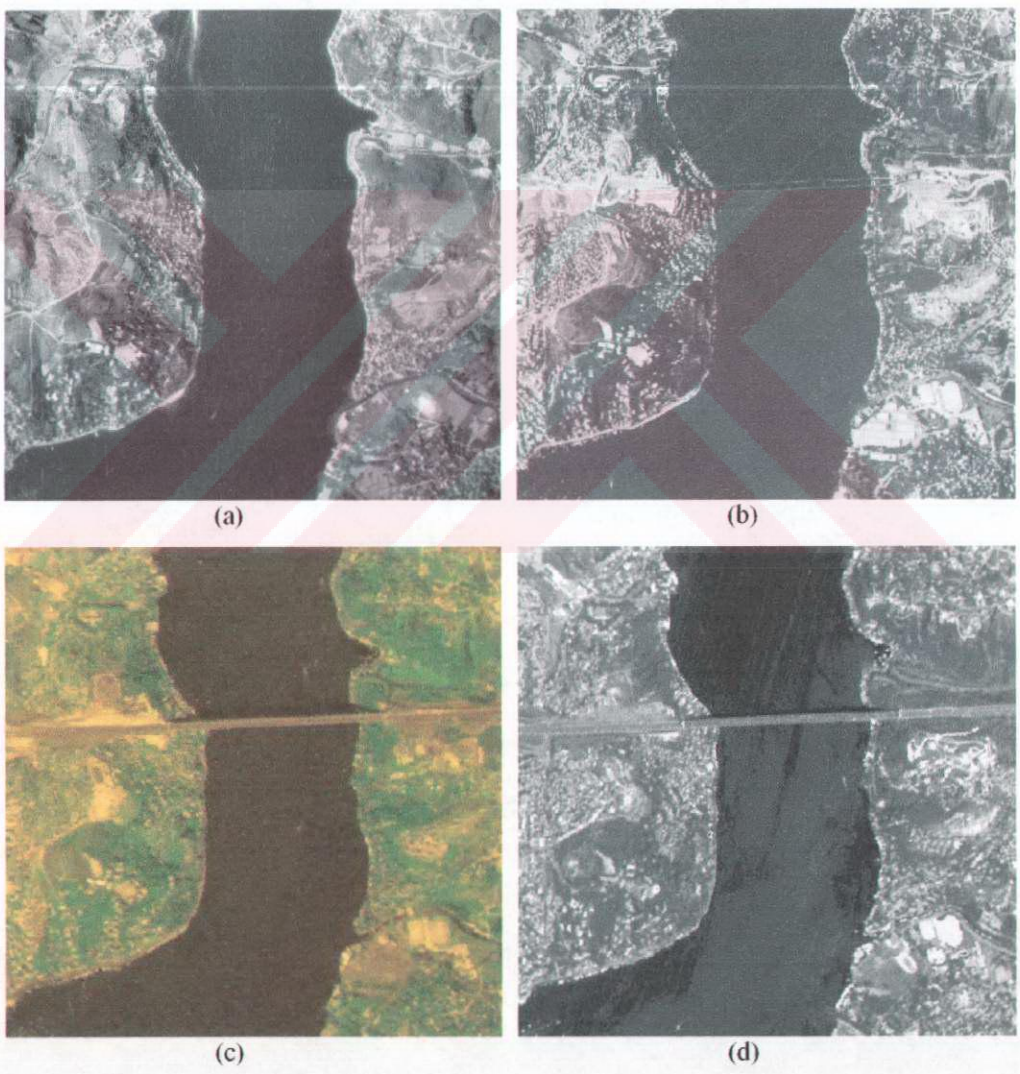


Figure 4.17 (a) Orthophoto from the year 1940ies. (b) KVR-1000 image from the year 1987, where the bridge is under construction. (c) KFA-1000 image from the year 1988 where the bridge is nearly finished. (d) IRS image from 2000

4.1.3 Statistical landuse results

In order to give some statistical results of landuse changes, it is very important to examine the results for each year individually. After that, individual results will be merged and in that way landuse changes will be analyzed and monitored.

4.1.3.1 Reference landuse data set 2000

As being the reference year, 2000 was the most important and difficult data set for evaluating. The results for the reference year are outlined in Table 4.1 and 4.2 and shown in Figure 4.18 and 4.19.

Table 4.1: Statistical results of the landuse classes for the reference year

Polygons 2000	class-size in ha	no. of areas/class	mean-size /area/class in ha	**Polygons 2000**	class-size in ha	no. of areas/class	mean-size /area/class in ha
1.1.1.1	21141,111	3332	6,345	2.1.1	2361,321	55	42,933
1.1.1.2	13886,323	1589	8,739	2.1.1.1	4099,154	122	33,600
1.1.1.3	385,841	103	3,746	2.1.1.2	54,533	5	10,907
1.1.2.1	5841,648	674	8,667	2.1.1.3	27,392	3	9,131
1.1.2.2	4238,708	379	11,184	2.1.2	26163,280	487	53,723
1.1.2.3	3003,208	429	7,000	2.3.1.1	0,000	0	
1.1.2.4	9,477	3	3,159	2.3.1.2	9,095	4	2,274
1.2.1.1	9669,110	621	15,570	2.4.2	0,000	0	
1.2.1.2	3361,853	726	4,631	2.4.2.1	726,401	4	181,600
1.2.1.3	1288,678	282	4,570	2.4.2.2	3574,202	144	24,821
1.2.1.4	376,182	25	15,047	2.4.3	168,193	4	42,048
1.2.1.5	91,291	14	6,521	2.4.3.1	1391,002	50	27,820
1.2.1.6	68,557	25	2,742	2.4.3.2	177,887	2	88,944
1.2.1.7	73,502	10	7,350	2.4.4	58,219	7	8,317
1.2.1.8	223,810	11	20,346	3.1.1	32292,347	289	111,738
1.2.1.9	1662,577	57	29,168	3.1.2	5055,004	92	54,946
1.2.1.10	114,321	11	10,393	3.1.2.1	0,000	0	
1.2.2.1	1443,408	43	33,568	3.1.3	34514,801	425	81,211
1.2.2.2	1264,568	71	17,811	3.1.3.1	47,855	1	47,855
1.2.2.3	249,172	19	13,114	3.2.1	3,595	2	1,798
1.2.2.4	11,866	1	11,866	3.2.1.1	2472,645	361	6,849
1.2.2.5	2,664	1	2,664	3.2.1.2	12073,014	734	16,448
1.2.2.6	160,965	46	3,499	3.2.1.3	149,695	10	14,970
1.2.2.7	120,447	26	4,633	3.2.4	2831,214	18	157,290
1.2.3	721,667	64	11,276	3.2.4.3	0,000	0	
1.2.4	1502,286	4	375,572	3.2.4.4	53,954	2	26,977
1.3.1	3947,684	85	46,443	3.3.1.1	10,201	1	10,201
1.3.2	12,014	1	12,014	3.3.1.2	75,662	13	5,820
1.3.3	5480,435	532	10,302	3.3.2.2	135,902	48	2,831
1.3.4	5118,123	374	13,685	3.3.3.1	2,435	2	1,218
1.4.1	1075,306	155	6,937	3.3.3.2	0,000	0	
1.4.1.1	378,766	47	8,059	4.1.2	8,273	2	4,137
1.4.2	571,407	106	5,391	5.1.1.1	59,327	6	9,888
				5.1.1.2	111,402	8	13,925
				5.1.2.1	4224,923	17	248,525
				5.1.2.2	3069,461	27	113,684
				5.2.3	87262,861	5	17452,572
				total	**310762,225**	**12816**	**24,248**

Table 4.2:Statistics relevant to the polygons and vectors of the reference year

total area size in ha	310762,225
Number of areas	12816
Area classes	65
Smallest area	0,102
Biggest area	69517,973
Areas per km²	4,124
Mean area-size in ha	24,248
Total line length in km	16559,228
Number of lines	117529
Lines per km²	37,820
Mean length in m	141
Line density in km/km²	5,329
Number of 3d objects	23
Total size in ha	43,306

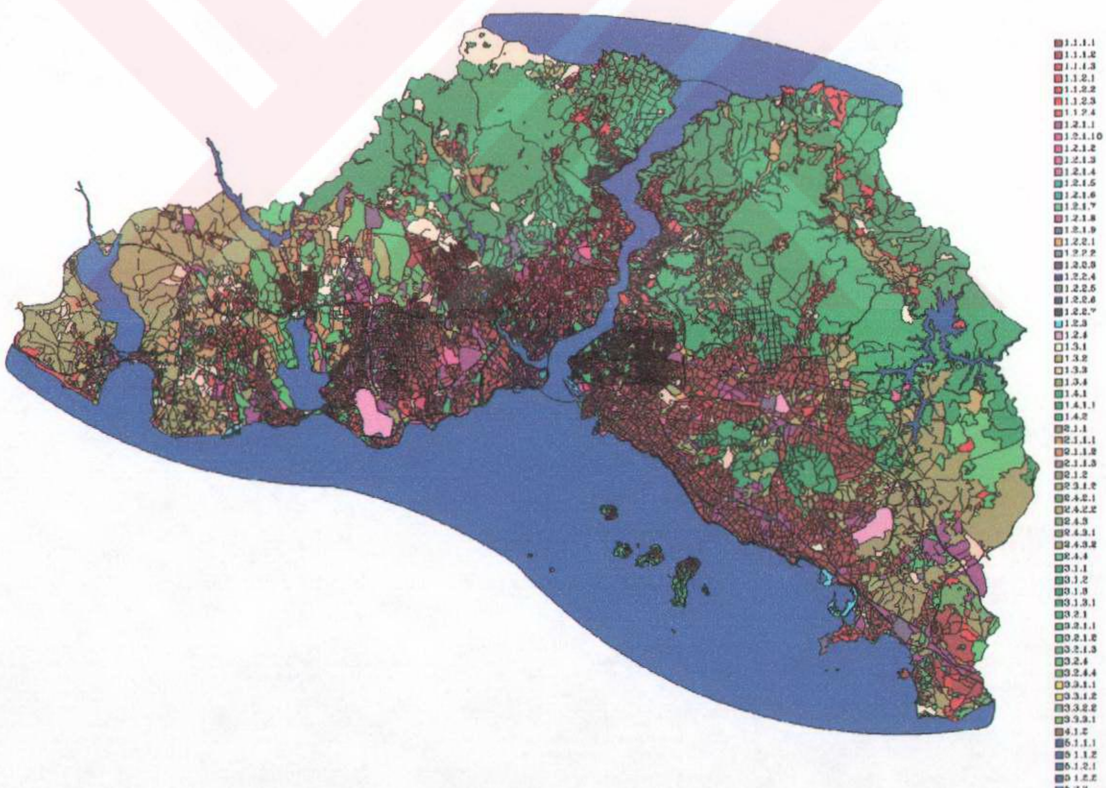


Figure 4.18 Landuse polygons with legendary for 2000

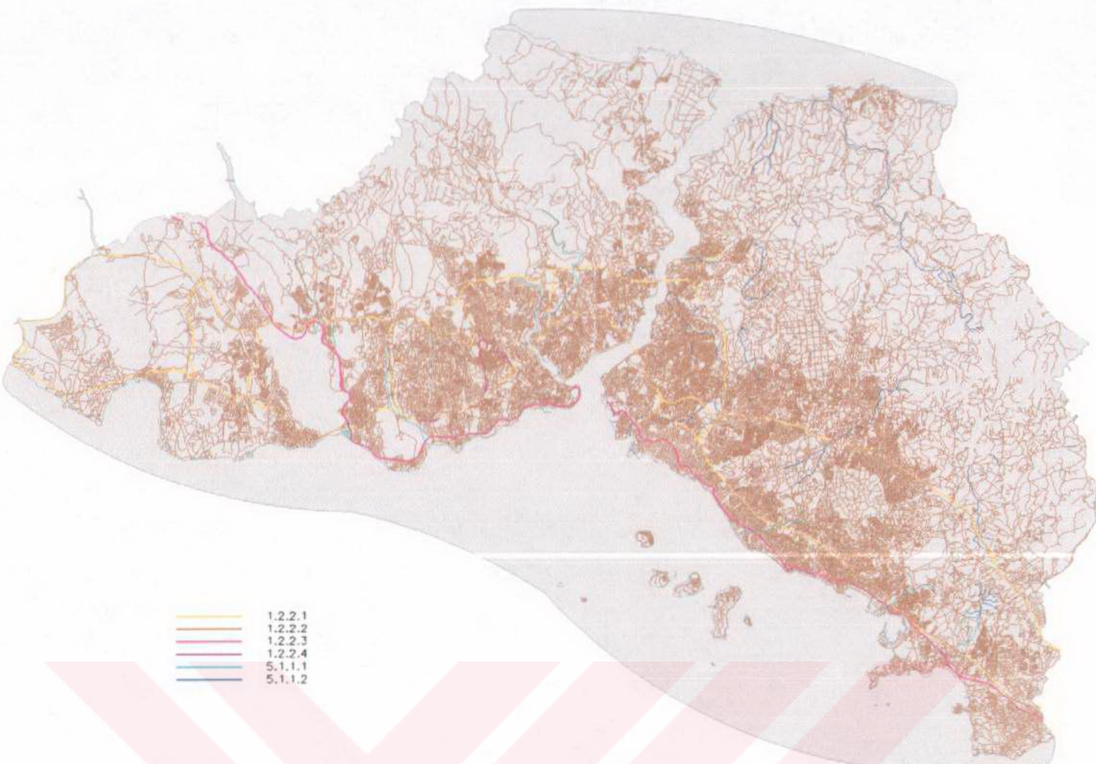


Figure 4.19 Transportation network with legendary for 2000

4.1.3.2 Landuse data set for 1988

After evaluating the reference year, evaluation for 1988 has been completed. The evaluation was done by downdating of the results of reference year. The results for the year 1988 are outlined in Table 4.3 and 4.4 and shown in Figure 4.20 and 4.21.

Table 4.3: Statistical results of the landuse classes for the year 1988

Polygons 1988	class-size in ha	no. of areas/class	mean-size /area/class in ha
1.1.1.1	8655,013	994	8,707
1.1.1.2	11412,937	956	11,938
1.1.1.3	99,379	20	4,969
1.1.2.1	5954,347	505	11,791
1.1.2.2	10130,285	812	12,476
1.1.2.3	622,174	71	8,763
1.1.2.4	11,629	2	5,815
1.2.1.1	5536,812	317	17,466
1.2.1.2	2163,754	410	5,277
1.2.1.3	899,393	156	5,765
1.2.1.4	125,148	11	11,377
1.2.1.5	96,318	14	6,880
1.2.1.6	56,548	18	3,142
1.2.1.7	67,148	6	11,191
1.2.1.8	222,865	10	22,287
1.2.1.9	1452,134	48	30,253
1.2.1.10	176,244	17	10,367
1.2.2.1	670,156	15	44,677
1.2.2.2	579,866	45	12,886
1.2.2.3	244,162	14	17,440
1.2.2.4	0,000	0	0,000
1.2.2.5	0,000	0	0,000
1.2.2.6	40,797	15	2,720
1.2.2.7	40,986	10	4,099
1.2.3	441,331	57	7,743
1.2.4	908,349	2	454,175
1.3.1	2273,432	49	46,397
1.3.2	6,942	1	6,942
1.3.3	5948,830	407	14,616
1.3.4	9797,446	896	10,935
1.4.1	1621,758	213	7,614
1.4.1.1	315,834	29	10,891
1.4.2	242,357	36	6,732

Polygons 1988	class-size in ha	no. of areas/class	mean-size /area/class in ha
2.1.1	9954,781	256	38,886
2.1.1.1	9139,731	154	59,349
2.1.1.2	230,334	8	28,792
2.1.1.3	0,000	0	0,000
2.1.2	36717,753	607	60,491
2.3.1.1	0,000	0	0,000
2.3.1.2	4,472	1	4,472
2.4.2	1,121	1	1,121
2.4.2.1	2094,433	14	149,602
2.4.2.2	3072,653	105	29,263
2.4.3	275,189	3	91,730
2.4.3.1	1048,041	29	36,139
2.4.3.2	0,000	0	0,000
2.4.4	41,814	5	8,363
3.1.1	21946,449	244	89,944
3.1.2	2310,495	70	33,007
3.1.2.1	18,674	1	18,674
3.1.3	48209,833	423	113,971
3.1.3.1	47,855	1	47,855
3.2.1	9,873	3	3,291
3.2.1.1	999,044	97	10,299
3.2.1.2	5386,959	198	27,207
3.2.1.3	197,931	10	19,793
3.2.4	3246,828	16	202,927
3.2.4.3	0,000	0	0,000
3.2.4.4	217,171	5	43,434
3.3.1.1	0,000	0	0,000
3.3.1.2	257,924	27	9,553
3.3.2.2	148,965	57	2,613
3.3.3.1	14,406	3	4,802
3.3.3.2	0,000	0	0,000
4.1.2	0,000	0	0,000
5.1.1.1	166,680	4	41,670
5.1.1.2	76,385	6	12,731
5.1.2.1	3993,455	11	363,041
5.1.2.2	2381,315	24	99,221
5.2.3	87728,897	4	21932,224
total	**310753,835**	**8543**	**36,375**

Table 4.4: Statistics relevant to the polygons and vectors of the year 1988

Total area size in ha	310753,835
Number of areas	8543
Area classes	62
Smallest area	0,222
Biggest area	69977,382
Areas per km²	2,749
Mean area-size in ha	36,375
Total line length in km	14684,661
Number of lines	106186
Lines per km²	34,170
Mean length in m	138
Line density in km/km²	4,725
Number of 3d objects	17
Total size in ha	29,791

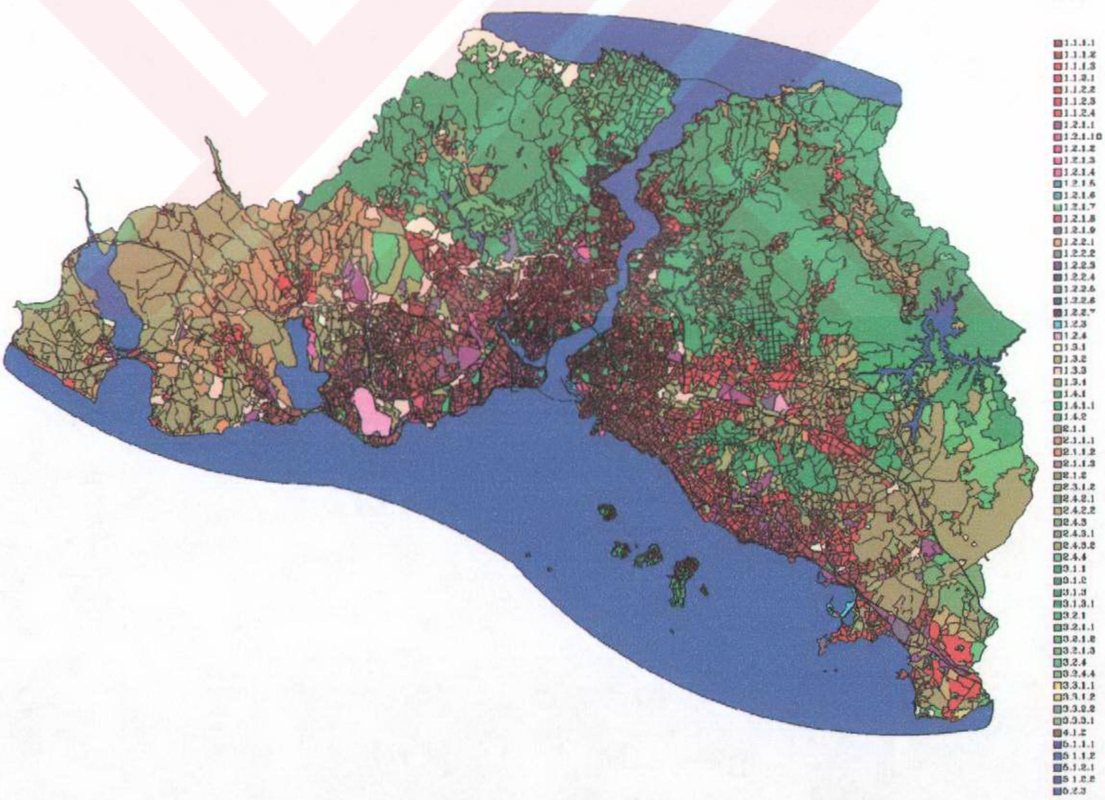


Figure 4.20 Landuse polygons with legendary for 1988

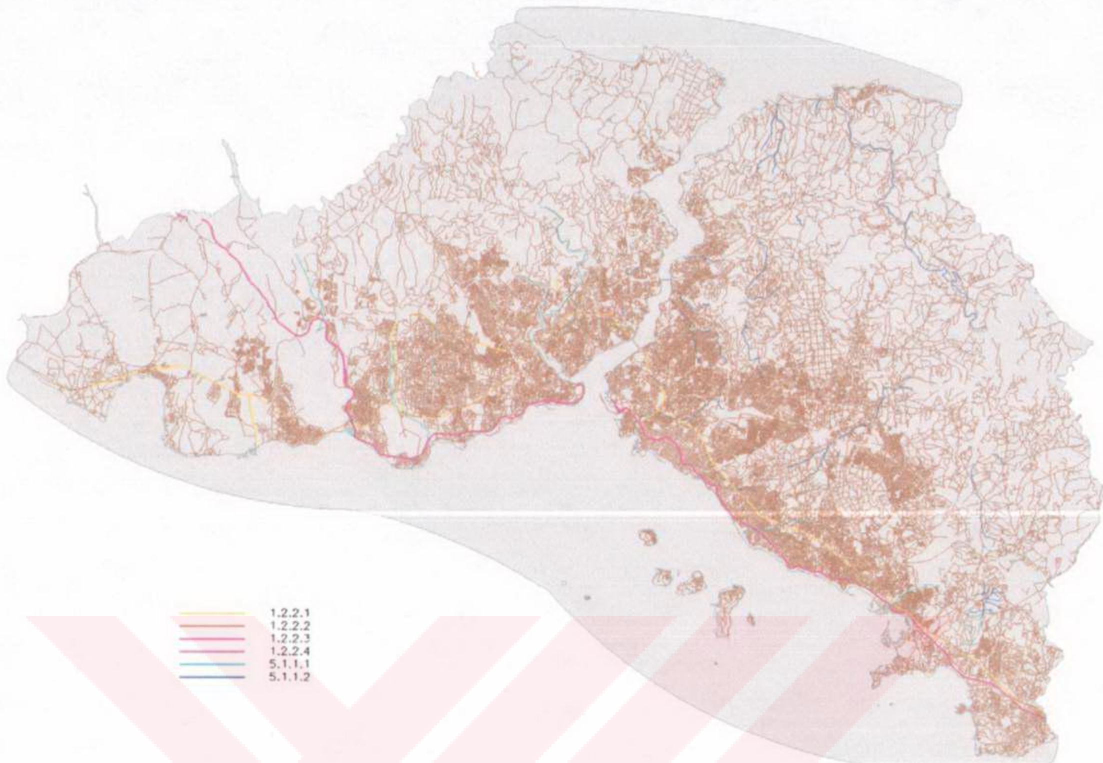


Figure 4.21 Transportation network with legendary for 1988

4.1.3.3 Landuse data set for 1968

For the historical year 1968, aerial photography has been used. For this purpose, 94 aerial photographs were scanned and all of them were orthorectified. Table 4.5 and Table 4.6 show the results of the historical year 1968.

Table 4.5: Statistical results of the landuse classes for the historical year 1968

Polygons 1968	class-size in ha	no. of areas/class	mean-size /area/class in ha
1.1.1.1	2228,343	318	7,007
1.1.1.2	4967,680	512	9,703
1.1.1.3	0,000	0	0,000
1.1.2.1	2797,559	250	11,190
1.1.2.2	4237,065	460	9,211
1.1.2.3	161,389	22	7,336
1.1.2.4	0,000	0	0,000
1.2.1.1	1597,150	174	9,179
1.2.1.2	1063,250	179	5,940
1.2.1.3	645,638	105	6,149
1.2.1.4	28,721	7	4,103
1.2.1.5	103,323	15	6,888
1.2.1.6	48,144	13	3,703
1.2.1.7	31,963	6	5,327
1.2.1.8	201,100	7	28,729
1.2.1.9	353,758	25	14,150
1.2.1.10	86,192	10	8,619
1.2.2.1	0,000	0	0,000
1.2.2.2	424,797	30	14,160
1.2.2.3	95,626	4	23,907
1.2.2.4	0,000	0	0,000
1.2.2.5	0,000	0	0,000
1.2.2.6	3,875	2	1,938
1.2.2.7	11,062	4	2,766
1.2.3	152,738	42	3,637
1.2.4	694,448	2	347,224
1.3.1	354,362	24	14,765
1.3.2	0,000	0	0,000
1.3.3	1607,121	133	12,084
1.3.4	6156,060	419	14,692
1.4.1	625,380	83	7,535
1.4.1.1	221,823	16	13,864
1.4.2	133,064	12	11,089

Polygons 1968	class-size in ha	no. of areas/class	mean-size /area/class in ha
2.1.1	8350,504	121	69,012
2.1.1.1	5349,926	56	95,534
2.1.1.2	1462,418	16	91,401
2.1.1.3	0,000	0	0,000
2.1.2	68942,586	1304	52,870
2.3.1.1	228,701	5	45,740
2.3.1.2	2283,269	95	24,034
2.4.2	0,000	0	0,000
2.4.2.1	1945,172	39	49,876
2.4.2.2	5024,678	236	21,291
2.4.3	51,004	2	25,502
2.4.3.1	478,794	6	79,799
2.4.3.2	0,000	0	0,000
2.4.4	15,761	1	15,761
3.1.1	25916,873	187	138,593
3.1.2	2385,485	63	37,865
3.1.2.1	0,000	0	0,000
3.1.3	48133,118	378	127,336
3.1.3.1	45,253	1	45,253
3.2.1	27,713	3	9,238
3.2.1.1	1866,537	74	25,223
3.2.1.2	12852,414	259	49,623
3.2.1.3	89,578	6	14,930
3.2.4	3615,349	18	200,853
3.2.4.3	0,000	0	0,000
3.2.4.4	122,417	3	40,806
3.3.1.1	405,666	4	101,417
3.3.1.2	91,828	15	6,122
3.3.2.2	201,123	56	3,591
3.3.3.1	4,703	3	1,568
3.3.3.2	0,000	0	0,000
4.1.2	0,000	0	0,000
5.1.1.1	96,930	3	32,310
5.1.1.2	157,575	10	15,758
5.1.2.1	2797,590	4	699,398
5.1.2.2	214,436	9	23,826
5.2.3	88564,598	4	22141,150
total	**310753,630**	**5855**	**53,075**

Table 4.6: Characteristics on the polygons and vectors for the historical year 1968

Total area size in ha	310753,630
Number of areas	5855
Area classes	57
Smallest area	0,213
Biggest area	70559,585
Areas per km²	1,884
Mean area-size in ha	53,075
Total line length in km	10184
Number of lines	62226
Lines per km²	20,024
Mean length in m	164
Line density in km/km²	3,277
Number of 3d objects	3
Total size in ha	4,361

The results for the year 1968 as vector on the maps are shown in Figure 4.22 and 4.23.

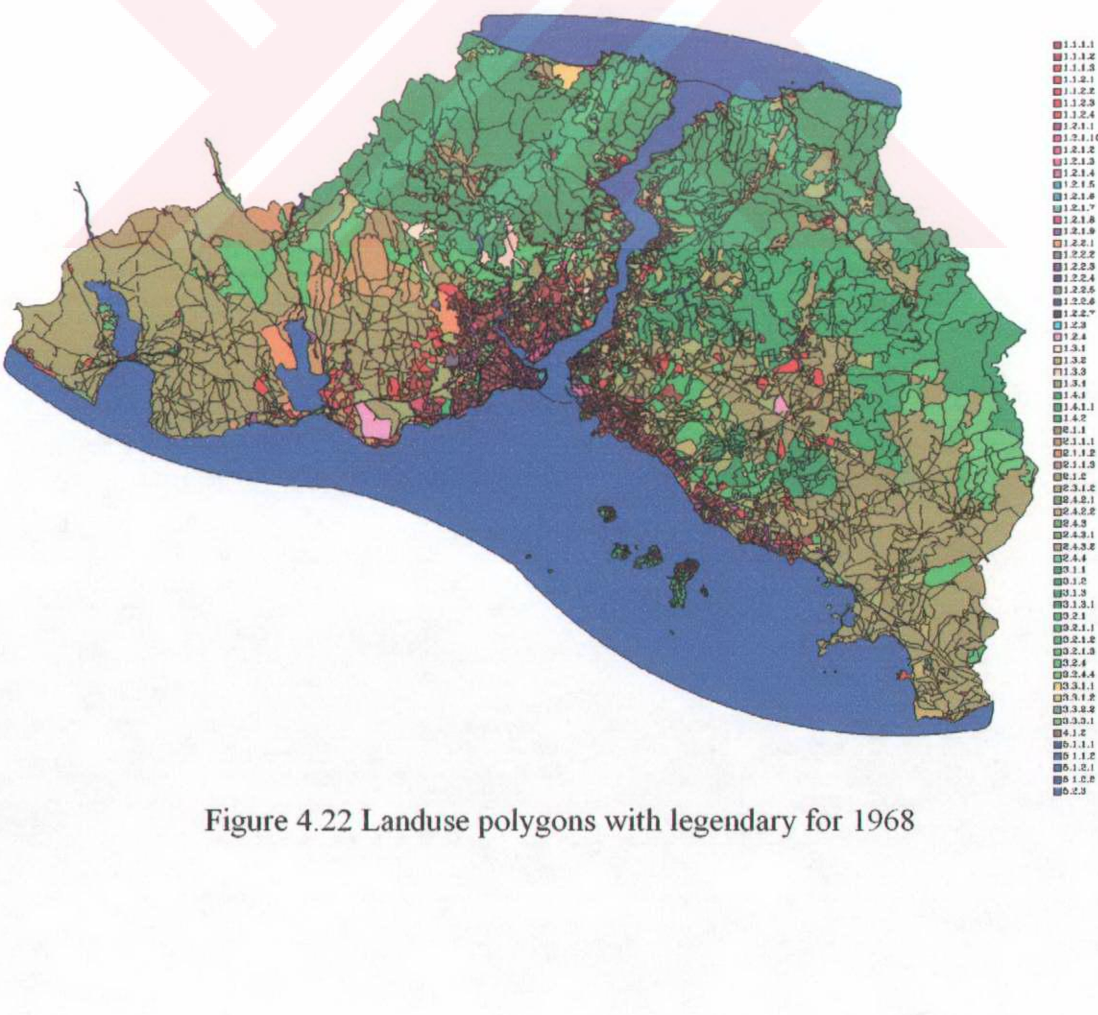


Figure 4.22 Landuse polygons with legendary for 1968

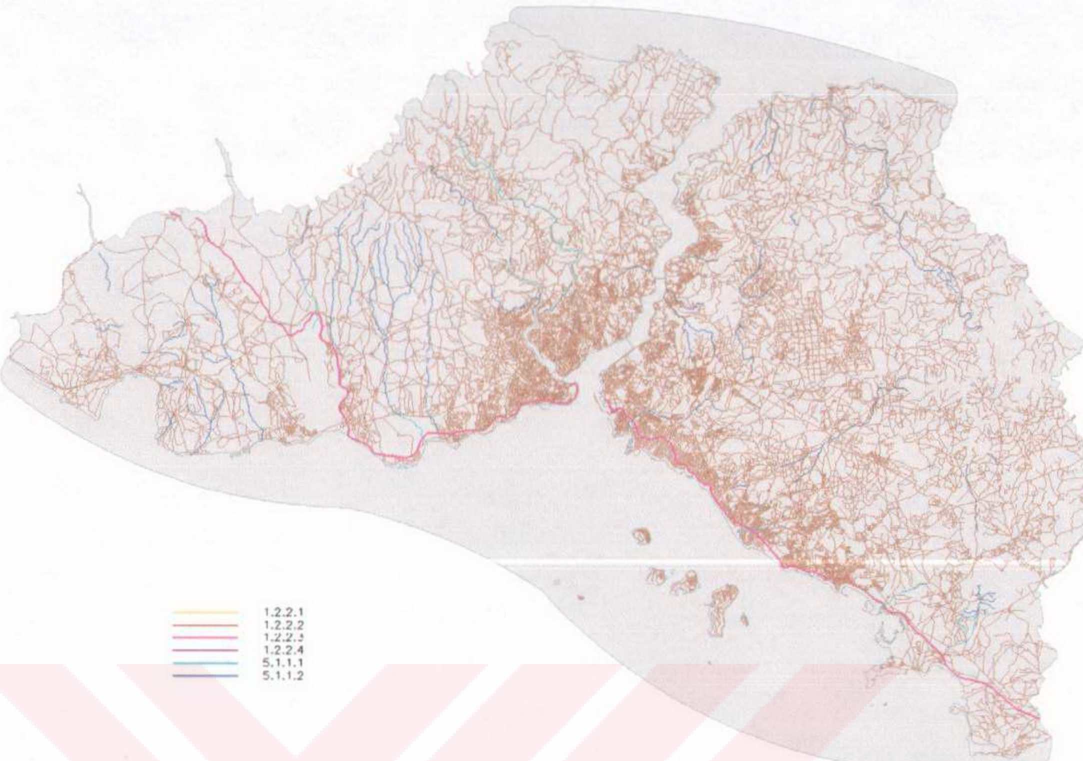


Figure 4.23 Transportation network with legendary for 1968

4.1.3.4 Landuse data set for 1940ies

For the historical year 1940ies, aerial photography has been used. For this purpose, 114 pieces of aerial photographs were scanned and all of them were orthorectified. Table 4.7 and Table 4.8 show the results of the historical year 1940ies.

Table 4.7: Statistical results of the landuse classes for the historical year 1940ies

Polygons 1940ies	class-size in ha	no. of areas/class	mean-size /area/class in ha
1.1.1.1	709,195	32	22,162
1.1.1.2	1423,319	149	9,552
1.1.1.3	0,000		
1.1.2.1	1418,775	116	12,231
1.1.2.2	2986,040	357	8,364
1.1.2.3	0,000	0	0,000
1.1.2.4	0,000	0	0,000
1.2.1.1	408,219	55	7,422
1.2.1.2	194,880	37	5,267
1.2.1.3	285,864	58	4,929
1.2.1.4	26,794	6	4,466
1.2.1.5	95,257	13	7,327
1.2.1.6	47,887	13	3,684
1.2.1.7	8,083	2	4,042
1.2.1.8	88,212	6	14,702
1.2.1.9	222,415	21	10,591
1.2.1.10	4,873	2	2,437
1.2.2.1	0,000	0	0,000
1.2.2.2	55,428	11	5,039
1.2.2.3	80,594	3	26,865
1.2.2.4	0,000	0	0,000
1.2.2.5	0,000	0	0,000
1.2.2.6	2,596	1	2,596
1.2.2.7	1,267	1	1,267
1.2.3	167,278	35	4,779
1.2.4	287,380	2	143,690
1.3.1	562,655	49	11,483
1.3.2	0,000	0	0,000
1.3.3	1220,427	142	8,595
1.3.4	1773,780	192	9,238
1.4.1	477,815	71	6,730
1.4.1.1	170,153	18	9,453
1.4.2	75,147	6	12,525

Polygons 1940ies	class-size in ha	no. of areas/class	mean-size /area/class in ha
2.1.1	1568,917	10	156,892
2.1.1.1	12108,581	128	94,598
2.1.1.2	0,000	0	0,000
2.1.1.3	0,000	0	0,000
2.1.2	54167,827	722	75,025
2.3.1.1	0,000	0	0,000
2.3.1.2	2097,941	49	42,815
2.4.2	0,000	0	0,000
2.4.2.1	20453,821	253	80,845
2.4.2.2	4462,965	150	29,753
2.4.3	0,000	0	0,000
2.4.3.1	114,478	2	57,239
2.4.3.2	0,000	0	0,000
2.4.4	16,803	1	16,803
3.1.1	24848,525	133	186,831
3.1.2	2430,162	11	220,924
3.1.2.1	0,000	0	0,000
3.1.3	49491,764	275	179,970
3.1.3.1	45,777	1	45,777
3.2.1	1,919	1	1,919
3.2.1.1	1255,939	71	17,689
3.2.1.2	28554,432	497	57,454
3.2.1.3	86,199	5	17,240
3.2.4	3369,168	9	374,352
3.2.4.3	309,730	5	61,946
3.2.4.4	109,984	2	54,992
3.3.1.1	362,593	2	181,297
3.3.1.2	117,201	15	7,813
3.3.2.2	201,261	55	3,659
3.3.3.1	3,608	2	1,804
3.3.3.2	1,494	1	1,494
4.1.2	0,000	0	0,000
5.1.1.1	20,655	1	20,655
5.1.1.2	118,259	6	19,710
5.1.2.1	2845,768	3	948,589
5.1.2.2	72,823	8	9,103
5.2.3	88720,972	5	17744,194
total	**310753,899**	**3821**	**81,328**

Table 4.8: Characteristics on the polygons and vectors for the 1940ies

Total area size in ha	310753,899
Number of areas	3821
Area classes	55
Smallest area	0,222
Biggest area	70499,826
Areas per km²	1,230
Mean area-size in ha	81,328
Total line length in km	7414,810
Number of lines	40225
Lines per km²	12,944
Mean length in m	184
Line density in km/km²	2,386
Number of 3d objects	2
Total size in ha	3,640

The results for the 1940ies as vector on the maps are shown in Figure 4.24 and 4.25.

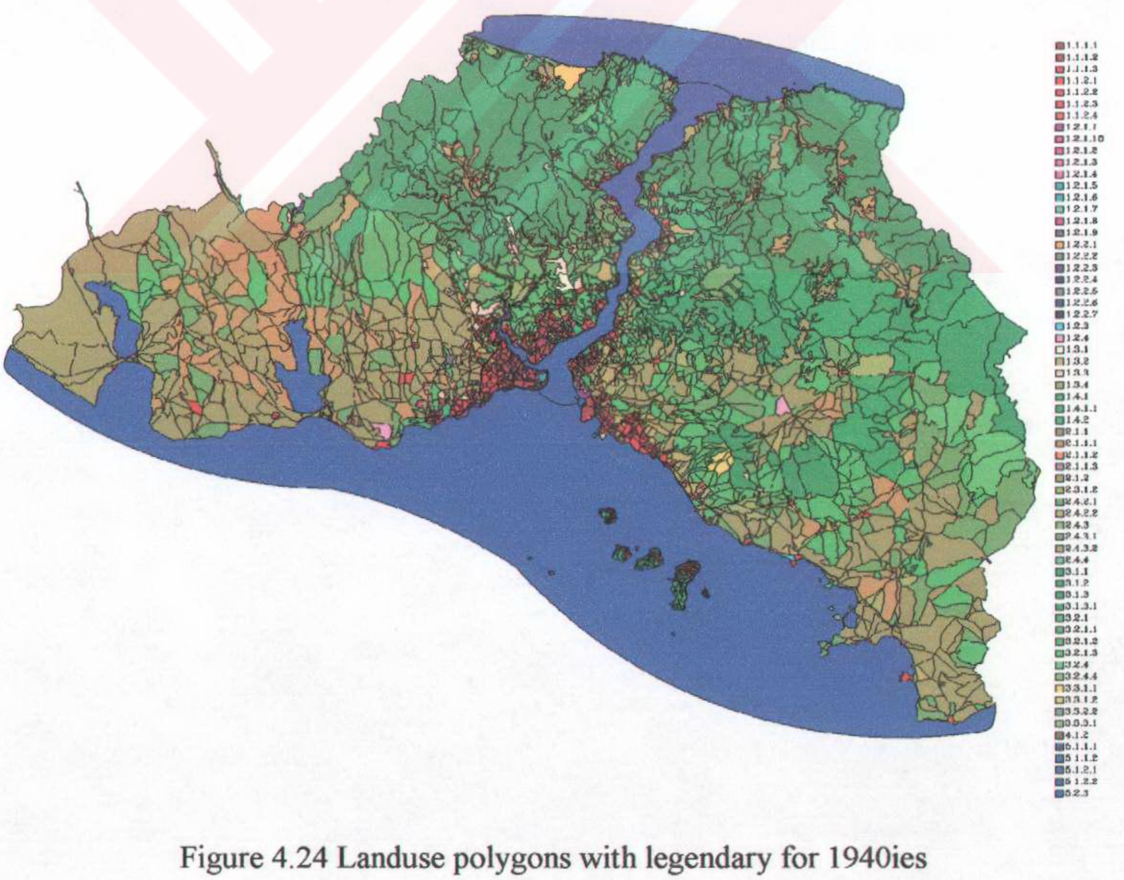


Figure 4.24 Landuse polygons with legendary for 1940ies

Figure 4.25 Transportation network with legendary for 1940ies

4.1.4 Change Statistics and Analysis

There are lots of landuse changes to be detected and analyzed. Here, only some of them are given. The first one is about the first level of landuse classes given in Chapter 1.

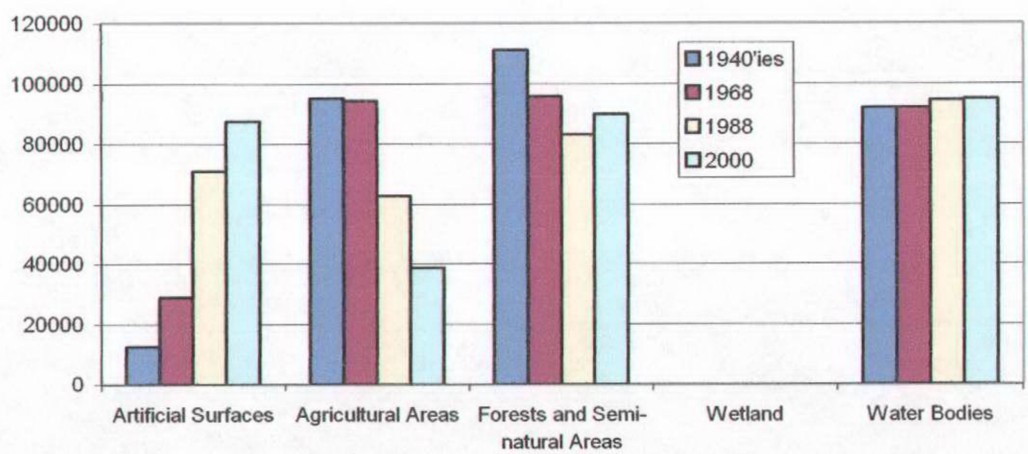


Figure 4.26 Graphical demonstration of change results for first level of landuse classes

In Figure 4.26, the critical increase of artificial surfaces and vice versa, critical decrease of agricultural areas can be seen clearly. In Figure 4.27 and 4.28, the transformation of agricultural areas to artificial surfaces is given with target subclasses as residential and business (Industrial, commercial and commercial) areas.

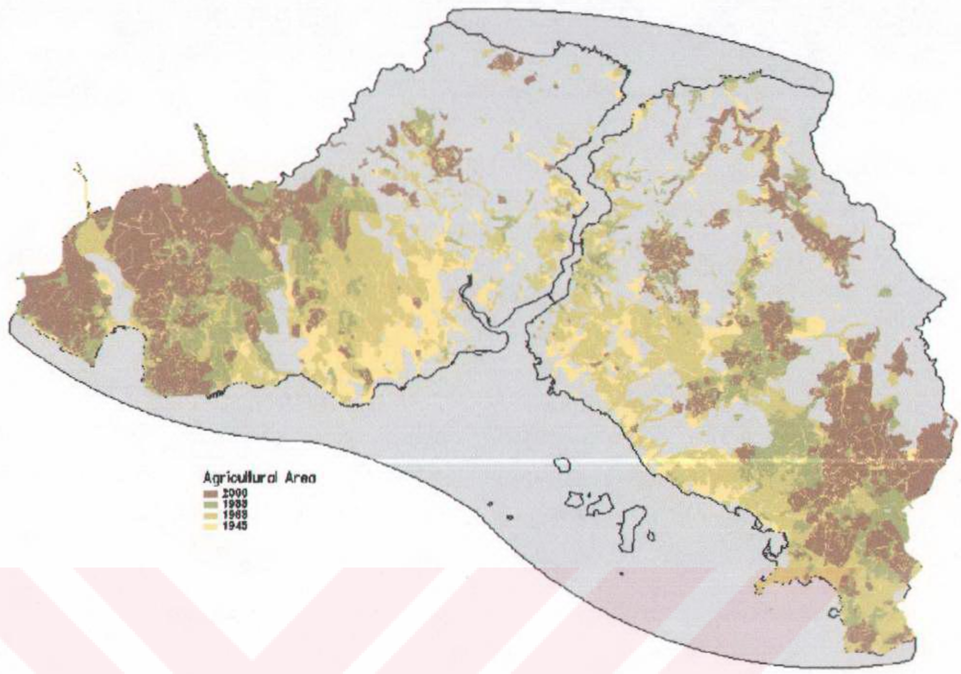


Figure 4.27 The transformation of agricultural areas from 1940ies to 2000

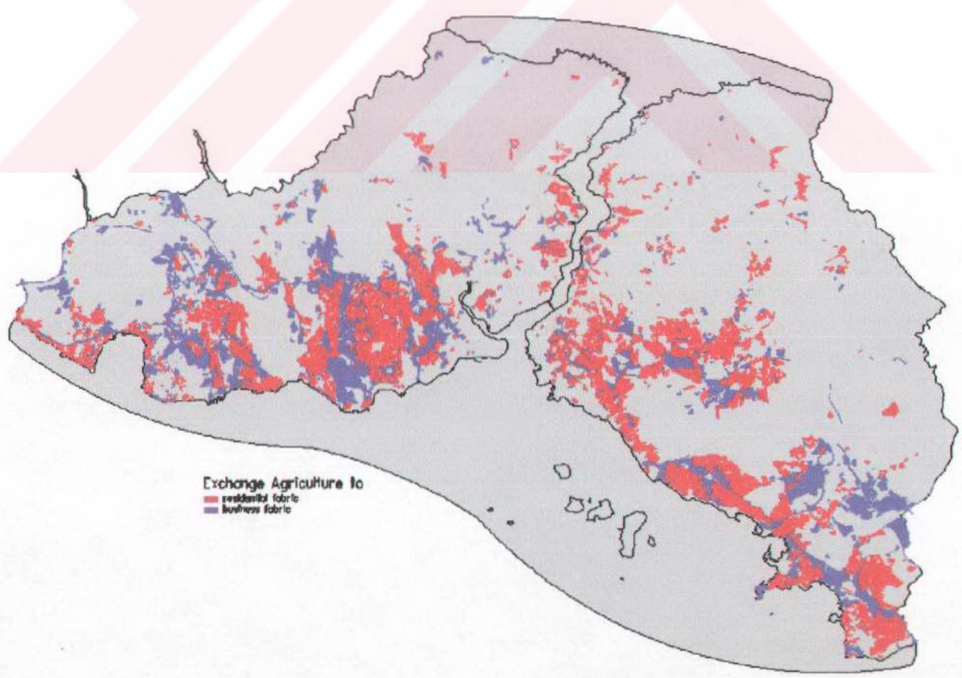


Figure 4.28 The loss of agricultural areas to residential and business areas

Another remarkable point in Figure 4.26 is the small increase of water bodies between the years 1968 and 1988. As well known, between these two years, the Ömerli Dam was built and the increase in the Figure 4.26 refers to this change.

4.2 Results Related to the Accuracy

As mentioned in Chapter 2, the results about the accuracy have two components. The first one is the geometric accuracy, where the second is thematic accuracy. These two components have their own techniques and methods as explained in referring chapter.

4.2.1 Geometric accuracy

Geometric accuracy has three main components. These are;

- Accuracy of points
- Accuracy of lines
- Accuracy of areas

As it is well known, the accuracy of an area depends on the accuracy of lines covering it and the accuracy of a line depends on accuracy of points, which define the beginning and ending of it. This causes the accuracy investigation to begin with points.

In the study area, there are 36705 lines in polygon layer for the year 2000. This reflects a point number of 73510 for the same layer. This big number of points makes the full inspection of geometric accuracy inapplicable. Because of that, a sampling method has been adapted to the points in the database.

4.2.1.1 Geometric accuracy of points

For the points, 60 samples were selected randomly from database, where the samples defines 30 lines overall. This is done in that way in order to make the accuracy investigation easier for lines.

After that, the positions of these 60 points i.e. 30 lines were found on the maps from 1:1000 scale. In this step, the positions of points from 1:1000 maps have been taken as true values.

The deviations between the sampling points and corresponding points from 1:1000 maps have been derived and given in Table 4.9.

Table 4.9 Observed and true coordinates of sampling points with their deviations

[m]	Observed Coordinates		True Coordinates		Deviations	
#	x	y	X	Y	ε_x	ε_y
1	4553994,076	415892,035	4553994,865	415898,267	-0,789	-6,232
2	4553875,630	415854,441	4553883,073	415870,616	-7,443	-16,175
3	4550427,019	399771,188	4550428,089	399773,917	-1,070	-2,729
4	4550630,293	399686,745	4550631,383	399689,598	-1,090	-2,853
5	4547468,481	399644,223	4547465,827	399643,717	2,654	0,506
6	4547469,619	399776,605	4547468,399	399776,430	1,220	0,175
7	4547207,479	399150,917	4547207,279	399152,841	0,200	-1,924
8	4547326,418	399147,629	4547332,137	399147,472	-5,719	0,157
9	4548830,328	407252,525	4548831,129	407250,877	-0,801	1,648
10	4548626,599	407046,718	4548626,599	407046,718	0,000	0,000
11	4543291,086	402901,122	4543291,532	402902,775	-0,446	-1,653
12	4542894,895	402947,939	4542892,860	402948,102	2,035	-0,163
13	4546119,453	407286,140	4546119,997	407286,313	-0,544	-0,173
14	4546250,423	406983,924	4546250,009	406983,884	0,414	0,040
15	4545713,630	407449,751	4545714,689	407445,557	-1,059	4,194
16	4545706,383	407484,155	4545706,750	407485,620	-0,367	-1,465
17	4541380,446	407031,004	4541383,715	407027,683	-3,269	3,321
18	4541354,356	407128,668	4541356,711	407128,279	-2,355	0,389
19	4542880,832	411384,779	4542879,955	411384,153	0,877	0,626
20	4543031,932	411221,288	4543033,477	411219,226	-1,545	2,062
21	4548605,853	386108,725	4548604,256	386113,161	1,597	-4,436
22	4548558,000	385993,533	4548562,434	385994,241	-4,434	-0,708
23	4548410,025	390361,276	4548410,225	390363,274	-0,200	-1,998
24	4548343,461	390294,111	4548343,910	390293,962	-0,449	0,149
25	4541734,861	385888,511	4541735,614	385888,981	-0,753	-0,470
26	4541661,208	386113,580	4541658,752	386113,938	2,456	-0,358
27	4553186,242	417575,291	4553192,116	417573,689	-5,874	1,602
28	4553241,936	417842,954	4553249,179	417837,616	-7,243	5,338
29	4548447,862	417530,987	4548449,172	417527,424	-1,310	3,563
30	4548718,831	417526,298	4548720,122	417529,567	-1,291	-3,269
31	4549032,701	423785,617	4549031,293	423790,344	1,408	-4,727
32	4549140,312	423309,680	4549143,498	423316,342	-3,186	-6,662
33	4549349,395	424240,355	4549350,617	424235,445	-1,222	4,910
34	4549140,576	424320,648	4549142,143	424324,192	-1,567	-3,544
35	4547749,829	428199,597	4547748,031	428194,537	1,798	5,060
36	4547642,054	428022,914	4547643,400	428021,287	-1,346	1,627
37	4544596,538	424051,347	4544590,374	424052,661	6,164	-1,314
38	4544569,133	424056,067	4544561,263	424058,955	7,870	-2,888
39	4542361,885	424224,116	4542369,935	424233,866	-8,050	-9,750
40	4542339,324	424171,964	4542343,179	424178,313	-3,855	-6,349
41	4541329,389	424219,514	4541335,019	424223,137	-5,630	-3,623
42	4541226,448	424084,292	4541228,638	424090,066	-2,190	-5,774
43	4543499,616	421182,670	4543499,970	421184,176	-0,354	-1,506
44	4543383,151	421237,944	4543385,623	421239,446	-2,472	-1,502
45	4544184,348	428376,127	4544190,427	428378,590	-6,079	-2,463
46	4544118,635	428233,611	4544121,962	428242,686	-3,327	-9,075
47	4543643,696	428144,296	4543655,357	428157,427	-11,661	-13,131
48	4543592,506	428067,343	4543591,237	428066,709	1,269	0,634
49	4541754,126	428208,039	4541763,945	428210,753	-9,819	-2,714

Table 4.9 (Continued)

[m]	Observed Coordinates		True Coordinates		Deviations	
#	x	y	X	Y	ε_x	ε_y
50	4541579,125	428548,155	4541587,967	428553,389	-8,842	-5,234
51	4545659,642	436289,289	4545668,726	436274,815	-9,084	14,474
52	4545564,889	436149,603	4545560,556	436163,436	4,333	-13,833
53	4541505,679	434583,088	4541496,713	434565,807	8,966	17,281
54	4541529,355	434593,975	4541518,116	434571,760	11,239	22,215
55	4541970,926	432841,281	4541960,122	432841,416	10,804	-0,135
56	4541989,833	432838,985	4541977,409	432839,390	12,424	-0,405
57	4539235,332	392735,285	4539242,759	392732,407	-7,427	2,878
58	4539204,316	392960,816	4539205,009	392956,635	-0,693	4,181
59	4540041,215	403183,754	4540045,600	403182,330	-4,385	1,424
60	4540049,694	402841,832	4540046,041	402838,464	3,653	3,368

Where;

$$\varepsilon_{x_i} = x_i - X_i \text{ and} \tag{4.1}$$

$$\varepsilon_{y_i} = y_i - Y_i \tag{4.2}$$

With the deviations, the following statistical values related to geometric accuracy have been calculated.

Theoretical standard deviations are,

$$\sigma_{\varepsilon_x} = \sqrt{\frac{\sum \varepsilon_{x_i}^2}{n}} = 5.027\,m. \tag{4.3}$$

$$\sigma_{\varepsilon_y} = \sqrt{\frac{\sum \varepsilon_{y_i}^2}{n}} = 6.187\,m. \tag{4.4}$$

$$\sigma_c = \sqrt{\frac{1}{2}\frac{\sum \varepsilon_{x_i}^2 + \sum \varepsilon_{y_i}^2}{n}} = \sigma_c = \sqrt{\frac{\sigma_{\varepsilon_x}^2 + \sigma_{\varepsilon_y}^2}{2}} = 5.637\,m. \tag{4.5}$$

where $\sigma_{\varepsilon x}$ and $\sigma_{\varepsilon y}$ are the standard deviations in X- and Y directions and σ_c is the circular standard deviation.

Circular probable error:

$$CPE = \sqrt{1.39\sigma_c^2} = 1.1774\sigma_c = 6.646\,m. \tag{4.6}$$

Mean square positional error

$$MSPE = \sqrt{2\sigma_c^2} = 1.4142\sigma_c = 7.971m. \tag{4.7}$$

Circular map accuracy standard:

$$CMAS = \sqrt{4.610\sigma_c^2} = 2.146\sigma_c = 12.102m. \tag{4.8}$$

Circular near certainty error:

$$CNCE = 3.5\sqrt{\sigma_c^2} = 3.5\sigma_c = 19.728m. \tag{4.9}$$

4.2.1.2 Geometric accuracy of lines

As mentioned above, accuracy of lines are depending on accuracy of beginning and endpoints. A positional accuracy of a line can be shown using the accuracy of the midpoint of it. Using the deviations of the beginning- and endpoints, Table 4.10 gives the positional accuracy of the sampling lines.

Table 4.10 Deviations of the sampling lines

[m]	Deviations			Deviations	
#	ε_x	ε_y	#	ε_x	ε_y
1	3,742	8,667	16	1,742	4,084
2	0,764	1,974	17	0,994	3,028
3	1,460	0,268	18	1,123	2,658
4	2,861	0,965	19	4,998	1,586
5	0,400	0,824	20	4,463	5,817
6	1,042	0,831	21	3,020	3,408
7	0,342	0,089	22	1,249	1,063
8	0,560	2,221	23	3,465	4,702
9	2,014	1,672	24	5,865	6,573
10	0,888	1,077	25	6,607	2,948
11	2,356	2,246	26	5,032	10,011
12	0,246	1,002	27	7,189	14,072
13	1,284	0,295	28	8,232	0,213
14	4,663	2,787	29	3,730	2,538
15	0,920	2,418	30	2,854	1,828

Using the deviations in Table 4.10, a general positional accuracy can be calculated as follows;

$$\sigma_{\varepsilon_x} = \sqrt{\frac{\sum \varepsilon_{x_i}^2}{n}} = 3.554m. \tag{4.10}$$

$$\sigma_{\varepsilon_y} = \sqrt{\frac{\sum \varepsilon_{y_i}^2}{n}} = 4.375\,m. \qquad (4.11)$$

$$\sigma_c = \sqrt{\frac{1}{2}\frac{\sum \varepsilon_{x_i}^2 + \sum \varepsilon_{y_i}^2}{n}} = \sigma_c = \sqrt{\frac{\sigma_{\varepsilon_x}^2 + \sigma_{\varepsilon_y}^2}{2}} = 4.712\,m. \qquad (4.12)$$

As it is mentioned in Chapter 2, the accuracy for the lines is error band. In order to draw these error bands for all the lines in sampling group, proportions were selected as ¼, ½ and ¾. The deviations on these portions of the sampling lines calculated are given in Table 4.11.

Table 4.11 Deviation on predefined portions along sampling lines

[m]	Deviations ε_x			Deviations ε_y		
#	Portion ¼	Portion ½	Portion ¾	Portion ¼	Portion ½	Portion ¾
1	1,953	3,742	5,586	6,180	8,667	12,231
2	0,848	0,764	0,860	2,167	1,974	2,246
3	2,014	1,460	1,130	0,382	0,268	0,182
4	1,438	2,861	4,290	1,444	0,965	0,495
5	0,601	0,400	0,200	1,236	0,824	0,412
6	0,609	1,042	1,530	1,240	0,831	0,431
7	0,421	0,342	0,339	0,130	0,089	0,053
8	0,800	0,560	0,382	3,167	2,221	1,519
9	2,521	2,014	1,946	2,493	1,672	0,880
10	0,763	0,888	1,179	0,697	1,077	1,554
11	1,632	2,356	3,349	3,332	2,246	1,230
12	0,187	0,246	0,340	1,499	1,002	0,512
13	0,834	1,284	1,852	0,364	0,295	0,293
14	4,763	4,663	5,627	1,796	2,787	4,023
15	1,034	0,920	1,022	2,794	2,418	2,609
16	1,323	1,742	2,415	3,917	4,084	5,134
17	0,997	0,994	1,214	3,788	3,028	2,928
18	1,390	1,123	1,105	3,817	2,658	1,758
19	5,024	4,998	6,100	1,222	1,586	2,191
20	6,114	4,463	3,523	7,483	5,817	5,349
21	4,258	3,020	2,163	3,077	3,408	4,424
22	0,673	1,249	1,856	1,190	1,063	1,188
23	4,634	3,465	2,922	2,926	4,702	6,834
24	8,752	5,865	3,067	9,850	6,573	3,317
25	7,689	6,607	7,071	2,420	2,948	3,984
26	6,899	5,032	3,965	11,393	10,011	10,988
27	7,288	7,189	8,722	14,101	14,072	17,212
28	8,678	8,232	9,702	0,143	0,213	0,306
29	5,573	3,730	1,928	2,398	2,538	3,217
30	3,413	2,854	2,951	1,360	1,828	2,551

Using the deviations given in Table 4.11, all error ellipses were drawn along the sampling lines in order to show the error bands for all the sampling lines. These error bands are given Appendix D.

4.2.1.3 Geometric accuracy of areas

For the areas, the geometric accuracy can be calculated the formula below.

$$\sigma_F = \sigma_c \sqrt{2F \,\mathrm{Sin}\left(\frac{360}{n}\right)} \qquad (4.13)$$

where F is the value of the area and n is number of edges. Using this formula, geometric accuracy of areas were calculated and shown graphically in Figure 4.29.

As it can be seen from the formula, accuracy of an area depends on the area and number of edges of itself.

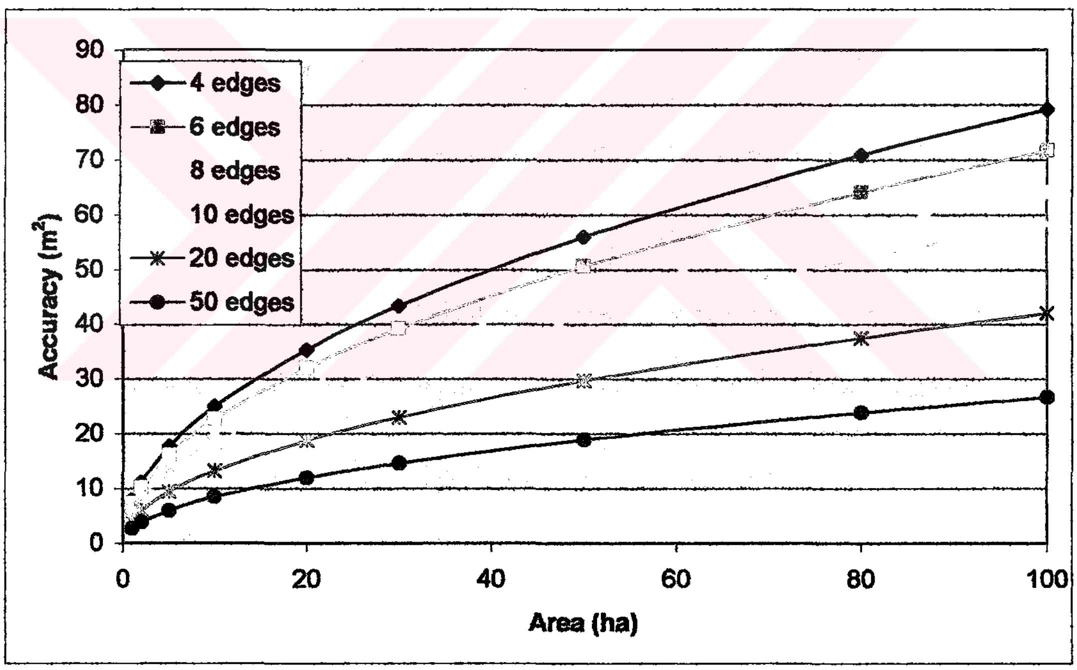


Figure 4.29 Geometric accuracy changes of areas from different edge numbers and areas

4.2.2 Thematic accuracy

In order to make an accuracy investigation, database must be revised and some statistical values must be taken from it. For the year 2000, some statistics about landuse, polygons and number of polygons can be seen in Table 4.1. For the year 2000, 12816 polygons have been created. Hence, that caused the accuracy investigation not applicable for a full investigation. Because of that, sampling groups have been created randomly from database for all the landuse types used in database. The rule for sampling is illustrated in Table 4.12.

Table 4.12 Sampling rule for thematic accuracy investigation

Number of Polygon	Sampling size
30 or more	30
Between 20 – 29	20
Between 10 - 19	10
Between 1 – 9	All

Applying the rule to the database for the year 2000, the sampling sizes have been calculated as in Table 4.13.

Table 4.13 Sampling sizes for landuse types

Landuse Type	Sampling Size	Landuse Type	Sampling Size	Landuse Type	Sampling Size
1.1.1.1	30	1.2.2.6	30	2.4.4	7
1.1.1.2	30	1.2.2.7	20	3.1.1	30
1.1.1.3	30	1.2.3	30	3.1.2	30
1.1.2.1	30	1.2.4	4	3.1.3	30
1.1.2.2	30	1.3.1	30	3.1.3.1	1
1.1.2.3	30	1.3.2	1	3.2.1	2
1.1.2.4	3	1.3.3	30	3.2.1.1	30
1.2.1.1	30	1.3.4	30	3.2.1.2	30
1.2.1.2	30	1.4.1	30	3.2.1.3	10
1.2.1.3	30	1.4.1.1	30	3.2.4	10
1.2.1.4	20	1.4.2	30	3.2.4.4	2
1.2.1.5	10	2.1.1	30	3.3.1.1	1
1.2.1.6	20	2.1.1.1	30	3.3.1.2	10
1.2.1.7	10	2.1.1.2	5	3.3.2.2	30
1.2.1.8	10	2.1.1.3	3	3.3.3.1	2
1.2.1.9	30	2.1.2	30	4.1.2	2
1.2.1.10	10	2.3.1.2	4	5.1.1.1	6
1.2.2.1	30	2.4.2.1	4	5.1.1.2	8
1.2.2.2	30	2.4.2.2	30	5.1.2.1	10
1.2.2.3	10	2.4.3	4	5.1.2.2	20
1.2.2.4	1	2.4.3.1	30	5.2.3	5
1.2.2.5	1	2.4.3.2	2	Total	1168

After calculating the sampling sizes, samples have generated using the random property of microprocessors. The sample polygons were identified with their unique number in database.

For all the polygons in the sampling group, a thematic accuracy process has been done manually. All the polygons have been controlled manually if they defined correctly by digitisation process. As a result, some defining errors about the landuse have been detected. Amounts of errors are given in Table 4.14 with their percentage to the sampling groups.

Table 4.14 Amount of errors with their percentages

Landuse Type	Sampling Size	Amount of Error	Error %	Landuse Type	Sampling Size	Amount of Error	Error %	Landuse Type	Sampling Size	Amount of Error	Error %
1.1.1.1	30	2	6,7	1.2.2.6	30	1	3,3	2.4.4	7	0	0,0
1.1.1.2	30	2	6,7	1.2.2.7	20	1	5,0	3.1.1	30	0	0,0
1.1.1.3	30	2	6,7	1.2.3	30	0	0,0	3.1.2	30	0	0,0
1.1.2.1	30	3	10,0	1.2.4	4	0	0,0	3.1.3	30	0	0,0
1.1.2.2	30	3	10,0	1.3.1	30	3	10,0	3.1.3.1	1	0	0,0
1.1.2.3	30	2	6,7	1.3.2	1	0	0,0	3.2.1	2	0	0,0
1.1.2.4	3	0	0,0	1.3.3	30	0	0,0	3.2.1.1	30	2	6,7
1.2.1.1	30	0	0,0	1.3.4	30	3	10,0	3.2.1.2	30	2	6,7
1.2.1.2	30	4	13,3	1.4.1	30	2	6,7	3.2.1.3	10	0	0,0
1.2.1.3	30	2	6,7	1.4.1.1	30	0	0,0	3.2.4	10	0	0,0
1.2.1.4	20	0	0,0	1.4.2	30	0	0,0	3.2.4.4	2	0	0,0
1.2.1.5	10	0	0,0	2.1.1	30	2	6,7	3.3.1.1	1	0	0,0
1.2.1.6	20	0	0,0	2.1.1.1	30	0	0,0	3.3.1.2	10	0	0,0
1.2.1.7	10	0	0,0	2.1.1.2	5	0	0,0	3.3.2.2	30	0	0,0
1.2.1.8	10	0	0,0	2.1.1.3	3	0	0,0	3.3.3.1	2	0	0,0
1.2.1.9	30	0	0,0	2.1.2	30	0	0,0	4.1.2	2	0	0,0
1.2.1.10	10	0	0,0	2.3.1.2	4	0	0,0	5.1.1.1	6	0	0,0
1.2.2.1	30	0	0,0	2.4.2.1	4	0	0,0	5.1.1.2	8	0	0,0
1.2.2.2	30	0	0,0	2.4.2.2	30	2	6,7	5.1.2.1	10	0	0,0
1.2.2.3	10	0	0,0	2.4.3	4	0	0,0	5.1.2.2	20	0	0,0
1.2.2.4	1	0	0,0	2.4.3.1	30	0	0,0	5.2.3	5	0	0,0
1.2.2.5	1	0	0,0	2.4.3.2	2	0	0,0	**Total**	**1168**	**38**	**3,3**

Table 4.14 gives information about the accuracy of the results. For example, it can be said that the landuse type 1.1.1.1 (Residential continuous dense urban fabric) has been defined with an error of 6.7% where the landuse type 3.1.3 (Mixed forest) has been defined without error.

In table 4.14, 48 landuse types have been shown as "totally true". 30 from these 48 landuse types have 10 or less sampling size i.e. they are few in total amount. This causes to define them much more correct than other landuse types. Other 18 landuse types, which are defined as "totally true", have whether specific information about their landuse on 1:25000 maps (e.g. vegetated cemeteries) or they are clearly visible and detectable from aerial or satellite imagery (e.g. industrial areas or seas). Using the additional data such as 1:25000 maps or 1:16000 city plans by digitisation and defining the areas causes accurate results. Another parameter, which causes the results to be accurate, is the knowledge of operator about the area. Defining the fast transit road and associated land can be a suitable example for this parameter.

In Table 4.14, it can be seen that a total error percentage is given as %3.3. This value is only a rough result for total accuracy. In order to give more precise result about accuracy, another investigation must be done wit the values in Table 4.14. In this investigation, error percentages for individual landuse types must be taken with their weight. The weight is selected as the percentage of number of landuse type to the total number of defined polygons.

In order to derive a total accuracy result, Bayes theorem must be used for the results given in Table 4.14.

$$P(F) = \sum \left[P(F / L_i) * P(L_i) \right] \tag{4.14}$$

where P(F) denotes the percentage of false defined polygons in total area, $P(L_i)$ the percentage of the landuse type within the all polygons and $P(F/L_i)$ the percentage of false defined polygons within the ith landuse type. These values are given in Table 4.15.

Table 4.15 Calculation of parameters in Bayes theorem for individual landuse types

Landuse Type	P(Li)	P(F/Li)	P(F/Li)*P(Li)	Landuse Type	P(Li)	P(F/Li)	P(F/Li)*P(Li)	Landuse Type	P(Li)	P(F/Li)	P(F/Li)*P(Li)
1.1.1.1	0,260	0,1	0,0173	1.2.2.6	0,004	0,0	0,0001	2.4.4	0,001	0,0	0,0000
1.1.1.2	0,124	0,1	0,0083	1.2.2.7	0,002	0,1	0,0001	3.1.1	0,023	0,0	0,0000
1.1.1.3	0,008	0,1	0,0005	1.2.3	0,005	0,0	0,0000	3.1.2	0,007	0,0	0,0000
1.1.2.1	0,053	0,1	0,0053	1.2.4	0,000	0,0	0,0000	3.1.3	0,033	0,0	0,0000
1.1.2.2	0,030	0,1	0,0030	1.3.1	0,007	0,1	0,0007	3.1.3.1	0,000	0,0	0,0000
1.1.2.3	0,033	0,1	0,0022	1.3.2	0,000	0,0	0,0000	3.2.1	0,000	0,0	0,0000
1.1.2.4	0,000	0,0	0,0000	1.3.3	0,042	0,0	0,0000	3.2.1.1	0,028	0,1	0,0019
1.2.1.1	0,048	0,0	0,0000	1.3.4	0,029	0,1	0,0029	3.2.1.2	0,057	0,1	0,0038
1.2.1.2	0,057	0,1	0,0076	1.4.1	0,012	0,1	0,0008	3.2.1.3	0,001	0,0	0,0000
1.2.1.3	0,022	0,1	0,0015	1.4.1.1	0,004	0,0	0,0000	3.2.4	0,001	0,0	0,0000
1.2.1.4	0,002	0,0	0,0000	1.4.2	0,008	0,0	0,0000	3.2.4.4	0,000	0,0	0,0000
1.2.1.5	0,001	0,0	0,0000	2.1.1	0,004	0,1	0,0003	3.3.1.1	0,000	0,0	0,0000
1.2.1.6	0,002	0,0	0,0000	2.1.1.1	0,010	0,0	0,0000	3.3.1.2	0,001	0,0	0,0000
1.2.1.7	0,001	0,0	0,0000	2.1.1.2	0,000	0,0	0,0000	3.3.2.2	0,004	0,0	0,0000
1.2.1.8	0,001	0,0	0,0000	2.1.1.3	0,000	0,0	0,0000	3.3.3.1	0,000	0,0	0,0000
1.2.1.9	0,004	0,0	0,0000	2.1.2	0,038	0,0	0,0000	4.1.2	0,000	0,0	0,0000
1.2.1.10	0,001	0,0	0,0000	2.3.1.2	0,000	0,0	0,0000	5.1.1.1	0,000	0,0	0,0000
1.2.2.1	0,003	0,0	0,0000	2.4.2.1	0,000	0,0	0,0000	5.1.1.2	0,001	0,0	0,0000
1.2.2.2	0,006	0,0	0,0000	2.4.2.2	0,011	0,1	0,0007	5.1.2.1	0,001	0,0	0,0000
1.2.2.3	0,001	0,0	0,0000	2.4.3	0,000	0,0	0,0000	5.1.2.2	0,002	0,0	0,0000
1.2.2.4	0,000	0,0	0,0000	2.4.3.1	0,004	0,0	0,0000	5.2.3	0,000	0,0	0,0000
1.2.2.5	0,000	0,0	0,0000	2.4.3.2	0,000	0,0	0,0000	**Total**			**0,0569**

5 CONCLUSION

Landuse and land cover change detection is used widely all around the world. For this purpose, several methods and techniques are developed. In this study, a classical on-screen digitization process has been done. This method has been selected according to the working scale as well as the minimum area of interest. Furthermore, the richness of classes in legend causes the automatic and semi-automatic methods not applicable in this study.

An originality of this study is the combination of data. As explained in Chapter 3.1, use of aerial photographs, digital elevation model, orthophotos, satellite imagery and topographical maps as basic data and some special maps and city plans as additional data carried out an interesting data mixture for the study. This specialty occurs as very suitable results in both geometric and thematic accuracy.

The first technical step of the study was scanning and georeferencing of the hardcopy topographical maps. As it is mentioned in chapter 3.1.1, maps have been used as basic topographical data and the satellite images have been georeferenced on the basis of these topographical maps.

The coordinate system of the hardcopy topographical maps from a scale of 1:25000 is UTM 6° with middle meridian 27° east. But as it is explained in Chapter 3.1.1, the coordinate system of the study was selected as UTM 3° with middle meridian 30° east. This was done because the topographical maps from large scale (1:5000 and 1:1000) have been produced in this coordinate system. Thus, to validate the results and in some cases to use the 1:1000 and 1:5000 maps outside of control mechanism such as georeferenciation or interpretation would be easier.

The next step was the georeferencing of satellite imagery for the years 2000 and 1987/88 and creating orthophotos for the other two historical time periods. It is derived that the geometric accuracy of IRS panchromatic is higher than IKONOS. Thinking about the specification and ground resolution of both imageries, this result seems like to be unreal but it must not be taken out of sight that this results are determined using the deviations. The ground resolution is not a parameter by this geometric accuracy mentioned above. This result is the accuracy of producer. Accuracy of user, which means the degree of a data collection from a product, depends on both accuracy of producer and ground resolution for satellite imagery. The value of user accuracy can vary depending on the data collection method, technique, software, personnel and hardware. The result in this study refers to the accuracy of producer.

As it is mentioned in the first chapter, the aim of this study was to fulfill the first step of action on urbanization, which is called as "change detection". The results can be data for other two steps "understanding" and "forecasting".

By evaluation, it was difficult to digitize every linear and planar object in the whole study area. But after a hard work, it was carried out with a suitable accuracy.

The thematic results of the study have showed that a large amount of landuse change has occurred in Istanbul. Especially a rapid growth of artificial surfaces against the critical decrease in agricultural areas showed that this landuse change was mainly from agricultural to artificial areas. The effects of urbanization can be specifically seen in class 1.1.2.3 (Residential urban blocks). In 40ies, there were any area for this class but beginning from 1968, the amount of this class has been increased rapidly. In 1968 161,389 ha, in 1987/88 622,174 ha and in 2000 3003,208 ha of the study area was covered with residential urban block. This is a small but effective evidence for the growth of the city.

Another rapid growth was about both industrial (1.2.1.1) and commercial areas (1.2.1.2). As being the most important city of Turkey's economy, these two classes of landuse have widely detected by the study. The historical growth can be summarized as follows. In 1940'ies only 408,219 ha for industrial and 194,880 ha for commercial use were detected. This values appeared for 1968 as 1597,150 ha and 1063,250 ha in order. As a result of global industrialization, in 1987/88 industrial surfaces reached a value of 5536,812 ha where commercial surfaces reach 2163,754 ha in area. These values were 9669,110 ha and 3361,853 ha for the year 2000 in the same order.

A last example about urbanization is the transportation network. In 1940ies and 1968, there weren't any highway in Istanbul. In 1987/88, the total area of highways was 670,156 ha and this value reaches to 1443,408 ha in 2000. The most effective example about this rapid increase was the construction of the second Bosphorus Bridge, named as Fatih Sultan Mehmet Bridge, which was opened in 1988 and its connections with Trans European Motorway (TEM).

A strange result about the landuse changes was the decrease in the area of seas. Especially along the Marmara coastline, a big amount of water areas had been filled up. This causes a gain of 1458,111 ha of area between 1940ies and 2000 and these areas are widely used for transportation, green urban areas and ports.

The first three examples on change detection, rapid growths in artificial surfaces, commercial and industrial areas and transportation network, are awaiting results for metropolises all around the world. It can be said that what differs a metropolis from a big city is the commercial activities in itself. These commercial activities are because of the industrial activities and geographical properties such as topography, climate and location. These three parameters are affecting each other. As an example, it is a disadvantage for the cities without a coast to the sea to have wide industrial activities. Without industry, an increase in commerce is very difficult. Unless one of these parameter, it is not expected to mention a big city as metropolis.

The results can be used for analyzing the current conditions and former growth of the city of Istanbul. Moreover, for all the steps of urban planning, the results can be taken in sight.

The results are not only useful for macro planning or analyzing but also suitable for micro processes such as local minor authorities of city parts too. This is caused by the minimum area of interest and the working scale. As it is mentioned in Chapter 3.2, the minimum area of interest was 1 ha. Some smaller areas then 1 ha were digitized too according to their importance for the whole city or surrounding of itself.

The results are acceptable in both geometric and thematic accuracy. Giving these results is very important for geomatic/geoinformatic people. This gives more information especially for the users of further works. Unless these results on accuracy, it is not so realistic to work with the outputs of the study.

By defining and calculating both the geometric and thematic accuracy, it has been detected that any national standard about geographical information system already exists in Turkey. This lack of standard must be satisfied by a coordination of scientists, authorities, applicators and if possible users. By this further work, international standards such as ISO TC/211 must be well studied and adapted to national circumstances.

REFERENCES

Baltasavias, E.P. and Waegli, B., 1996. Quality analysis and calibration of DTP-scanners, *International Archieves of Photogrammetry and Remote Sensing,* **XXXI-B1,** 13-19.

Backhaus, R. and Braun, G., 1998. Integration of remotely sensed and model data to provide the spatial information basis for sustainable landuse, *Acta Astronautica,* **42-9,** 541-546.

Beard, K. and Mackaness, W., 1993. Visual access to data quality in geographic information systems, *Cartographica,* **30-2,3,** 37-45.

Bossard, M., Feranec, J. and Otahel , J., 2000.Corine Land cover technical guide-Addendum 2000, *European Environment Agency,* **Report No:40,** Copenhagen, Denmark.

Brown, L.G., 1992. A survey of image registration techniques, *ACM Computing Surveys,* **24-4,** 325-376.

Buttenfield, B.P., 1993. Representing Data Quality, *Cartographica,* **30-2,3,** 1-7.

Ehlers, M., Gaehler, M. and Janowsky, R.,2003. Automated analysis of ultra high resolution remote sensing data for biotope type mapping: new possibilities and challenges, *ISPRS Jornal of Photogrammetry & Remote Sensing,* **1252,** 1-12.

Fraser, C.S. and Hanley, H.B., 2003. Bias compensation in rational functions for Ikonos satellite imagery, *Photogrammetric Engineering & Remote Sensing,* **69-1,** 53-57.

Gerlach, F., 2000. Chracteristics of Space Imaging's one-meter resolution satellite products, *International Archives of Photogrammetry and Remote Sensing,* **XXXIII-B1,** 128-134.

Glossary of Cartographic Terms, www.lib.utexas.edu/Libs/PCL/Map_collection/glossary.html, accessed on 15.06.2003.

Grodecki, J. and Dial, G., 2003. Block adjustment of high-resolution satellite images described by rational polynomials, *Photogrammetric Engineering & Remote Sensing,* **69-1,** 59-68.

Hashiba, H., Kameda, K., Sugimura, T. and Takasagi, K., 1998. Analysis of landuse change in periphery of Tokyo during last twenty years using the same seasonal Landsat data, *Adv. Space Res.,* **22-5,** 681-684.

Hashiba, H., Kameda, K., Uesugi, S. and Tanaka, S., 2000. Landuse change analysis of Tama River basin with different spatial resolution sensor data by Landsat/MSS and TM, *Adv. Space. Res.,* **26-7,** 1069-1073.

IKONOS Products and Product Guide, 2002. Version 1.1., Space Imaging L.L.C.

ISO/TC 211 N 1030, 2000. Final text for CD 19114, Geographic information – Quality evaluation procedures, International Organization for Standardization, Oslo, Norway.

ISO/TC 211 N 1034, 2001. Text for DIS 19113, Geographic information – Quality principles, as sent to ISO Central Secretariat for issuing as Draft International Standard, International Organization for Standardization, Oslo, Norway.

Kemper G., Altan, M.O. and Celikoyan, T.M., 2002. Final report for the project Monitoring landuse dynamics for the city of Istanbul, *European Commision, Joint Research Centre, Institute for Environment and Sustainability,* Speyer, Germany

Ketin, İ., 1990. *Geological Map of Istanbul,* Scale 1:50,000, 1 sheet.

Kok, K. and Veldkamp, A., 2001. Evaluating impact of spatial scales on land use pattern analysis in Central America, *Agriculture, Ecosystems and Environment,* **85,** 205-221.

Morrison, J., 2002. Spatial data quality, in Spatial databases : with applications to GIS pp. 500-516, Rigaux, P. Scholl, M. and Voisard, A., Morgan Kaufmann Publishers, San Francisco.

Radhadevi, P.V., Ramachandran, R. and Murali Mohan, A.S.R.K.V., 1998. Restitution of IRS-1C PAN data using an orbit attitude model and minimum control, *ISPRS Journal of Photogrammetry and Remote Sensing,* **53,** 262-271.

Radwan, M.M., Onchaga, R. and Morales, J., 2001. A structureal approach to the amangement and optimisation of geoinformation processes, *European Organisation for Experimental Photogrammetric Research,* **Official Publication No:41**, Frankfurt am Main, Germany.

Russian data-high resolution, http://ofd.ac.at/ofd/Systems/russian.html, accessed on 04.02.2004.

Sadeghian, S., Zoej, M.J.V., Delavar, M.R. and Abootalebi, A., 2001. Precision rectification of high resolution satellite imagery without ephemeris data, *JAG,* **3-4,** 366-371.

Satellite Constellation, IRS-1C&1D, http://www.spaceimagingme.com, accessed on 29.03.2004.

Taştan, H., 1999. Data quality in geographic information systems, *PhD Thesis,* ITU Institute for Science and Technology, Istanbul. (in Turkish).

Toutin, T., 2003. Error tracking in Ikonos geometric processing using a 3D parametric model, *Photogrammetric Engineering & Remote Sensing,* **69-1,** 43-51.

Young, T., 1994. Towards an international classification of land use, Consultancy report to United Nations Environmental Programme, Food and Agriculture Organisation (UNEP/FAO)

APPENDIX A

Coordinates, deviations and distributions of ground control points used for georeferencing of satellite images.

Table A.1 Coordinates and deviations of ground control points for IRS-1D image (west)

#	Coordinates (m)		Deviations (m)	
	Easting	Northing	Easting	Northing
1	379272,86	4544603,19	3,17	-13,58
2	374083,34	4542891,61	9,89	12,33
3	374632,02	4547919,46	2,47	-8,44
4	375132,54	4558168,71	7,80	-11,51
5	374633,49	4541932,86	-6,61	8,27
6	377159,45	4540710,24	9,22	10,30
7	376139,51	4562389,65	15,12	-22,61
8	379175,08	4553569,69	-0,83	-5,26
9	386166,88	4560509,80	-10,93	16,29
10	384713,83	4543991,72	11,54	-7,16
11	384265,70	4539459,20	12,52	10,25
12	388652,98	4538160,85	-9,86	-9,24
13	392350,48	4546964,92	2,89	-17,45
14	374849,28	4541769,85	9,69	20,87
15	386167,21	4552218,14	17,12	-27,75
16	389459,65	4553920,09	11,22	-11,97
17	394105,65	4538940,96	-7,14	13,44
18	391957,29	4539452,85	1,02	8,06
19	397444,52	4544278,22	-12,59	0,16
20	400249,89	4538057,45	1,84	-10,51
21	405928,45	4541636,51	-6,89	7,75
22	407395,68	4545674,30	8,80	6,30
23	406093,17	4551578,90	-0,07	-8,84
24	409482,61	4558901,71	7,79	0,34
25	409254,30	4563110,46	-7,70	-2,00
26	405356,00	4561778,73	-5,31	-1,64
27	406869,12	4559299,88	7,10	3,47
28	400857,34	4540835,30	-7,41	18,10
29	402219,63	4543753,88	-2,03	-9,13
30	403526,22	4546150,34	3,02	2,18
31	405340,79	4542232,00	1,74	1,51
32	405530,12	4548710,50	-2,50	-0,44
33	399523,13	4549320,41	-4,28	3,97
34	400807,40	4554454,95	-1,66	4,61
35	403523,69	4550724,52	9,88	0,18
36	404352,67	4554393,26	-0,93	-6,23
37	389381,01	4544559,33	-5,58	5,12
38	386577,11	4551425,80	-7,46	-1,01
39	397028,37	4552574,78	-8,55	-0,23
40	398996,95	4550516,63	-2,98	-2,49
41	397981,41	4542996,17	-2,76	-8,83
42	400141,70	4548273,05	5,28	0,34
43	405942,24	4553210,39	-0,43	-2,82
44	409591,56	4556884,17	5,28	-8,57
45	412365,17	4566241,62	9,86	6,86
46	410496,31	4568156,18	-1,38	17,68
47	409751,21	4565304,52	9,62	-11,39
48	383743,38	4556244,01	-7,95	1,16
49	382930,80	4552753,42	-7,38	9,42
50	394546,45	4563654,59	-9,63	6,11
51	394444,24	4565971,70	-6,21	-0,47
52	393339,39	4567991,57	-8,83	2,96
53	394687,47	4568874,09	-5,70	8,81
54	393548,66	4560285,15	-0,96	14,69
55	394708,76	4560052,79	-3,91	2,70
56	394161,31	4554801,77	-5,80	10,61
57	396587,78	4554702,12	2,92	-4,02
58	381089,76	4563519,46	-5,81	-3,57
59	382139,21	4563850,47	-2,77	9,46
60	390481,65	4552994,62	2,83	-3,87
61	387775,01	4549597,38	-3,13	-0,25
62	388098,40	4551896,95	-1,02	5,07
63	405509,82	4538475,66	15,38	-12,76
64	409106,25	4551123,23	0,60	10,32
65	381919,33	4538661,70	-12,96	-20,22
66	382137,80	4538071,76	9,13	12,10
67	383910,37	4537295,62	-1,34	1,23
68	387822,25	4536901,92	-0,68	-21,32
69	399858,26	4536595,92	14,30	-12,33
70	401541,15	4536355,83	-10,69	-12,01
71	405739,25	4538313,22	-8,38	9,86

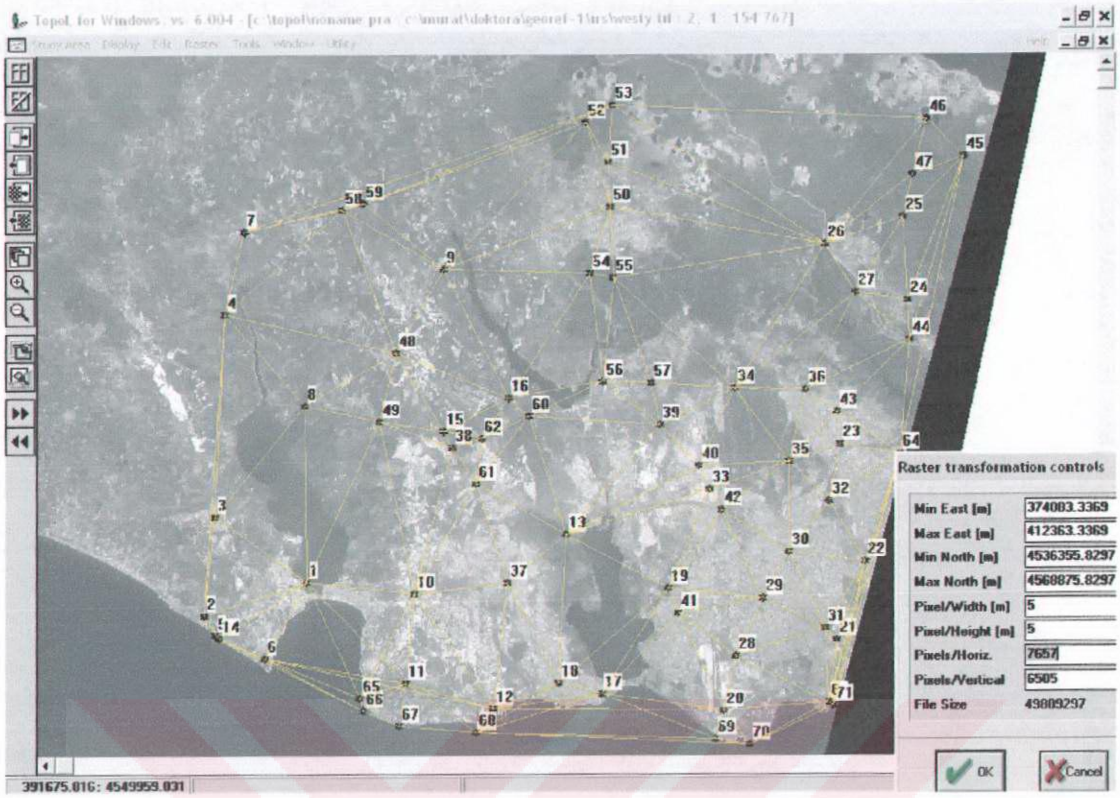


Figure A.1 Distribution of ground control points on IRS-1D image (west)

Table A.2 Coordinates and deviations of ground control points for IRS-1D image (east)

#	Coordinates (m)		Deviations (m)		#	Coordinates (m)		Deviations (m)	
	Easting	Northing	Easting	Northing		Easting	Northing	Easting	Northing
1	396949,53	4539971,52	9,65	-13,72	50	422308,81	4551872,67	-2,72	0,45
2	406312,02	4539144,62	-4,21	5,62	51	422011,11	4551474,78	10,67	-9,57
3	410546,22	4541902,57	6,28	7,28	52	426424,16	4551163,34	-1,06	-6,30
4	401272,38	4538501,91	-15,94	-4,25	53	424339,09	4549722,77	10,74	-10,69
5	399603,32	4549212,13	-6,43	17,61	54	420708,02	4549354,80	6,91	-12,91
6	402598,65	4548284,96	3,51	-7,12	55	420840,91	4546647,01	16,01	-13,77
7	396843,16	4545203,94	-16,67	13,89	56	426109,89	4544467,41	3,43	-8,14
8	396545,78	4545242,29	-13,06	4,44	57	422018,47	4541802,79	1,06	-3,53
9	401088,12	4544947,08	-13,04	-0,76	58	417098,57	4542111,23	1,99	10,63
10	405563,40	4548701,17	4,92	17,71	59	418244,25	4540191,57	17,13	-2,26
11	406266,69	4546414,89	-6,91	14,80	60	431894,02	4547718,45	1,27	-4,52
12	404583,04	4541724,77	-18,15	-6,85	61	430725,17	4551837,58	6,59	-8,14
13	413796,46	4543712,86	1,00	5,72	62	430533,72	4552987,41	2,43	-0,12
14	412402,57	4548597,20	-0,67	11,69	63	428990,68	4549920,04	7,37	3,03
15	417000,23	4549428,17	7,07	-2,89	64	429578,41	4548772,56	3,31	-1,61
16	418183,60	4551571,44	-3,15	-7,32	65	446186,97	4553542,68	-16,40	16,90
17	417832,06	4554519,47	5,62	-4,16	66	446974,94	4552159,25	-9,70	-7,58
18	421170,45	4555461,52	7,00	-3,33	67	444810,91	4550892,54	-2,23	6,40
19	413129,65	4553309,97	-4,46	21,99	68	446727,04	4548887,94	0,40	-2,81
20	409379,17	4551930,38	-4,50	5,97	69	445519,37	4544672,63	-2,04	16,15
21	408593,32	4553393,70	-1,99	-14,86	70	437113,45	4545160,91	-7,82	16,69
22	403643,11	4554204,95	-4,64	-14,96	71	438966,90	4543897,19	9,50	-2,43
23	406418,98	4561804,09	13,60	-6,94	72	439880,78	4541317,49	-7,25	4,43
24	409899,14	4559263,16	-4,77	8,22	73	437052,46	4549524,95	-8,09	-2,47
25	414449,34	4558975,40	-15,91	11,57	74	442422,63	4552989,05	-10,29	-1,62
26	415322,26	4560760,42	-6,79	-12,39	75	433233,51	4543815,74	-12,14	4,05
27	418565,49	4558743,90	4,50	-2,48	76	441900,54	4549391,67	3,07	17,87
28	423236,49	4563905,70	1,11	-4,87	77	422255,10	4538982,28	-4,34	-9,16
29	425852,71	4567057,02	3,10	-3,69	78	423878,92	4536554,77	11,09	-0,26
30	424536,92	4567713,04	5,68	2,80	79	423468,89	4535740,02	0,37	-9,76
31	419660,39	4565345,23	3,25	-1,73	80	421416,44	4528283,12	-11,14	4,99
32	416091,93	4567622,01	1,91	-0,14	81	425720,80	4523574,02	0,68	17,27
33	410288,42	4563345,04	-12,06	-3,17	82	425256,95	4520958,20	-3,17	28,11
34	409221,35	4568542,61	-2,13	-3,66	83	429514,00	4541896,69	16,89	15,72
35	407491,58	4559317,94	-2,30	-6,03	84	426150,57	4534161,74	6,42	-1,26
36	405737,88	4555257,26	6,70	9,35	85	431909,50	4535433,60	-12,77	7,30
37	413313,48	4564451,09	-15,40	9,64	86	434085,91	4540275,65	-1,46	-2,14
38	433065,09	4561089,77	-2,99	-0,23	87	435961,57	4538364,54	5,19	-16,08
39	428951,00	4563536,54	6,43	-0,74	88	430283,69	4540170,74	-2,56	-5,82
40	434516,60	4565946,46	9,59	-2,43	89	428210,48	4530112,89	6,38	-1,81
41	426951,40	4556240,79	3,50	0,64	90	430755,00	4531825,55	-7,03	-6,93
42	424306,23	4560976,20	-0,69	5,33	91	447271,63	4540737,66	-16,76	-3,02
43	427006,20	4559639,16	16,13	-1,55	92	446797,50	4536923,35	-5,35	10,67
44	434175,90	4556419,74	3,30	1,03	93	446817,01	4535219,93	-4,86	-16,71
45	436334,61	4554927,27	3,91	-6,93	94	446209,73	4529532,21	-17,43	6,34
46	429727,88	4554431,15	-11,58	4,49	95	446696,37	4528189,34	-10,63	9,77
47	424497,28	4555023,79	2,62	-3,15	96	446555,91	4524441,88	-2,57	-5,38
48	425286,20	4555869,73	-0,70	4,94	97	443287,92	4538216,23	-9,49	17,55
49	425561,55	4552407,89	-5,78	-0,49	98	442992,55	4537218,82	5,39	6,91

Table A.2 Coordinates and Deviations of ground control points for IRS-1D image (east, continued)

#	Coordinates (m)		Deviations (m)	
	Easting	Northing	Easting	Northing
99	443999,96	4532155,12	-2,59	-1,30
100	441275,27	4530760,97	5,98	-10,71
101	436308,28	4533286,51	2,51	0,22
102	437177,13	4531850,29	6,26	-5,02
103	446342,30	4514039,97	-0,23	0,31
104	445395,58	4514283,89	14,20	-14,96
105	437747,14	4519792,22	4,37	-5,16
106	444669,80	4521831,44	17,92	-9,19
107	443031,23	4525898,74	5,66	2,06
108	437162,58	4528009,35	-3,96	-2,91
109	432673,75	4528600,52	9,36	6,32

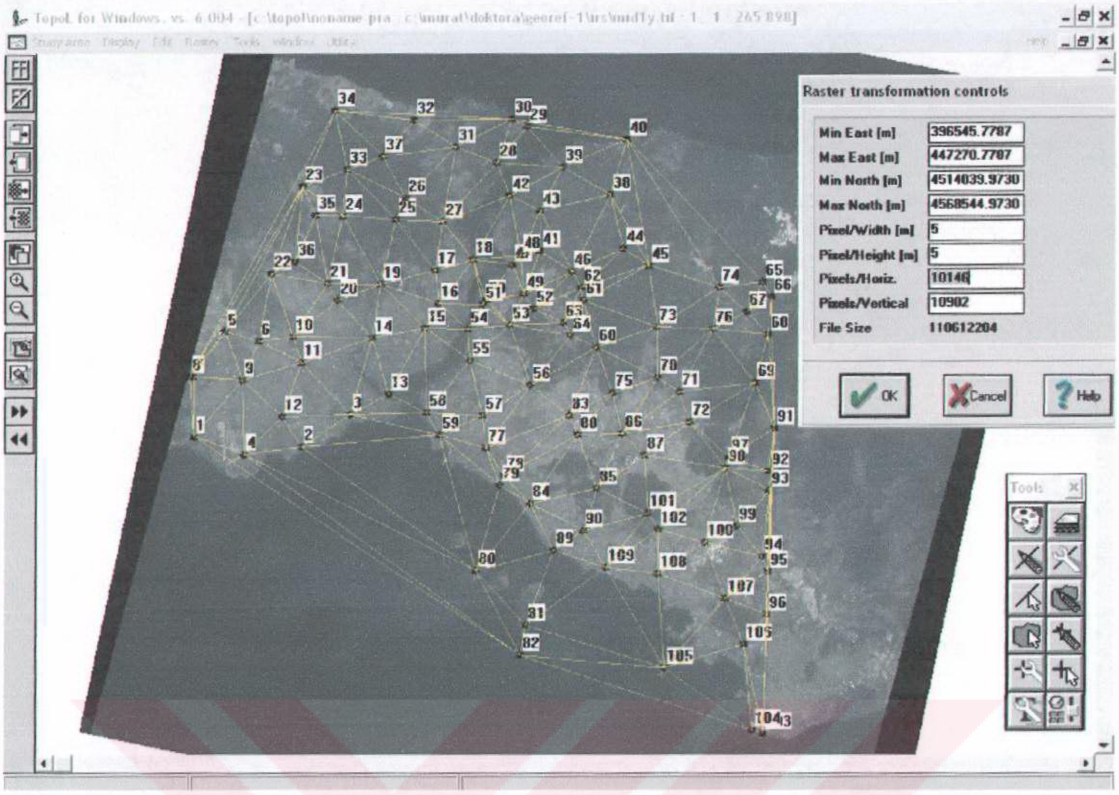


Figure A.2 Distribution of ground control points on IRS-1D image (east)

Table A.3 Coordinates and deviations of ground control points for IKONOS image (north)

#	Coordinates (m)		Deviations (m)			#	Coordinates (m)		Deviations (m)	
	Easting	**Northing**	**Easting**	**Northing**			**Easting**	**Northing**	**Easting**	**Northing**
1	416102,08	4567632,80	-11,59	-3,16		23	419542,61	4564499,40	1,68	2,68
2	419179,09	4568525,06	-5,31	-9,28		24	417550,78	4564635,16	0,78	1,65
3	422869,82	4568236,89	5,87	-3,34		25	422265,15	4566255,37	9,17	5,17
4	418923,92	4565645,40	-0,62	-15,83		26	417022,27	4562478,63	6,19	1,64
5	420891,31	4567267,87	-2,26	-2,85		27	415927,80	4560864,67	7,69	7,26
6	418106,35	4567084,68	7,66	-11,21		28	417944,39	4561105,63	-1,31	-3,85
7	416887,03	4564065,57	-2,74	-0,24		29	420168,15	4562266,27	0,49	-2,93
8	419103,29	4563005,83	4,94	-8,42		30	420398,56	4561618,63	-22,21	-8,56
9	420313,40	4565830,19	7,67	6,27		31	416189,48	4564440,15	7,05	5,30
10	421198,03	4569358,62	-8,36	-5,24		32	417611,18	4565953,64	-0,94	10,00
11	424534,38	4567712,91	7,92	6,85		33	416001,27	4559881,32	-3,39	12,47
12	425788,21	4566876,40	1,81	7,37		34	418467,48	4559998,54	4,13	-1,99
13	424565,76	4564426,20	-3,87	1,42		35	419969,21	4560452,98	-7,81	-3,60
14	424867,83	4564044,46	-17,16	-4,64		36	420757,20	4559894,70	7,71	3,69
15	423113,60	4566643,02	4,37	10,43		37	427113,90	4562921,62	14,62	7,75
16	423177,11	4565789,17	5,32	2,63		38	426768,83	4560372,94	-2,33	2,36
17	424114,59	4566036,26	4,04	2,68		39	424328,41	4560048,14	-13,58	-2,30
18	421481,06	4564432,88	9,73	8,50		40	425574,11	4561539,13	-7,84	-4,32
19	423237,28	4563905,16	4,32	-5,67		41	422747,28	4569429,57	-6,91	1,89
20	422310,94	4561425,32	-10,05	-6,92		42	425584,75	4567521,55	-7,16	-10,93
21	421870,74	4563199,46	9,26	13,81		43	419425,25	4569834,68	-1,93	7,64
22	420976,62	4562595,23	4,96	-4,19						

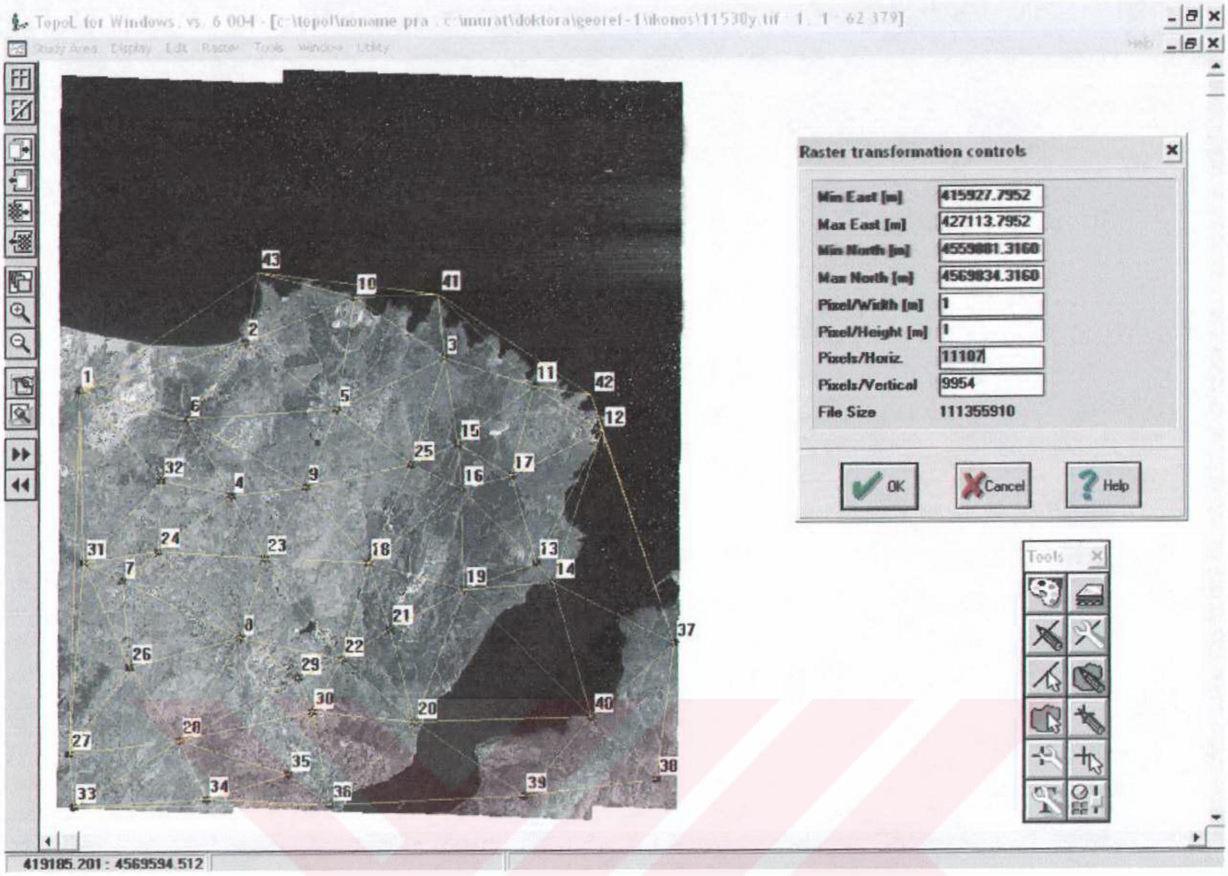


Figure A.3 Distribution of ground control points on IKONOS image (north)

Table A.4 Coordinates and deviations of ground control points for IKONOS image (middle)

#	Coordinates (m)		Deviations (m)			#	Coordinates (m)		Deviations (m)	
	Easting	Northing	Easting	Northing			Easting	Northing	Easting	Northing
2	417665,63	4546404,95	-2,18	8,37		32	418192,76	4551270,48	11,19	15,74
3	416650,69	4547644,38	-1,75	0,25		33	418783,01	4550556,58	4,26	1,73
4	416928,12	4547205,39	-3,98	-9,24		34	419881,34	4552654,26	-11,45	-4,94
5	416095,31	4546415,86	-12,89	-13,17		35	421586,65	4554421,51	-3,01	6,81
6	417027,40	4549566,77	6,03	8,16		36	424214,17	4554172,46	-1,26	-14,36
7	416574,10	4550070,43	-2,39	3,25		38	424641,37	4553811,74	0,54	-9,15
8	417224,13	4550948,27	9,87	8,83		39	425429,84	4553959,58	9,05	8,63
9	416132,40	4551627,80	-2,21	9,54		40	425629,81	4554094,22	-0,68	8,05
10	416231,37	4552254,15	4,38	-5,80		41	426098,31	4554556,79	0,17	1,22
11	417206,03	4553181,27	1,64	-0,31		42	422889,84	4552976,84	-2,34	-8,96
12	417930,63	4553261,92	2,60	-3,99		43	422908,86	4551792,27	10,62	6,50
13	419537,51	4553475,17	8,35	5,65		44	423364,65	4551508,12	20,87	3,84
14	420623,76	4553894,62	-7,79	-17,11		45	421587,39	4552258,06	-0,37	-8,09
15	420274,38	4554162,62	-12,83	-0,99		46	421657,06	4550326,96	-10,34	-0,91
16	421855,46	4554891,95	-0,52	9,85		47	422699,03	4550918,44	11,08	-0,38
17	421019,74	4554783,33	-8,11	17,11		48	422294,57	4549372,98	1,63	2,18
18	420051,53	4554581,45	-12,52	-10,30		49	423196,91	4547883,77	-10,10	-6,96
19	417679,23	4554572,79	18,52	-1,52		50	423960,33	4549052,04	-5,42	-10,34
20	418579,43	4553719,75	-3,47	-11,20		51	420992,42	4549274,45	6,23	-7,62
21	420894,61	4553154,78	-11,09	3,80		52	422378,95	4548736,62	-13,66	0,19
22	420535,68	4552521,94	-11,82	-6,19		53	420489,49	4547726,82	12,26	1,09
23	420755,62	4552792,42	-4,63	-11,63		54	422217,98	4547571,34	-7,37	5,86
24	420403,26	4551919,87	-3,98	-15,92		55	421382,11	4547570,69	11,32	-5,16
25	418989,06	4548397,21	4,84	1,02		56	420368,39	4546563,21	9,09	0,94
26	418300,86	4549908,72	6,30	4,71		57	420866,32	4546661,62	19,34	5,14
27	420049,64	4550739,34	7,91	9,70		58	422298,19	4546658,20	-2,81	17,97
28	420612,42	4550243,51	8,77	7,65		59	425581,60	4546802,41	-6,16	-7,55
29	419266,79	4547799,58	-0,10	1,79		60	423362,67	4546450,19	4,68	4,27
30	418410,55	4546671,91	-12,83	-1,69		61	425967,11	4551002,57	3,92	-4,88
31	418491,67	4547157,47	1,52	-3,15		62	425809,98	4549711,59	7,39	-0,11

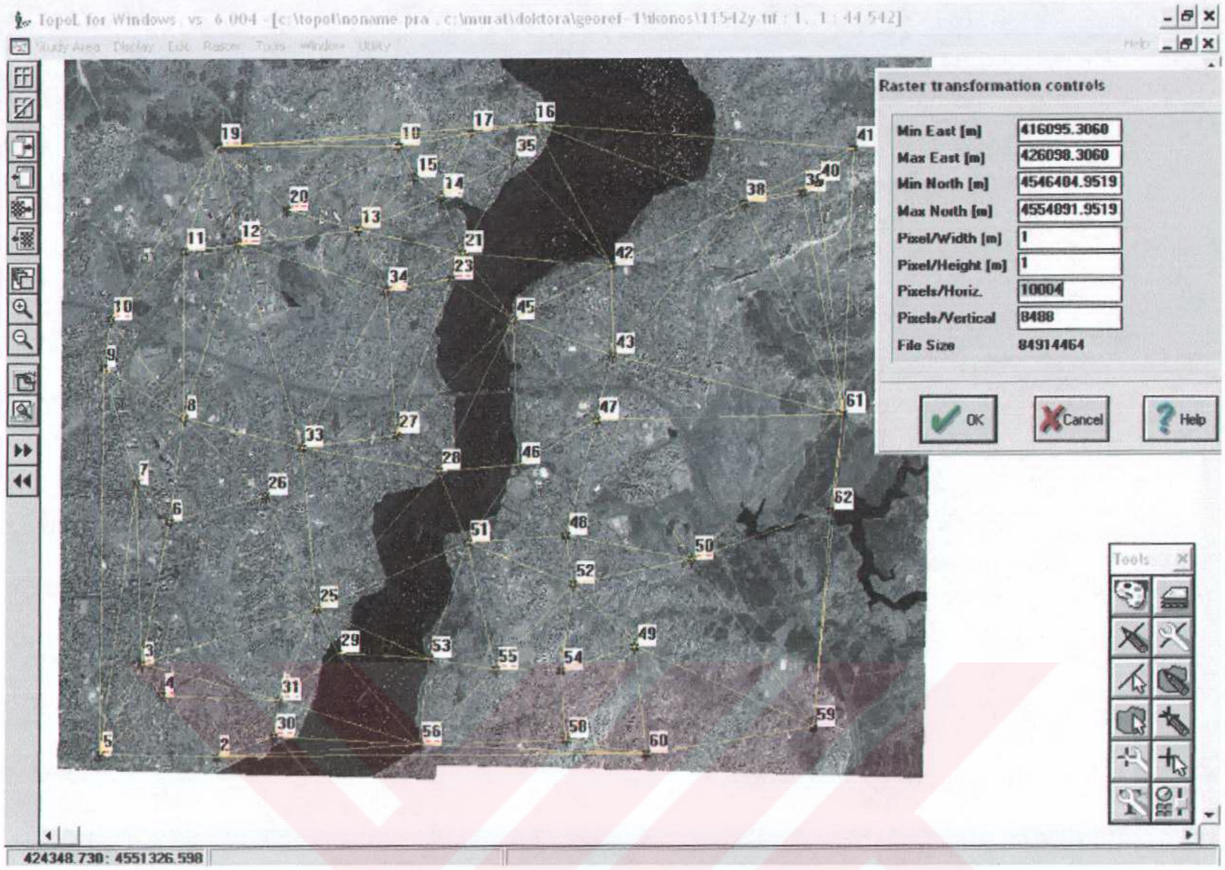


Figure A.4 Distribution of ground control points on IKONOS image (middle)

Table A.5 Coordinates and deviations of ground control points for IKONOS image (south)

#	Coordinates (m)		Deviations (m)		#	Coordinates (m)		Deviations (m)	
	Easting	Northing	Easting	Northing		Easting	Northing	Easting	Northing
1	416280,24	4543588,68	-5,98	3,97	28	422366,68	4546301,63	-5,19	-1,37
2	417660,51	4544664,73	2,17	-4,31	29	421903,31	4545158,69	-2,26	6,82
3	418142,42	4543408,63	1,48	3,97	30	421362,03	4546246,71	-7,59	-9,68
4	417317,73	4542567,89	4,86	-3,22	31	420205,62	4537580,40	1,37	-1,04
5	418711,87	4545475,68	6,97	-2,02	32	421098,22	4539147,70	1,06	7,95
6	419335,29	4544375,24	-2,00	5,87	33	422892,46	4540661,74	0,11	-2,28
7	419172,62	4542512,91	-6,25	0,44	34	423765,44	4542361,73	-5,75	-0,70
8	418100,92	4541626,03	-2,14	-0,64	35	424887,74	4543745,39	-3,41	1,74
9	416995,00	4540805,37	4,53	4,53	36	424489,49	4545221,73	-7,99	3,77
10	416073,34	4542263,19	-6,12	-5,43	37	422144,70	4537096,11	-0,94	2,56
11	420327,74	4543823,52	3,26	-7,39	38	423279,11	4538579,90	-0,90	8,58
12	420565,72	4542510,98	3,63	1,70	39	424992,59	4539899,39	1,67	-0,45
13	421850,94	4543667,58	11,76	8,11	40	425641,42	4542197,25	5,23	2,43
14	421314,24	4544932,82	13,43	-2,63	41	426775,05	4544189,47	7,08	7,39
15	420434,85	4545440,06	-1,71	-4,66	42	423872,71	4535801,90	-3,61	-8,82
16	419809,13	4546216,33	-7,40	-1,53	43	425188,69	4537721,21	-3,41	-1,16
17	419925,96	4541538,32	-0,20	-1,37	44	426918,47	4539725,24	8,06	-9,32
18	419077,51	4540700,67	5,03	0,40	45	425560,13	4534372,93	-7,53	-1,89
19	418206,46	4540353,53	10,62	-7,85	46	426653,07	4536006,51	3,03	-0,52
20	417789,29	4539456,68	9,83	4,89	47	424132,00	4537639,13	5,94	-0,86
21	419096,63	4539105,30	-1,48	-4,21	48	425598,10	4536005,34	-7,37	-4,54
22	418730,89	4537989,78	0,82	2,17	49	421960,44	4538141,69	-5,31	0,60
23	420053,86	4540081,75	-2,42	3,46	50	416189,21	4545923,90	-3,49	-5,57
24	421320,53	4540957,54	7,93	-3,78	51	418235,74	4546470,25	2,39	-1,23
25	422242,70	4542720,97	-0,33	7,86	52	416262,51	4539486,99	-2,97	6,38
26	423336,10	4543811,74	1,33	5,95	53	417701,76	4536883,14	-4,45	2,69
27	422850,26	4544816,04	9,83	-0,28					

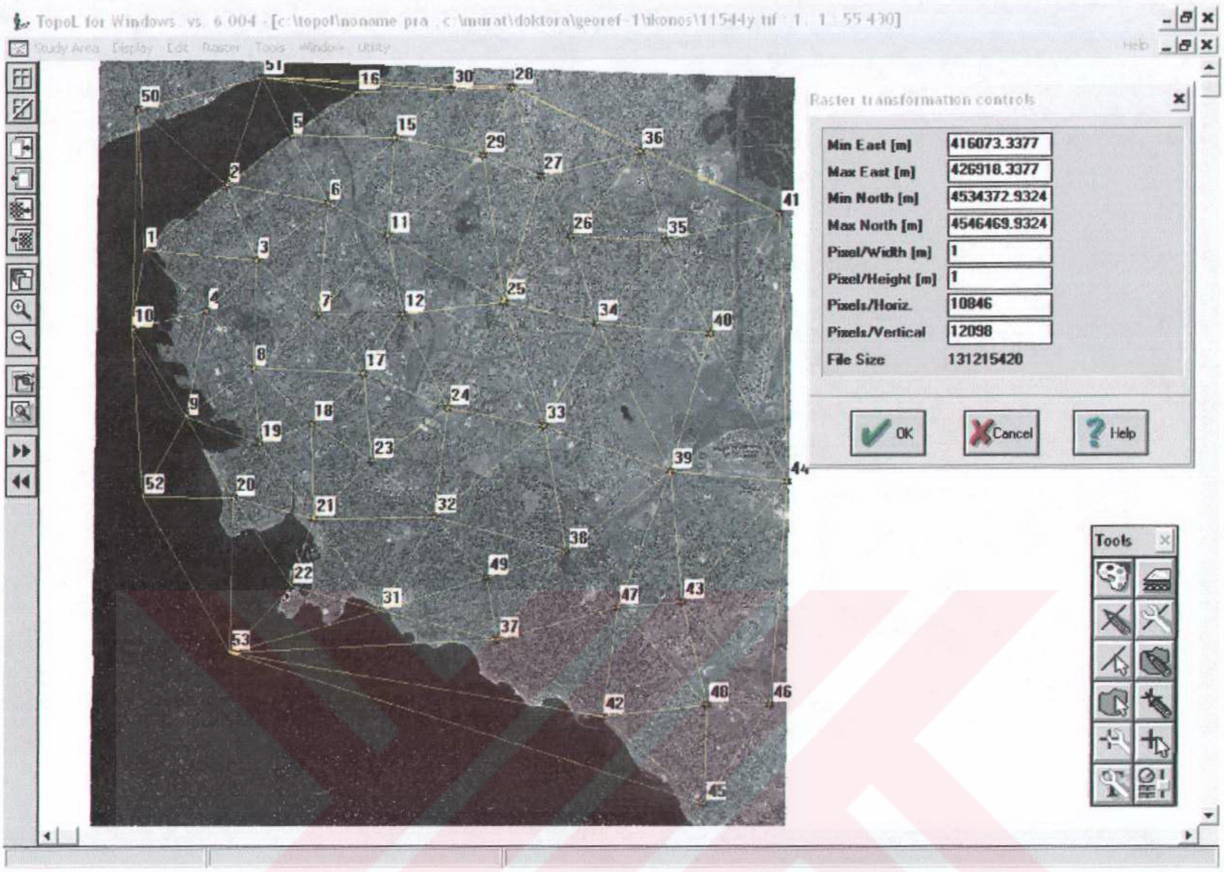


Figure A.5 Distribution of ground control points on IKONOS image (south)

Table A.6 Coordinates and deviations of ground control points for KFA-1000 image (east)

#	Coordinates (m)		Deviations (m)			#	Coordinates (m)		Deviations (m)	
	Easting	Northing	Easting	Northing			Easting	Northing	Easting	Northing
1	437783,98	4520628,70	-4,64	12,68		19	441062,43	4541109,27	9,56	-0,16
2	438252,27	4525703,63	-10,94	-1,22		20	441760,30	4543247,04	-1,13	2,80
3	443315,22	4522788,93	-1,39	0,05		21	440815,66	4545389,56	0,14	0,57
4	443111,70	4520659,20	4,21	-2,71		22	440835,57	4547282,17	3,13	-2,35
5	443662,36	4525774,58	8,31	0,26		23	441839,49	4549564,07	7,77	-4,29
6	446314,44	4514021,77	-2,75	-1,77		24	443754,68	4552566,22	-6,44	-0,43
7	445567,54	4513966,75	6,42	-1,32		25	441758,19	4554163,01	-1,95	4,28
8	446210,27	4531373,97	0,30	0,79		26	443052,19	4557883,98	5,34	0,75
9	439398,84	4528483,64	8,95	-3,30		27	444094,30	4537313,37	-1,06	-1,13
10	442233,59	4529461,84	-1,79	-3,69		28	447243,96	4540730,60	-0,79	-4,54
11	443995,73	4532152,47	4,98	-3,13		29	446698,17	4536869,67	-4,98	-4,70
12	444111,90	4534641,31	-10,56	1,25		30	446211,05	4542094,76	4,23	12,25
13	443215,39	4535699,91	1,77	0,62		31	445098,67	4544891,07	9,24	-11,40
14	446772,78	4524951,22	1,49	-4,54		32	447144,36	4544318,07	-9,76	4,81
15	446812,28	4535219,45	-1,74	18,36		33	445371,76	4546346,92	-5,45	4,55
16	439763,94	4534045,84	-8,88	-2,86		34	446170,57	4549054,88	-1,53	-9,80
17	440698,21	4536582,14	6,23	-5,21		35	444692,19	4550754,77	-8,82	3,78
18	440787,54	4538039,56	-4,47	1,17		36	446397,43	4553953,17	6,98	-0,42

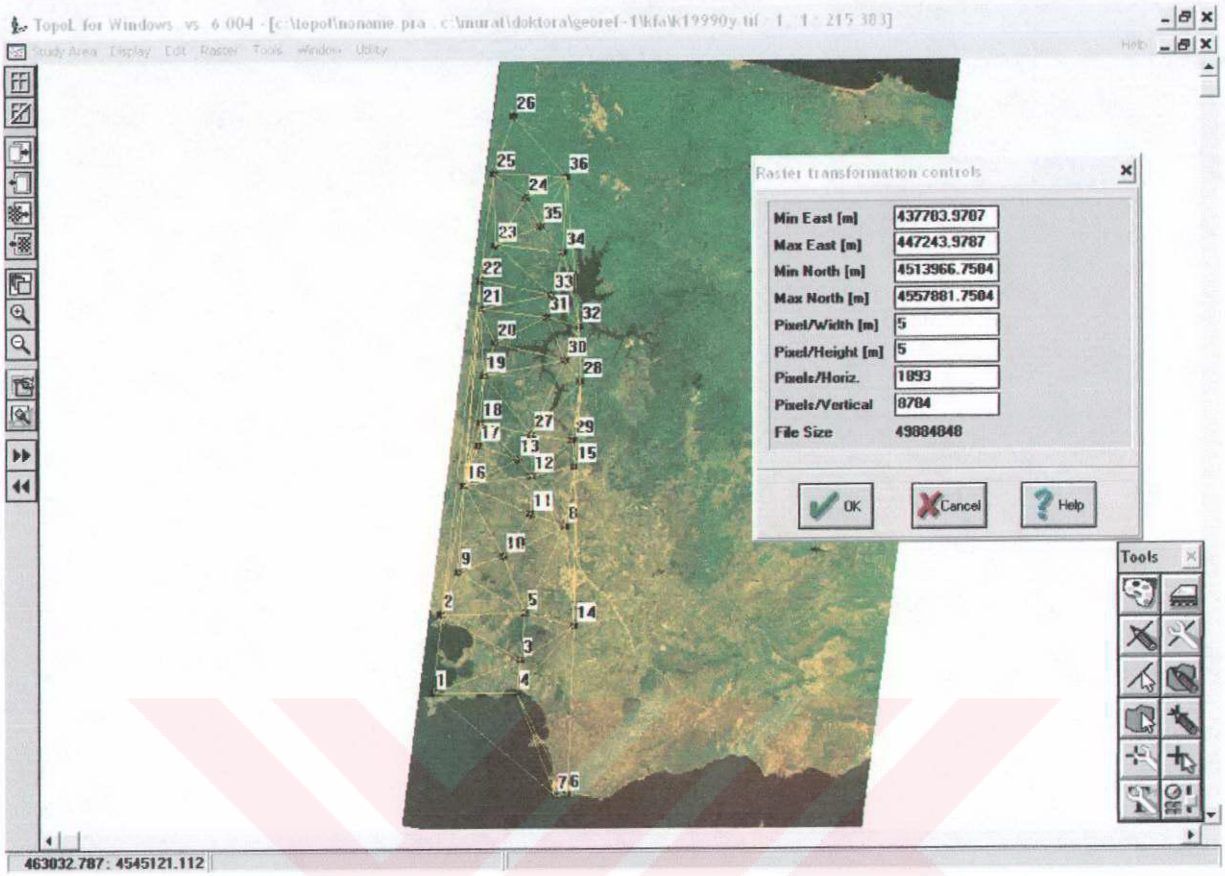


Figure A.6 Distribution of ground control points on KFA-1000 image (east)

Table A.7 Coordinates and deviations of ground control points for KFA-1000 image (west)

#	Coordinates (m)		Deviations (m)			#	Coordinates (m)		Deviations (m)	
	Easting	Northing	Easting	Northing			Easting	Northing	Easting	Northing
1	377325,73	4540099,55	-13,62	-6,24		50	409020,40	4558089,77	-4,25	3,97
2	375848,17	4545330,62	-4,93	-5,72		51	409559,09	4555418,97	4,52	-0,42
3	374530,94	4550545,64	7,25	-10,27		52	410495,40	4551628,05	-3,80	-2,70
4	373446,13	4555236,31	-0,97	-2,28		53	411440,89	4548256,51	-7,98	7,79
5	374309,54	4561379,78	0,11	12,25		54	412756,85	4543879,83	18,41	-9,47
6	373844,35	4565992,29	-8,20	12,38		55	413571,75	4543308,34	-5,22	5,63
7	382167,18	4538259,37	4,24	-3,60		56	414579,96	4541905,40	3,42	-5,20
8	382788,36	4543545,33	3,74	-8,07		57	415090,05	4545870,08	-1,24	7,95
9	380877,61	4551011,15	3,27	1,50		58	414627,44	4550623,74	-1,62	1,62
10	381352,47	4556533,90	9,83	1,70		59	414107,36	4557133,10	-0,03	-11,20
11	381025,31	4563441,88	-0,16	-2,70		60	414819,43	4560817,09	4,09	-8,90
12	385244,95	4537667,86	3,81	2,63		61	416025,41	4567097,90	-7,35	-4,31
13	385920,84	4542203,21	-2,43	-1,05		62	417447,08	4568496,24	-3,11	-2,07
14	386984,97	4547491,85	-14,84	1,11		63	419379,45	4569831,69	-1,05	-8,58
15	387879,38	4548755,99	-4,98	1,14		64	419905,64	4567200,49	12,32	-10,90
16	387704,89	4553027,24	-7,29	5,27		65	421433,01	4564111,36	4,00	-0,01
17	388271,24	4556888,89	0,27	1,49		66	420846,32	4561169,54	4,06	-0,12
18	384076,09	4559503,38	14,11	-6,45		67	419072,61	4558434,50	-8,99	-2,45
19	385879,58	4563480,51	-0,21	1,70		68	419630,65	4552285,00	-1,86	-9,34
20	386264,10	4565267,69	-2,33	-2,23		69	417431,52	4547648,38	0,76	1,58
21	390709,36	4567808,94	-0,61	-0,16		70	419104,94	4545852,64	0,89	-5,16
22	390151,13	4564034,60	-4,37	-2,19		71	417389,08	4542168,45	3,34	3,59
23	391177,85	4560959,55	-0,44	1,81		72	419122,86	4538743,41	-3,01	3,52
24	391930,29	4557680,31	4,29	5,63		73	420693,95	4537121,39	1,57	-1,00
25	393281,52	4553285,37	0,53	-0,70		74	423935,80	4538990,75	5,88	14,81
26	393363,66	4549621,36	0,69	-9,00		75	424150,98	4535646,48	6,09	5,68
27	393071,68	4545618,59	1,15	7,42		76	424781,12	4543973,44	-12,53	3,78
28	396201,12	4542921,93	3,42	1,04		77	426165,66	4545761,14	0,82	-2,90
29	396559,90	4540260,41	3,63	-7,23		78	423689,76	4551034,42	4,94	10,82
30	399804,01	4536704,41	5,92	9,12		79	424428,47	4554775,42	-2,15	-0,33
31	399756,69	4541083,25	-2,64	1,04		80	425675,65	4557582,52	-0,13	-7,00
32	399843,46	4546487,88	1,04	-15,26		81	426531,15	4562245,08	-0,51	6,76
33	399293,94	4551303,07	-1,41	-6,85		82	426743,80	4563906,42	-7,46	4,56
34	399104,60	4554359,98	-9,76	-6,51		83	430786,68	4565317,56	1,47	0,11
35	402252,43	4554588,61	4,52	16,11		84	429863,43	4561437,31	4,08	6,80
36	403426,37	4551559,53	4,76	3,53		85	430985,81	4558002,49	-0,22	11,26
37	402779,28	4548174,48	-1,21	1,32		86	430865,51	4553785,04	2,41	4,26
38	403023,51	4544605,58	6,00	-0,86		87	430637,41	4551887,00	0,31	-2,68
39	403720,09	4540024,26	-4,77	-1,03		88	431449,21	4547113,69	2,95	-7,44
40	405738,29	4538344,75	-0,46	7,33		89	430991,48	4543003,94	0,99	-5,31
41	406262,58	4542378,99	1,30	-0,92		90	430243,52	4541419,98	1,13	-9,92
42	406286,22	4545800,67	1,03	7,66		91	430874,39	4535622,85	-0,72	3,63
43	406194,40	4548293,43	0,83	3,48		92	429940,57	4529895,19	-0,25	-1,20
44	406514,76	4553299,98	0,42	-2,63		93	433173,42	4528089,22	-2,46	1,08
45	405940,03	4558316,61	2,17	-2,42		94	434757,87	4534284,10	3,98	3,64
46	406331,85	4562594,93	-0,33	-2,30		95	434115,39	4540171,00	5,84	6,19
47	406358,86	4567585,51	-3,15	4,33		96	434162,11	4545329,50	-1,56	-2,93
48	409546,67	4567661,40	1,34	4,28		97	433054,83	4548933,36	-1,84	6,53
49	409216,52	4563040,36	3,89	8,43		98	434860,69	4554197,20	-6,97	4,37

Table A.7 Coordinates and deviations of ground control points for KFA-1000 image (west, continued)

#	Coordinates (m)		Deviations (m)			#	Coordinates (m)		Deviations (m)	
	Easting	Northing	Easting	Northing			Easting	Northing	Easting	Northing
99	437600,27	4566524,46	-5,67	-2,14		106	443833,38	4550140,11	10,01	-10,08
100	436537,05	4527470,87	-7,41	-1,24		107	444555,89	4546183,43	-1,85	-10,24
101	436532,28	4531429,55	1,87	-5,83		108	441942,21	4543028,24	-6,36	-0,59
102	437143,94	4536266,75	-0,94	-3,32		109	442364,61	4540805,14	-1,40	6,64
103	439011,03	4541240,13	-6,18	-5,53		110	441529,47	4537160,94	1,35	1,61
104	439942,29	4546901,79	5,41	-0,50		111	439831,31	4530122,52	-7,90	1,34
105	440638,73	4550108,27	2,73	4,46						

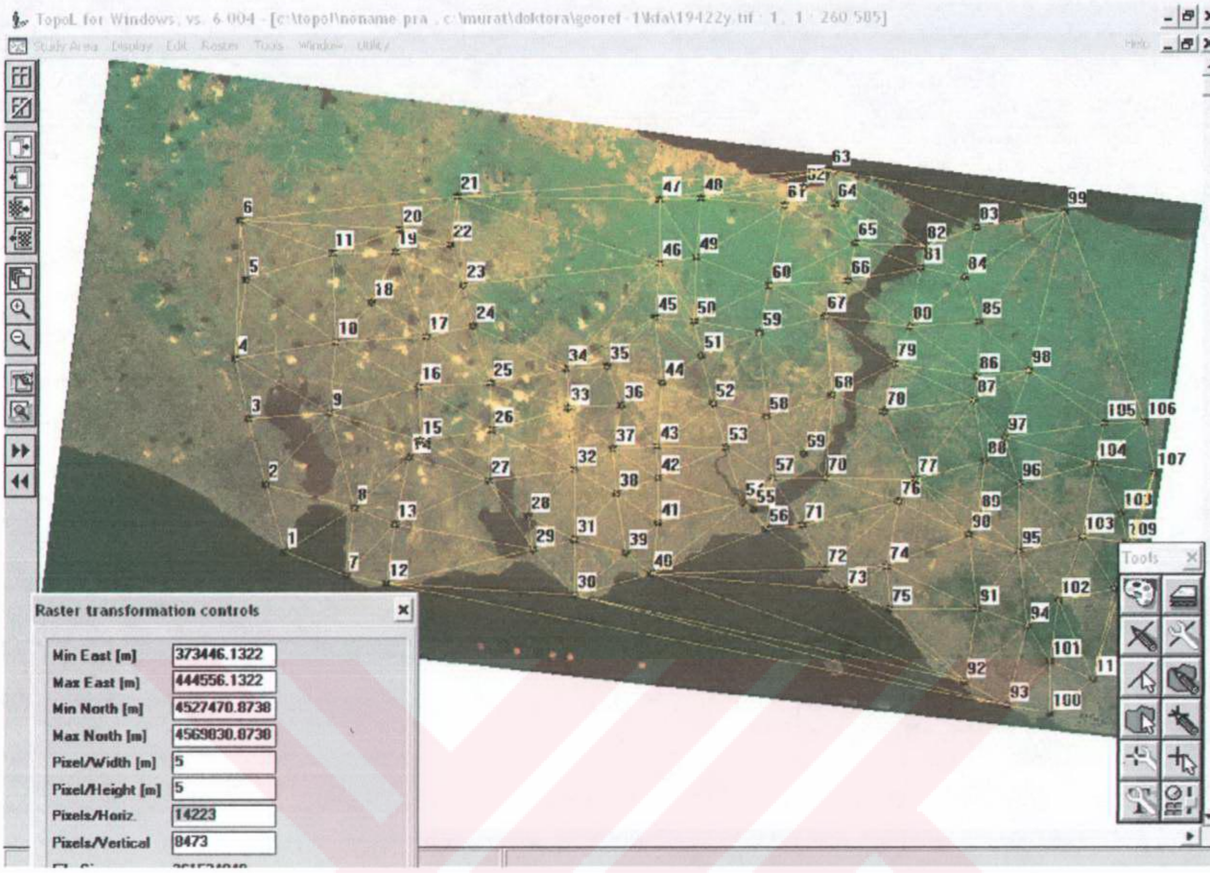


Figure A.7 Distribution of ground control points on KFA-1000 image (west)

APPENDIX B

Legend with explanations **(Kemper et al., 2002)**

1.1.1 Continuous urban fabric

Structures and the transport network cover most of the land. Buildings, roads and artificially surfaced areas cover more than 80% of the total surface. Non-linear areas of vegetation and bare soil are exceptional.

When roads and structures along roads are less then 25 metres wide, as long as they are more than 1 hectare in size, they have been classified as continuous dense urban fabric. Possible comments (e.g. if a class should be marked as "not permanently residential" in field Comments or as 1.2.2.2 in the field Alt-legend) will be described in the attribute table.

1.1.1.1 Residential continuous dense urban fabric

Residential structures cover more than 80% of the total surface.

"Continuous" refers to the downtown residential environment, including high-rise dwellings, with few gardens; "residential structures" refers only to buildings, roads and concrete areas (thus excluding green spaces such as gardens). More than 50% of the buildings have three or more stories.

1.1.1.2 Residential continuous medium dense urban fabric

Residential structures cover more than 80% of the total surface (private gardens are not considered as a part of residential structures). Less than 50% of the buildings have three or more stories.

1.1.1.3 Informal settlements

More than 80% of buildings and structures are illegal, unplanned and/or unregulated (including Gecekondus).

1.1.2 Discontinuous urban fabric

Most of the land is covered by structures. Buildings, roads and artificially surfaced areas are associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces. This type of land cover can be distinguished from continuous urban fabric by the presence of non-impermeabilised surfaces: gardens, parks, planted areas and non-surfaced public areas.

Between 10% and 80% of the land is covered by residential structures. Possible comments (e.g. if a class should be marked as "not permanently residential") will be described in the attribute table.

1.1.2.1 Residential discontinuous urban fabric

Buildings, roads and other artificially surfaced areas cover between 50% and 80% of the total surface. "Discontinuous" refers to suburban housing with gardens, although "residential structures" refers only to buildings, roads and concrete areas (again the green areas themselves such as gardens are not explicitly included in residential structures).

1.1.2.2 Residential discontinuous sparse urban fabric

Buildings, roads and other artificially surfaced areas cover between 10% and 50% of the total surface. The vegetated areas are predominant, but the land is not dedicated to forestry or agriculture.

1.1.2.3 Residential urban blocks

High-rise apartment buildings with eight or more stories (including "panel houses" for areas located in former European socialist countries).

1.1.2.4 Informal discontinuous residential structures

Illegal, unplanned and/or unregulated buildings and structures cover between 10% and 80% of the land.

1.2.1 Industrial (and), commercial, public and private units

Artificially surfaced areas (with concrete, asphalt, tamacadam, or stabilised, e.g. beaten earth) devoid of vegetation, occupy (most) more than 50% of the area in question, which also contains buildings and/or vegetated areas.

1.2.1.1 Industrial areas

Surfaces occupied by industrial activities, including their related areas.

1.2.1.2 Commercial areas

Surfaces mainly occupied by commercial activities, including their related areas.

1.2.1.3 Public and private services not related to the transport system

Surfaces occupied by general government, semi-public or private administrations including their related areas (access ways, lawns, parking areas).

1.2.1.4 Technological infrastructures for public service

Power plants (but not nuclear power plants), incinerators, waste water treatment plants, etc.

1.2.1.5 Archaeological sites

Including monuments, fortresses, ancient walls, etc.

1.2.1.6 Places of worship (not cemeteries)

Sanctuaries, convents, monasteries, holy places.

1.2.1.7 Non-vegetated cemeteries

Less than 40% of the land is covered with vegetation.

1.2.1.8 Hospitals

1.2.1.9 Restricted access services

Military areas, nuclear power plants, etc.

1.2.1.10 Agro-industrial complexes

Buildings (such as animal sheds, production buildings, residential blocks for workers etc.) related to agricultural industry in the countryside. This class covers the built-up part of the large agricultural complexes that are typical in the former socialistic countries (such as LPGs in eastern parts of Germany), as well as all other agro-industrial complexes with a minimum built-up area of three hectares. Fields related to these complexes are classified within the various categories of Class 2 ("Agricultural areas"), according to the land use. Contrary to the other artificial classes, the minimum mapping unit for Class 1.2.1.10 is three hectares.

1.2.1.11 Surface Pipelines

All important surface pipelines. In the column 'integrative information' it should be mentioned which type of pipeline it is (OIL, GAS, WATER).

1.2.2 Road and rail networks and associated land

Motorways, railways, including associated installations (stations, platforms, embankments, roundabouts). Areas enclosed by motorways with no detectable access are classified as "associated land".

With the exception of classes' 1.2.2.6 and 1.2.2.7, they have been normally digitised and labelled in the vector-line data set. The minimum width for inclusion in the vector-polygon data set is 25 m.

1.2.2.1 Fast transit roads and associated land

Motorways, by-pass roads, toll-ways, etc.

1.2.2.2 Other roads and associated land

Including roundabouts.

1.2.2.3 Railways and associated land

1.2.2.4 Other rails

Single-track railways, light rail, underground when visible, etc.

1.2.2.5 Additional transport structures

Those structures that are superimposed to other surfaces (e.g. bridges and viaducts), or that are hidden by other surfaces (e.g. tunnels). The typology of the mapped superimposed or hidden structure is pointed out and described in the column "Integrative information" of the attribute table. The words used in the "Integrative information" column are BRIDGE, VIADUCT, TUNNEL, and FLYOVER.

1.2.2.6 Parking sites for private vehicles

1.2.2.7 Parking sites for public vehicles

Including private vehicles carrying out public services (e.g. coaches, taxis, trams, etc.).

1.2.3 Port areas

Infrastructure of port areas, including quays, dockyards and marinas.

1.2.4 Airports

Airport installations: runways, buildings and associated land.

1.3.1 Mineral extraction sites

Areas with open-pit extraction of industrial minerals (sandpits, quarries) or other minerals (opencast mines). Includes flooded gravel pits, except for riverbed extraction.

1.3.2 Dump sites

Landfill or mine dump sites, industrial or public.

1.3.3 Construction sites

Spaces under construction development, soil or bedrock excavations, earthworks.

1.3.4 Abandoned land

Land where no particular use can be seen. It includes abandoned mineral extraction sites, which, if known, it is pointed out, and described in the column "Comments" of the attribute table.

1.3.4.1 Bombed areas

Only for those areas subject to recent war episodes (e.g. Belgrade). This class is used if the destructed area is larger than one hectare. A separate point layer will be prepared for areas smaller than one hectare. The level of destruction will be specified in the column "integrative information" of the attribute table of the point layer. The words used in the "Integrative information" column should be PARTIAL or TOTAL. Any comments concerning, for instance, the current functional use of the building will be specified in the column "comments" of the attribute table.

1.4.1 Green urban areas

Areas with vegetation within urban fabric. Includes city parks

1.4.1.1 Vegetated cemeteries

More than 40% of the land is covered with vegetation.

1.4.2 Sport and leisure facilities

Camping grounds, sports grounds, leisure parks, golf courses, racecourses, amusement parks, etc. It includes formal parks not surrounded by urban zones.

2.1.1 Non-irrigated arable land

Cereals, legumes, folder crops, root crops and fallow land. Includes flower and tree (nurseries) cultivation, land and vegetables, whether open fields, under plastic or glass (includes market gardening).

Includes aromatic, medicinal and culinary plants. Excludes permanent pastures.

2.1.1.1 Arable land without dispersed vegetation

2.1.1.2 Arable land with scattered vegetation

Scattered vegetation occupies less than 15% of the area in question.

2.1.1.3 Greenhouses

2.1.1.4 Drained arable land

Drainage network intended to ameliorate wet soils. The area is a former wetland, now cultivated. Canals to drain the area are visible on the image.

2.1.2 Permanently irrigated land

Crops irrigated permanently and periodically, using a permanent infrastructure (irrigation channels, drainage network). Most of these crops could not be cultivated without an artificial water supply.

Does not include sporadically irrigated land.

2.1.3 Rice fields

Flat surfaces with irrigation channels for rice cultivation. Surfaces regularly flooded.

2.2.1 Vineyards

Areas planted with vines.

2.2.2 Fruit trees and berry plantations

Parcels planted with fruit trees or shrubs: single or mixed fruit species, fruit trees associated with permanently grassed surfaces.

Includes chestnuts and walnut groves.

2.2.3 Olive groves

Areas planted with olive trees.

Including mixed occurrence of olive and vines on the same parcel.

2.3.1 Pastures

Dense grained grass and floral composition not under a rotation system. Mainly used for grazing, but the folder may be harvested mechanically. Includes areas with hedges.

2.3.1.1 Pastures without trees and shrubs

Extensively managed grassland where trees and shrubs occupy less than 15% of the area in question.

2.3.1.2 Pastures with trees and shrubs

Extensively managed grassland where trees and shrubs occupy more than 15% of the area in question.

2.4.1 Annual crops associated with permanent crops

Non-permanent crops (arable lands or pasture) associated with permanent crops on the same parcels.

2.4.2 Complex cultivation patterns

Juxtaposition of small parcels of diverse annual crops, pasture and/or permanent crops.

2.4.2.1 Complex cultivation patterns without settlements

Juxtaposition of small plots of diverse annual crops, pastures or permanent crops without settlement

2.4.2.2 Complex cultivation patterns with scattered settlements

Juxtaposition of small plots of diverse annual crops, pastures or permanent crops with settlement

2.4.3 *Land principally occupied by agriculture (LPOA), with significant areas of natural vegetation (SANV)*

Areas principally (more than 50%) occupied by agriculture, interspersed with significant natural areas.

2.4.3.1 *Prevalence of arable land and SANV*

LPOA with SANV where arable land covers more than 50% of the area in question. The rest of the area in question is made of strips/patches of woodland, grassland, and/or water areas.

2.4.3.2 *Prevalence of pasture and SANV*

LPOA with SANV where pastures (extensively managed grassland) covers more than 50% of the area in question. The rest of the area in question is made of strips/patches of woodland, grassland, and/or water areas.

2.4.4 *Agro-forestry areas*

Annual crops or grazing land under the wooded cover of forestry species. It includes dehesa.

3.1.1 *Broad-leaved forests*

Vegetation formation composed principally of trees where broad-leaved (in the sense of not coniferous) species predominate.

It includes shrubs and bush under storeys.

For any of the following level 4 classes, it is be pointed out and described in the column "Comments" of the attribute table if:

1- The forest lies on mineral or on swampy soil (if known).

2- The forest is damaged due to pollution, injurious agents or natural disasters such as acid rain, meteorological events or floods (if known).

3.1.1.1 *Deciduous forest with continuous canopy*

Deciduous woodland where continuous canopy covers more than 80% of the area in question.

3.1.1.1 *Deciduous forest with discontinuous canopy*

Deciduous woodland where canopy covers less than 80% of the area in question.

3.1.1.2 *Evergreen forest with continuous canopy*

Evergreen woodland where continuous canopy covers more than 80% of the area in question.

3.1.1.3 Evergreen forest with discontinuous canopy

Evergreen woodland where canopy covers less than 80% of the area in question.

3.1.2 Coniferous forests

Vegetation formation composed principally of trees where coniferous species predominate. Including shrub and bush under storeys.

For any of the following level 4 classes, it should be pointed out and described in the column "Comments" of the attribute table if:

1- The forest lies on mineral or on swampy soil (if known).

2- The forest is damaged due to pollution, injurious agents or natural disasters such as acid rain, meteorological events or floods (if known).

3.1.2.1 Coniferous forest with continuous canopy

Coniferous woodland where continuous canopy covers more than 80% of the area in question.

3.1.2.2 Coniferous forest with discontinuous canopy

Coniferous woodland where canopy covers less than 80% of the area in question.

3.1.3 Mixed forests

Vegetation formation composed principally of tress, where broad-leaved and coniferous species predominate. It includes shrub and bush under storeys.

For any of the following level 4 classes, it should be pointed out and described in the column "Comments" of the attribute table if:

1- The forest lies on mineral or on swampy soil (if known).

2- The forest is damaged due to pollution, injurious agents or natural disasters such as acid rain, meteorological events or floods (if known).

3.1.3.1 Forest mixed by alternation of single trees with continuous canopy

Forest mixed by alternation of single trees of coniferous and broad-leaved woodland where continuous canopy covers more than 80% of the area in question.

3.1.3.2 Forest mixed by alternation of single trees with discontinuous canopy

Forest mixed by alternation of single trees of coniferous and broad-leaved woodland where canopy covers less than 80% of the area in question.

3.1.3.3 Forest mixed by alternation of stands of trees with continuous canopy

Forest mixed by alternation of stands of trees of coniferous and broad-leaved woodland where continuous canopy covers more than 80% of the area in question.

3.1.3.4 Forest mixed by alternation of stands of trees with discontinuous canopy

Forest mixed by alternation of stands of trees of coniferous and broad-leaved woodland where canopy covers less than 80% of the area in question.

3.2.1 Natural grassland

Low productivity grassland often situated in areas of rough uneven ground. Frequently includes rocky areas, briars and heartland.

3.2.1.1 Coarse permanent grassland / Tall herbs without trees and shrubs

Coarse permanent grassland / Tall herbs where trees and shrubs cover less than 15% of the area in question. Including alpine/subalpine grasslands, steppic grassland. Please add the relevant observations and particularities in the column "Comments" of the attribute table.

3.2.1.2 Coarse permanent grassland / Tall herbs with trees and shrubs

Coarse permanent grassland / Tall herbs where trees and shrubs cover more than 15% of the area in question. Including alpine/subalpine grasslands, steppic grassland. Please add the relevant observations and particularities in the column "Comments" of the attribute table.

3.2.1.3 Coastal and floodplain meadow

Grass formations of inundated coastal and alluvial plains, lowlands associated with rivers and lakes, or coastal plains. Human influence is very low with regard to natural conditions – of grass formation – extreme soil humidity and seasonal inundated. Coastal meadow includes:

- saline coastal meadows, with dominance of Eleocharetum uniglumis, Punccinellietum maritimae, Honckenya peploides, Leymetum arenarius, Cakile maritima, Salsola kali, Juncus maritima, Glaux maritima, etc. Saline grassland grown on temporary wet areas of saline soil and located next to the reed communities.
- suprasaline coastal meadows, with dominance of Festuca rubra, Festuca arundinacea.

Floodplain meadow includes:

- fresh floodplain grassland, with dominance of Festuca ovina, Anthoxanthum odoratum, Sesleria caerulea, Galium boreale, etc.
- wet floodplain grassland, with dominance of Deschampsia cespitosa, Festuca rubla, Carex cespitosa, Elymus repens, etc.

3.2.2 Moors and heath land

Vegetation with low and closed cover, dominated by bushes, shrubs and herbaceous plants.

For any of the following level 4 classes, it is pointed out and described in the column "Comments" of the attribute table if the vegetation is damaged due to pollution, injurious agents or natural disasters such as acid rain, meteorological events or floods (if known).

3.2.2.1 Heath land

Mainly dense shrubs and herbaceous plants.

3.2.2.2 Dwarf pine

3.2.3 Sclerophyllous vegetation

Bushy sclerophyllous vegetation. It includes maquis and garrigue. It includes maquis (a dense vegetation composed of numerous shrubs associated with siliceous soil) and garrique (discontinuous bushy association with calcareous plateau).

Generally composed of kermes oak, arbust lavender, thyme, cistus, etc.

For any of the following level 4 classes, it is pointed out and described in the column "Comments" of the attribute table if the vegetation is damaged due to pollution, injurious agents or natural disasters such as acid rain, meteorological events or floods (if known).

3.2.4 Transitional woodland/shrub

Bushy or herbaceous vegetation with scattered trees. Can represent either woodland degradation or forest regeneration/recolonisation.

For any of the following level 4 classes, it is pointed out and described in the column "Comments" of the attribute table if:

1. The vegetation lies on mineral or on swampy soil (if known and relevant).
2. The vegetation is damaged due to pollution, injurious agents or natural disasters such as acid rain, meteorological events or floods (if known).

3.2.4.1 Artificial young stands

Planted young stands after logging.

3.2.4.2 Natural young deciduous stands

3.2.4.3 Natural young coniferous stands

3.2.4.4 Wooded fens, bog and wooded transitional bog

Shrubby herbaceous formations with scattered tree at the margin of peat bogs, located on soil with peat deposit more than 30cm thick. The relevant observations and particularities (e.g. presence of pools, wooded fens, wooded lawn bogs, wooded transitional bog) in the column "Comments" of the attribute table is added if known.

3.3.1 Beaches, dunes, sands

Beaches, dunes and litoral expenses of sand or cabbles in coastal or continental location inclu-ding beds of stream channels with torrential regime.

3.3.1.1 Dunes

3.3.1.2 Beaches

3.3.1.3 Inland sand

Including other soft sediments, such as riverbanks.

3.3.2 Bare rock

Screes, cliffs, rock outcrops, including active erosion, rocks and reef flats situated above the high-water mark.

3.3.2.1 Littoral/sub-littoral rocks

3.3.2.2 Coastal cliffs

3.3.2.3 Inland cliffs/bare rock/volcanic debris

3.3.3 Sparsely vegetated areas

Includes steppes, tundra and badlands. Scattered high-altitude vegetation.

3.3.3.1 Sparse vegetation on sands

3.3.3.2 Sparse vegetation on bare rock

3.3.4 Burnt areas

Areas affected by recent fires.

3.3.5 Glaciers and perpetual snow

Land covered by glaciers and permanent snowfields.

4.1.1 Inland marshes

Low-lying land usually flooded in winter and more or less saturated by water all year round.

4.1.1.1 Marshes with reeds

4.1.1.2 Marshes without reeds

4.1.1.3 Open fen and transitional bog

Herbaceous formation, located on fen or peat soil with peat deposit more than 30 cm thick. Located in inland through flow basins, in river flood valley, areas of springs and margin zones of raised bogs.

4.1.2 Peat bog

Peat-land consisting mainly of decomposed moss and vegetable matter. May or may not be exploited for peat bogs with lawn communities.

4.1.2.1 Exploited peat bog with lawn communities

4.1.2.2 Unexploited peat bog with lawn communities

4.1.2.3 Peat bog with pool communities

4.2.1 Salt marshes

Vegetated low-lying areas, above the high-tide line, susceptible to flooding by sea water. Often in the process of filling in, gradually being colonised by halophytic plants.

4.2.1.1 Salt marshes with reeds

4.2.1.2 Salt marshes without reeds

4.2.2 Salines

Saltpans, active or in process of abandonment. Sections of salt marsh exploited for the production of salt by evaporation. They are clearly distinguishable from the rest of the marsh by their parcellation and embankment systems.

4.2.3 Intertidal flats

Generally unvegetated expanses of mud, sand or rock lying between high and low water marks. 0m contour on maps.

5.1.1 Water courses

Natural or artificial water courses serving as water drainage channels. Includes canals. They will normally be digitised and labelled in the vector-line data set. The minimum width for inclusion in the vector-polygon data set is 25m.

5.1.1.1 Canals

5.1.1.2 Rivers

5.1.2 Water bodies

Natural or artificial stretches of standing water.

5.1.2.1 Natural standing waters

5.1.2.2 Artificial reservoirs

5.2.1 Coastal lagoons

Stretches of salt or brackish water in coastal areas which are separated from the sea by a tongue of land or other similar topography. These water bodies can be connected to the sea at limited points, either permanently or for parts of the year only.

5.2.2 Estuaries

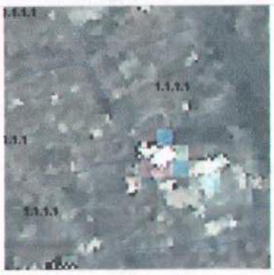
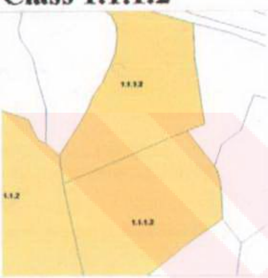
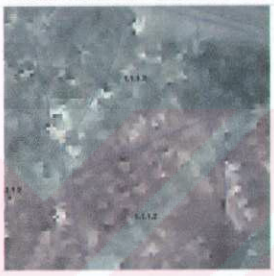
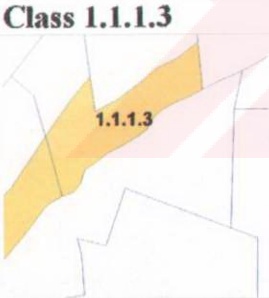
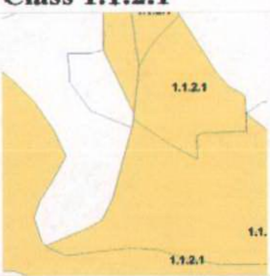
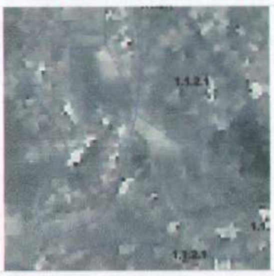
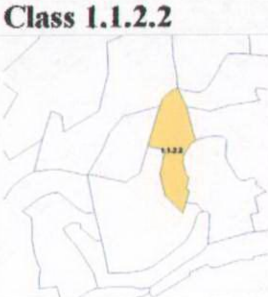
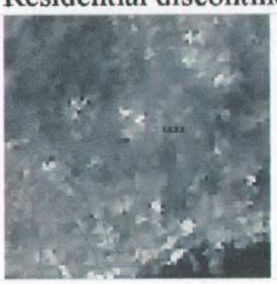
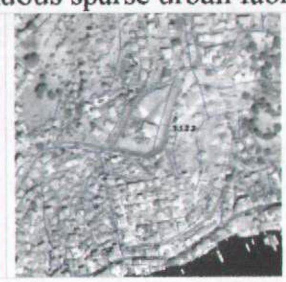
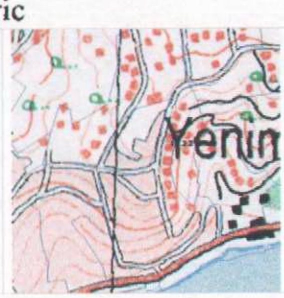
The mouth of a river, within which the tide ebbs and flows.

5.2.3 Sea and oceans

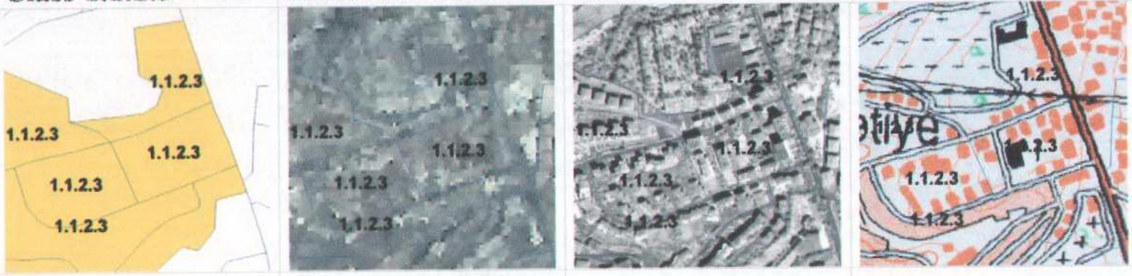
Zones seaward of the lowest tide limit.

APPENDIX C

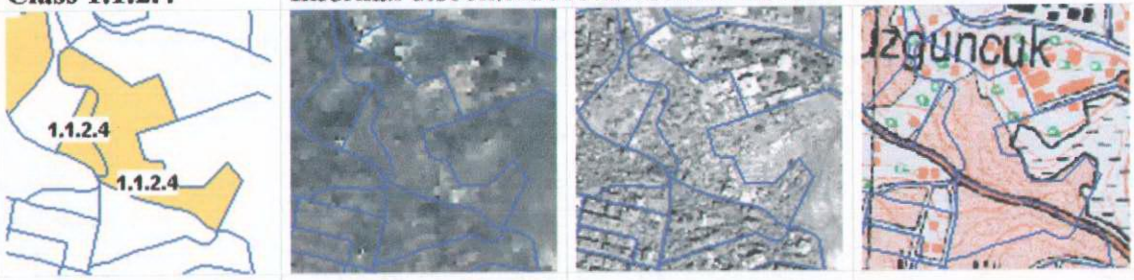
Examples for the used classes

Vector-Polygon	IRS-D merged	Ikonos Pan	Map
Class 1.1.1.1	Residential continuous dense urban fabric		
			
Class 1.1.1.2	Residential continuous medium dense urban fabric		
			
Class 1.1.1.3	Informal settlements		
			
Class 1.1.2.1	Residential discontinuous urban fabric		
			
Class 1.1.2.2	Residential discontinuous sparse urban fabric		
			

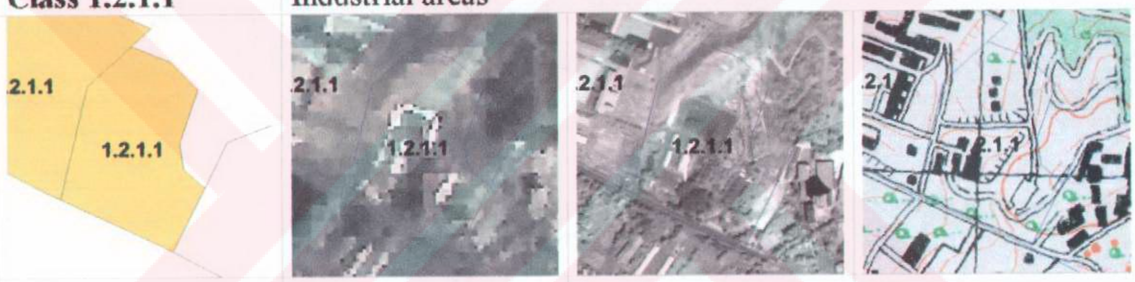
Class 1.1.2.3 Residential urban blocks



Class 1.1.2.4 Informal discontinuous residential structures



Class 1.2.1.1 Industrial areas

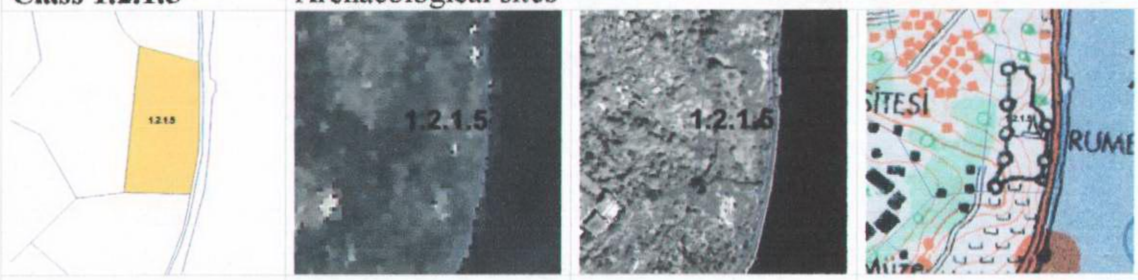


Class 1.2.1.2 Commercial areas

Class 1.2.1.3 Public and private services not related to the transport system

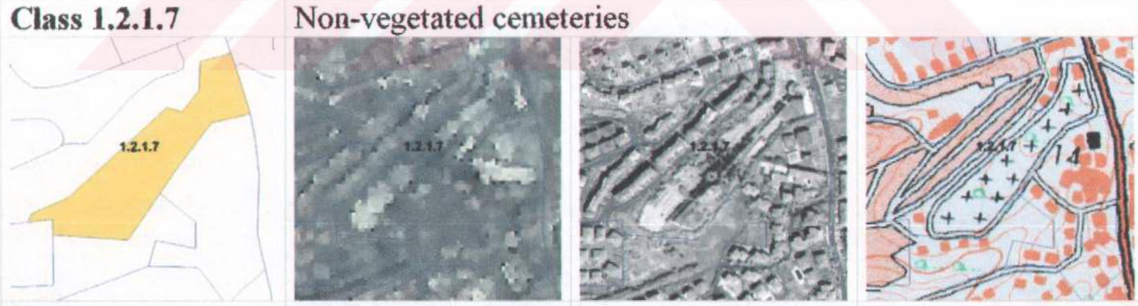
Class 1.2.1.4	Technological infrastructures for public service

Class 1.2.1.5	Archaeological sites



Class 1.2.1.6	Places of worship

Class 1.2.1.7	Non-vegetated cemeteries

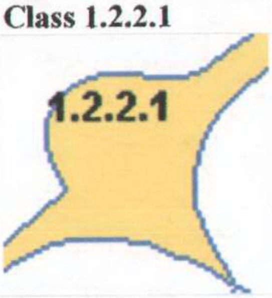


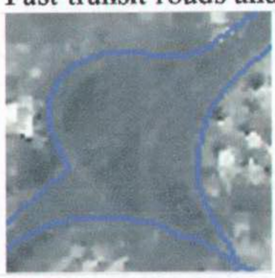
Class 1.2.1.8	Hospitals

Class 1.2.1.9 Restricted access services

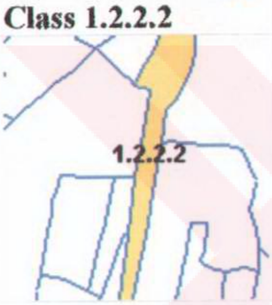


Class 1.2.2.1 Fast transit roads and associated land



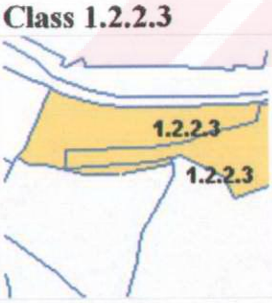



Class 1.2.2.2 Other roads and associated land





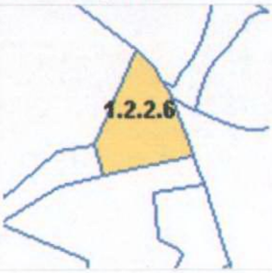
Class 1.2.2.3 Railways and associated land

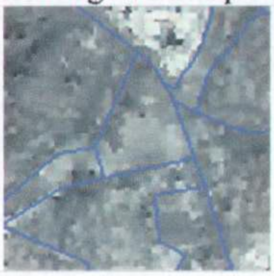
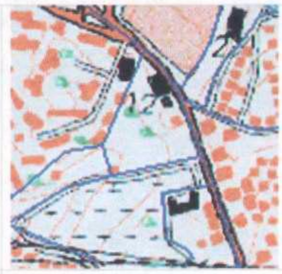



Class 1.2.2.4 Other rails

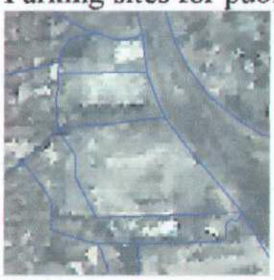


Class 1.2.2.6 Parking sites for private vehicles

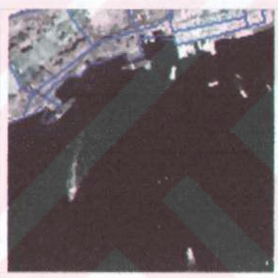


Class 1.2.2.7 Parking sites for public vehicles

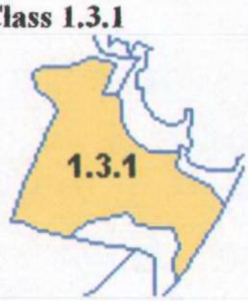


Class 1.2.3 Port areas

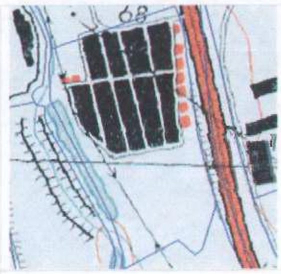

Class 1.2.4 Airports


Class 1.3.1 Mineral extraction sites

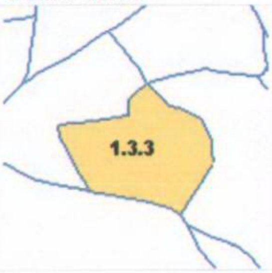




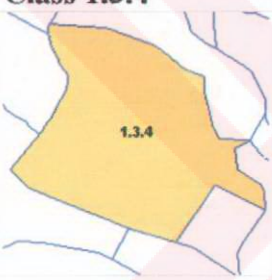
Class 1.3.2 Dump sites

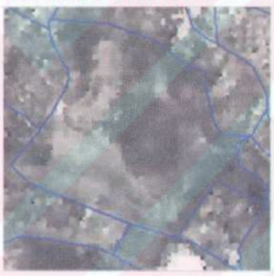


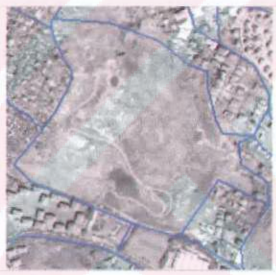
Class 1.3.3 Construction sites



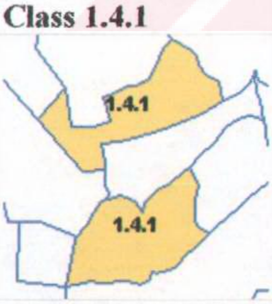
Class 1.3.4 Abandoned land

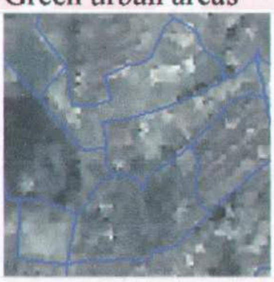




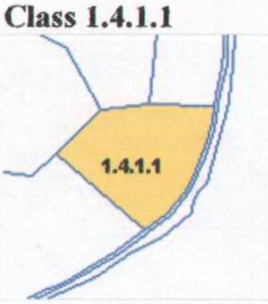


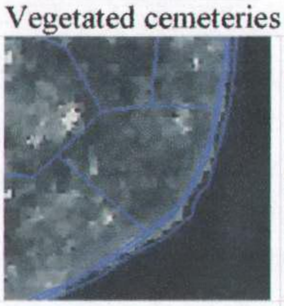
Class 1.4.1 Green urban areas

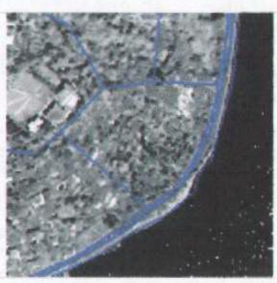




Class 1.4.1.1 Vegetated cemeteries



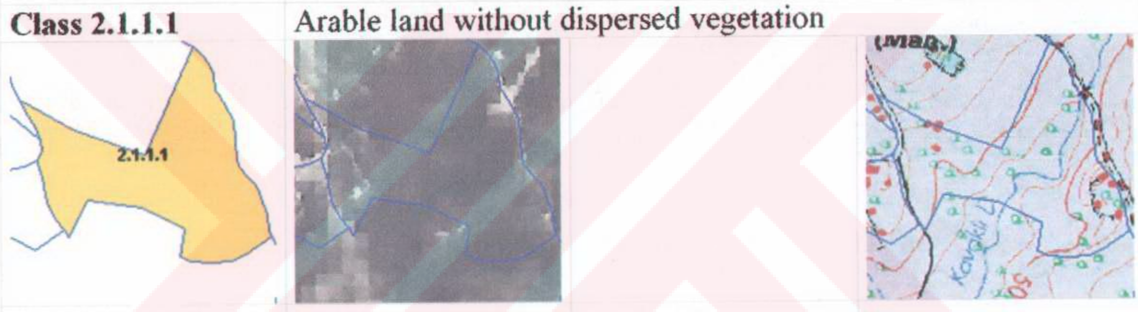




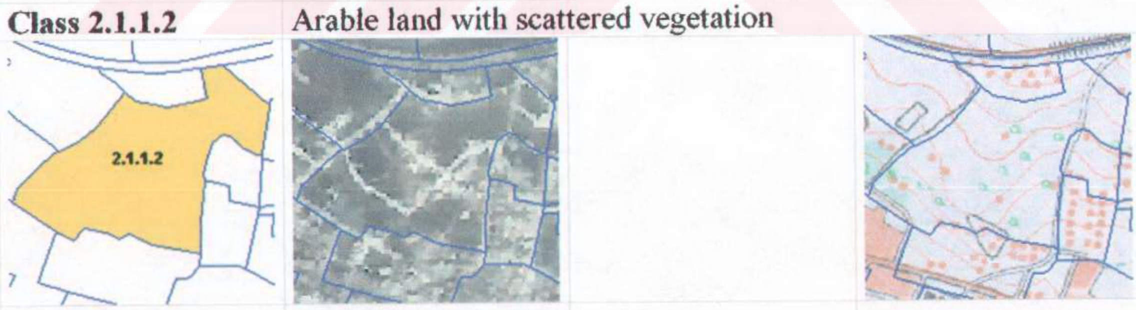
Class 1.4.2	Sport and leisure facilities

Class 2.1.1	Non-irrigated arable land

Class 2.1.1.1	Arable land without dispersed vegetation

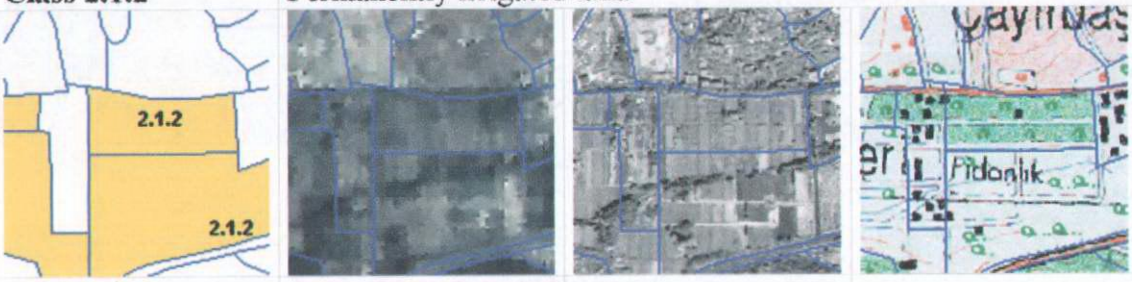


Class 2.1.1.2	Arable land with scattered vegetation



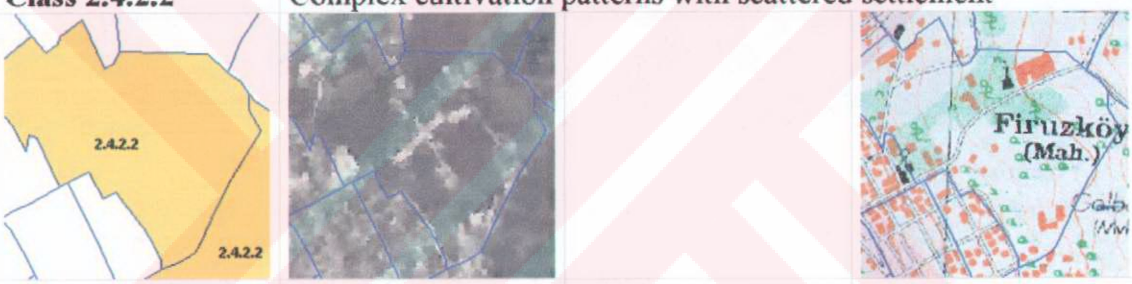
Class 2.1.1.3	Greenhouses

Class 2.1.2	Permanently irrigated land



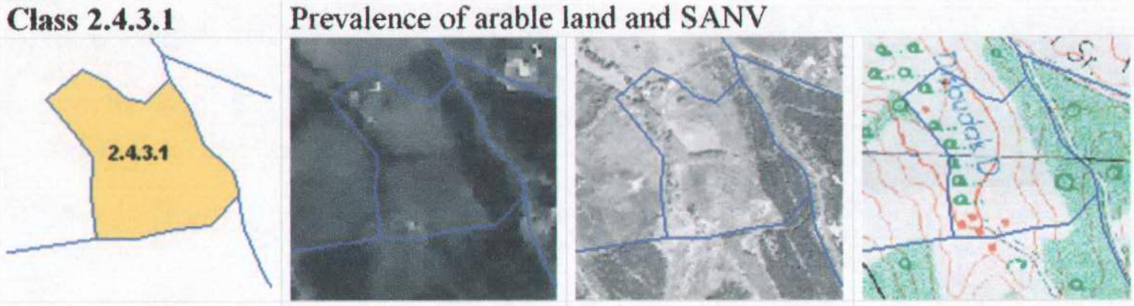
Class 2.3.1.2	Pastures with trees and shrubs

Class 2.4.2.2	Complex cultivation patterns with scattered settlement

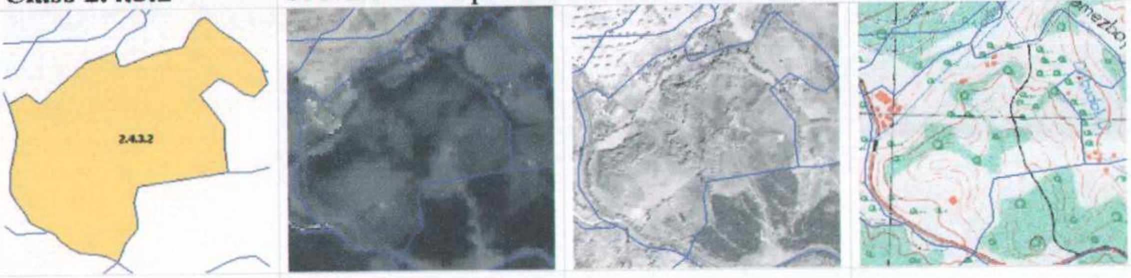


Class 2.4.3	Land principally occupied by agriculture (LPOA), with significant areas of natural vegetation (SANV)

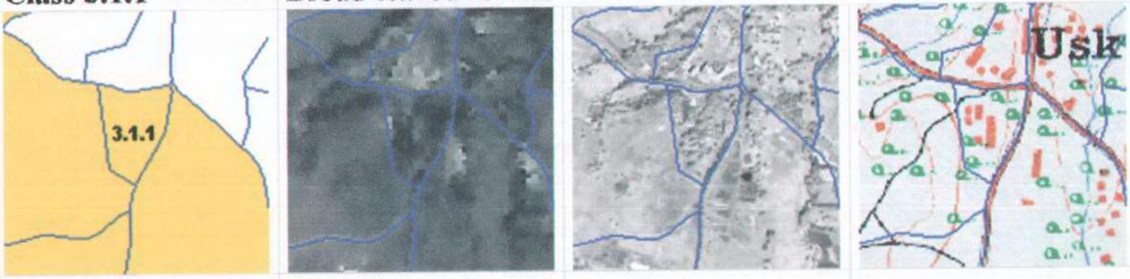
Class 2.4.3.1	Prevalence of arable land and SANV



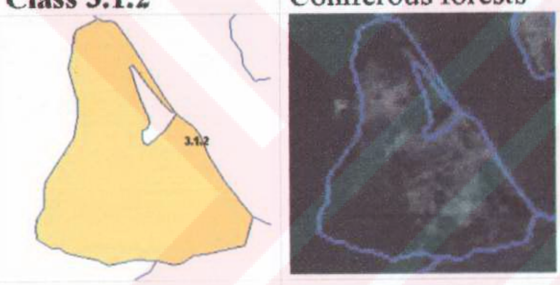
Class 2.4.3.2 Prevalence of pastures and SANV



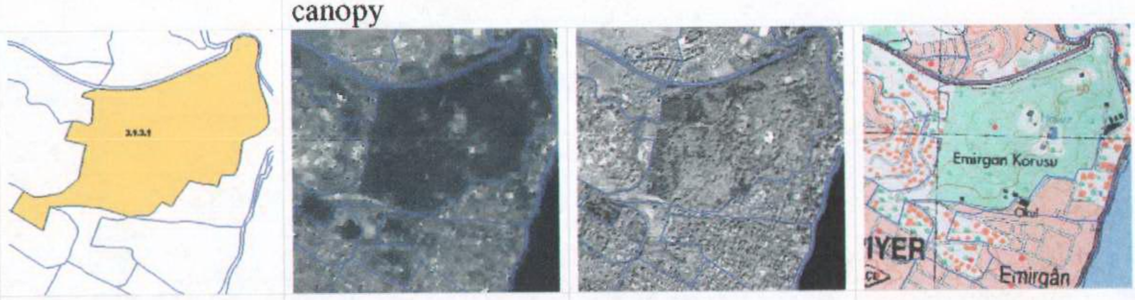
Class 3.1.1 Broad-leaved forests



Class 3.1.2 Coniferous forests

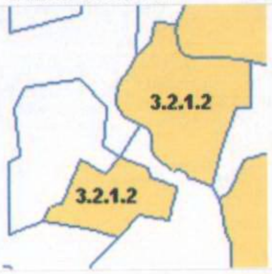


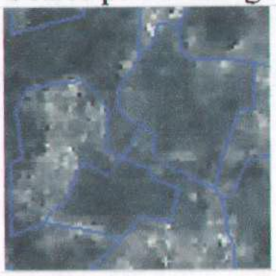
Class 3.1.3.1 Forest mixed by alternation of single trees with continuous canopy



Class 3.2.1.1 Coarse permanent grassland / Tall Herbs without trees and shrubs

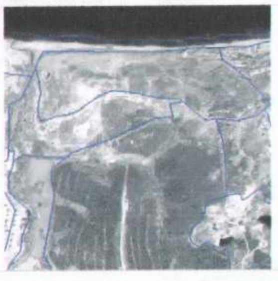
Class 3.2.1.2 Coarse permanent grassland / Tall Herbs with trees and shrubs



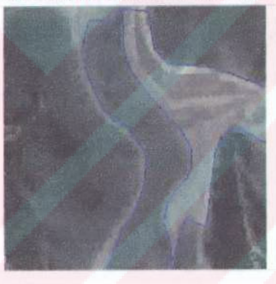
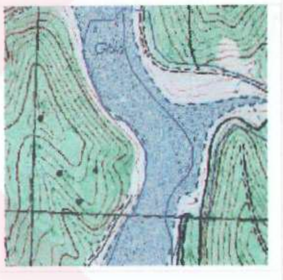


Class 3.2.1.3 Coastal and floodplain meadow

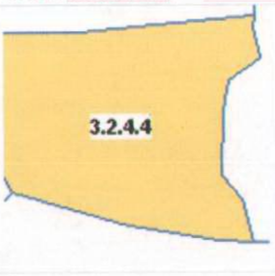




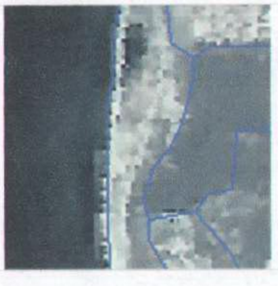
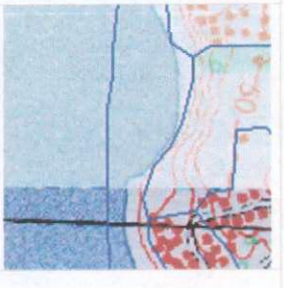

Class 3.2.4 Transitional woodland/shrub

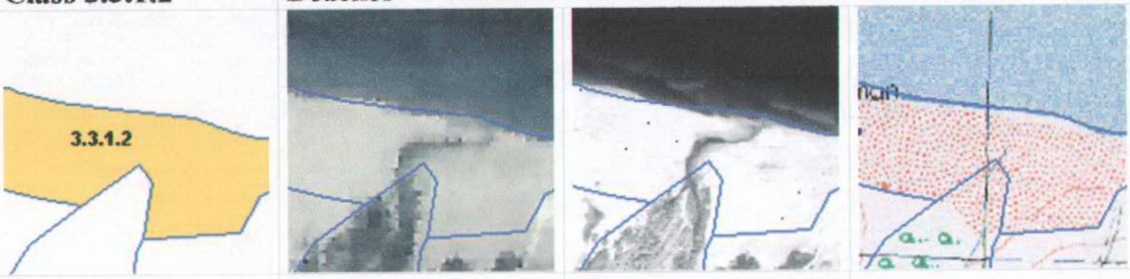
Class 3.2.4.4 Wooded fens, bog and wooded transitional bog



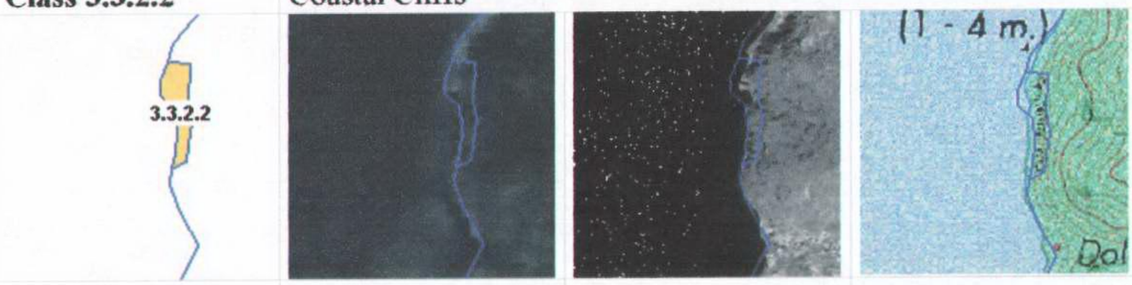

Class 3.3.1.1 Dunes

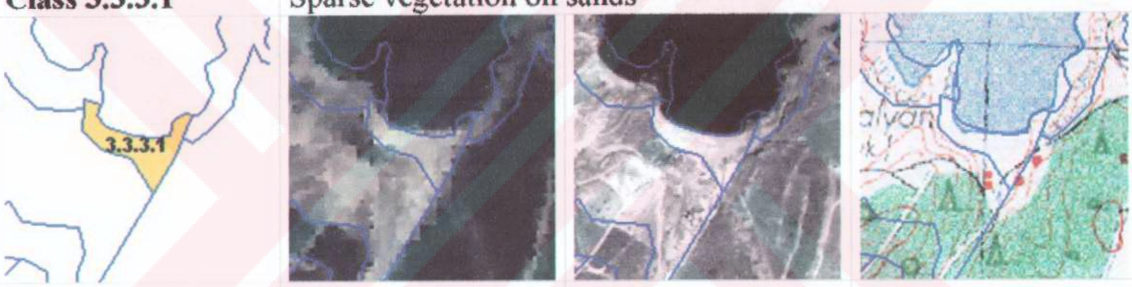
Class 3.3.1.2 Beaches



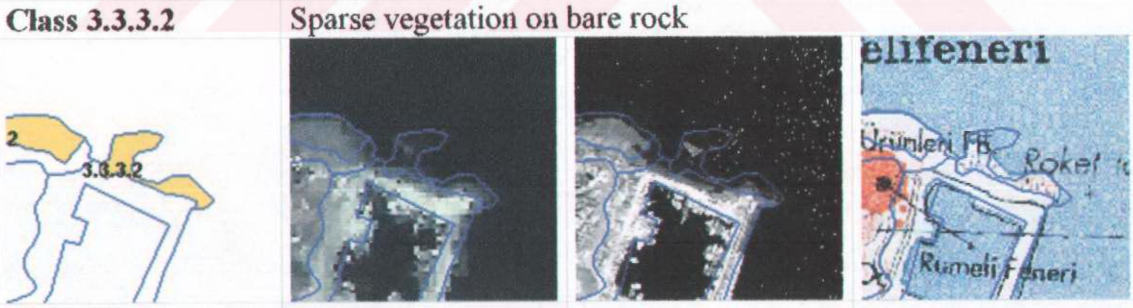
Class 3.3.2.2 Coastal Cliffs



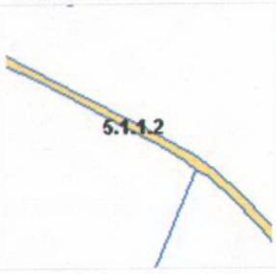
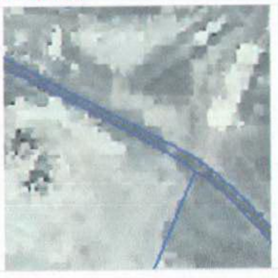
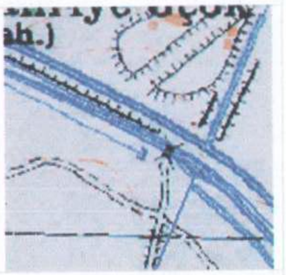
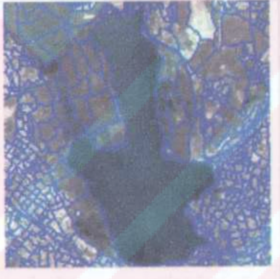
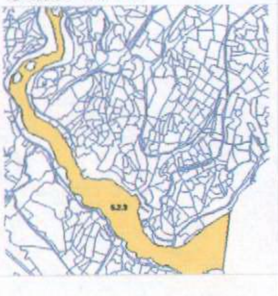
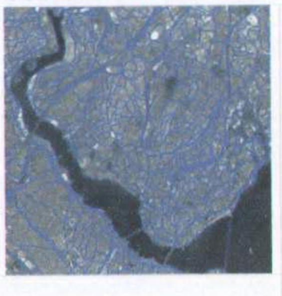
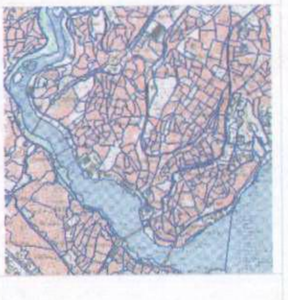
Class 3.3.3.1 Sparse vegetation on sands



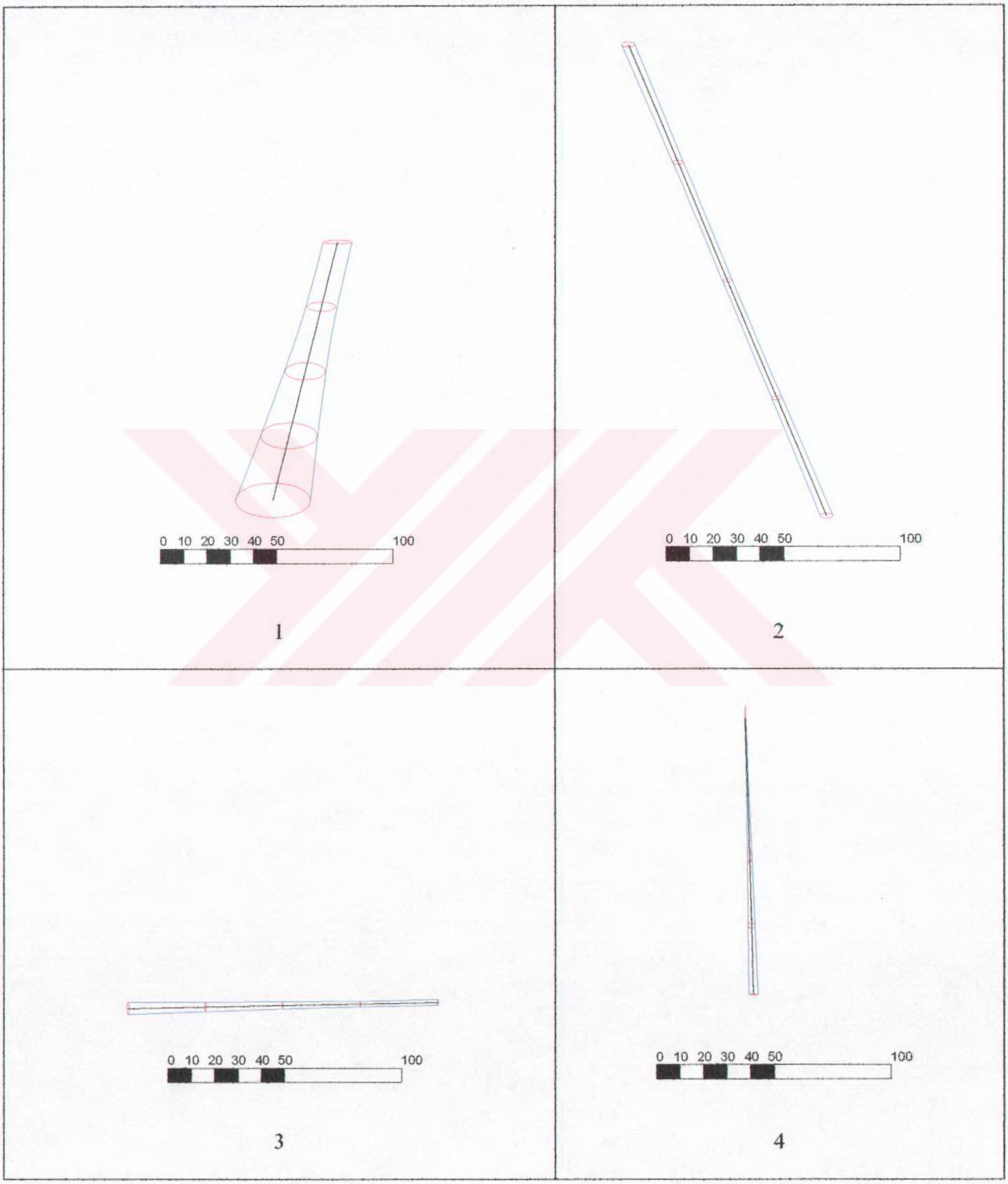
Class 3.3.3.2 Sparse vegetation on bare rock

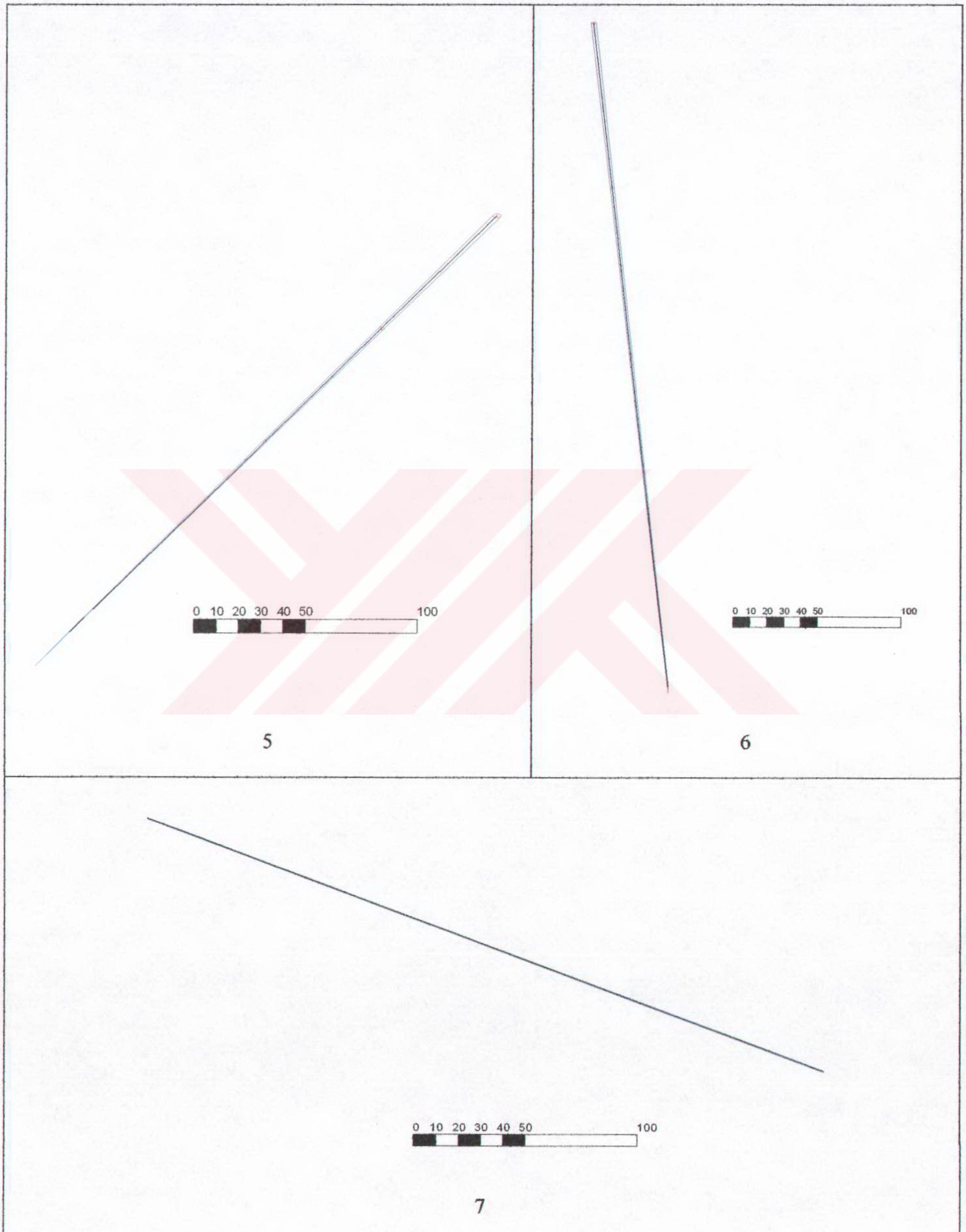


Class 4.1.2 Peat bog

Class 5.1.1.1	Canals		
			
Class 5.1.1.2	Rivers		
			
Class 5.1.2.1	Natural standing water		
			
Class 5.1.2.2	Artificial reservoirs		
			
Class 5.2.3	Sea and oceans		
			

APPENDIX D
Error bands for the sampling lines

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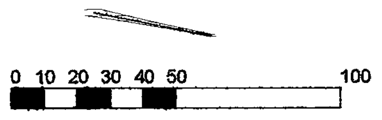
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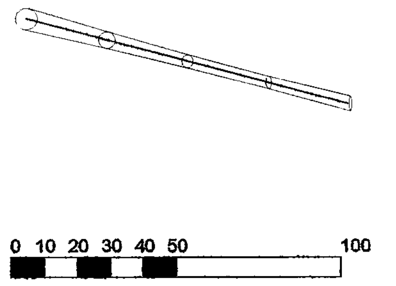
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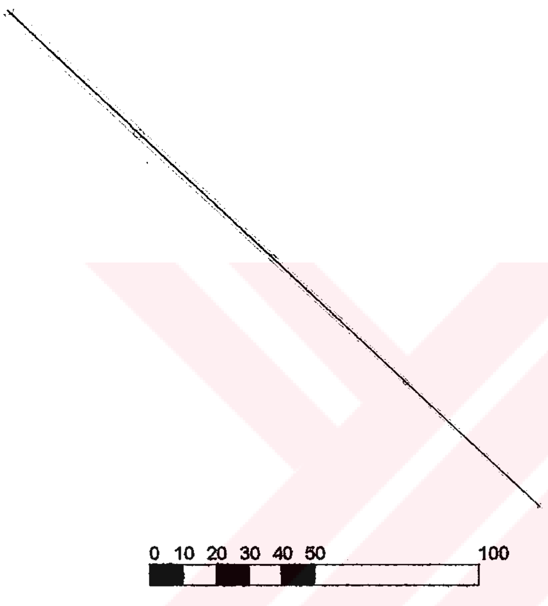
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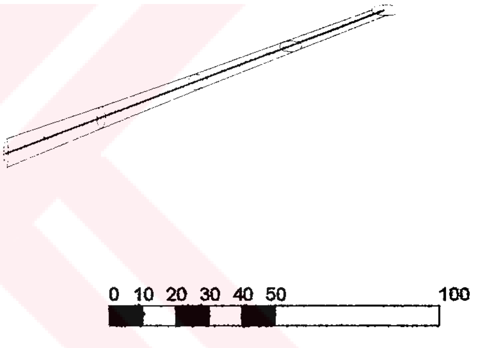
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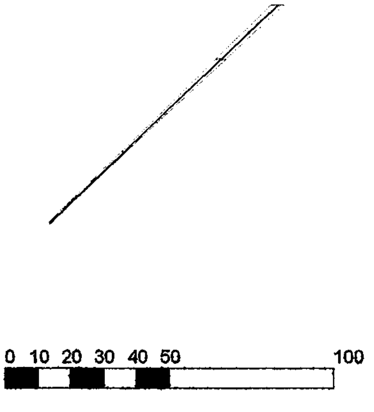
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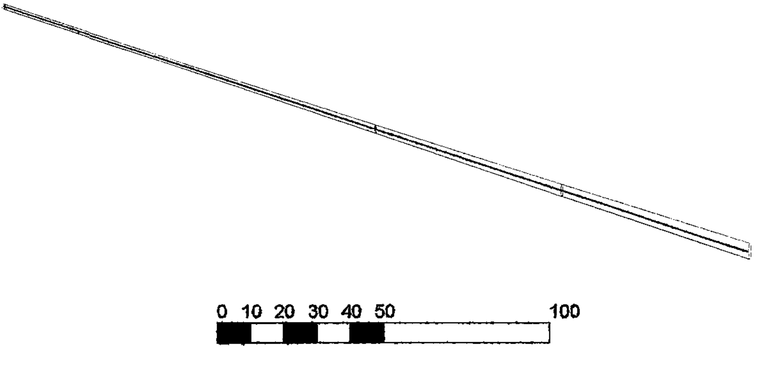
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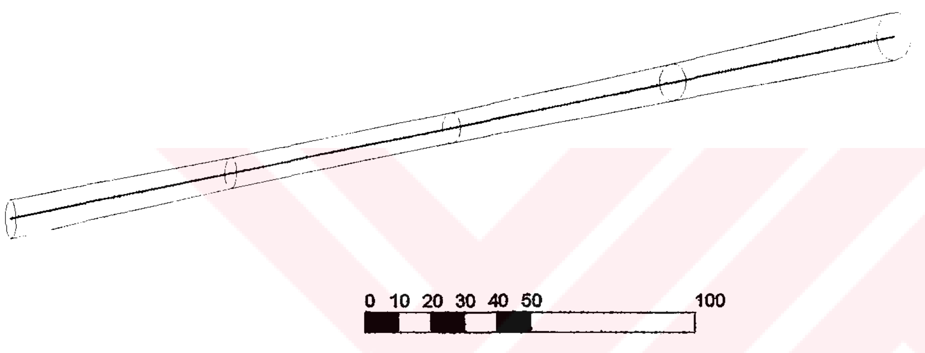

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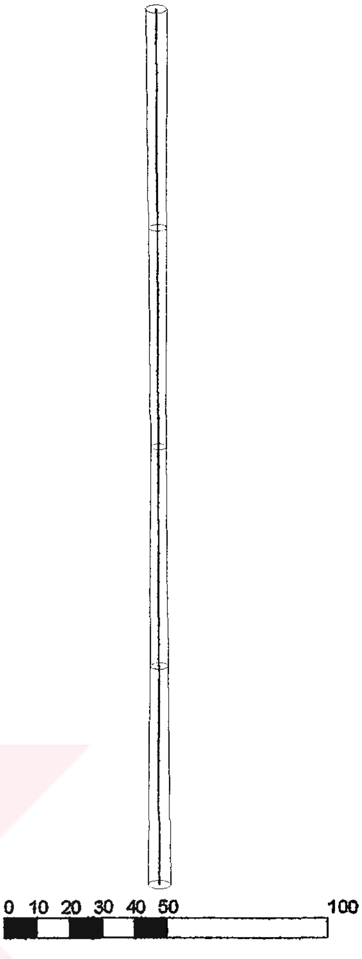

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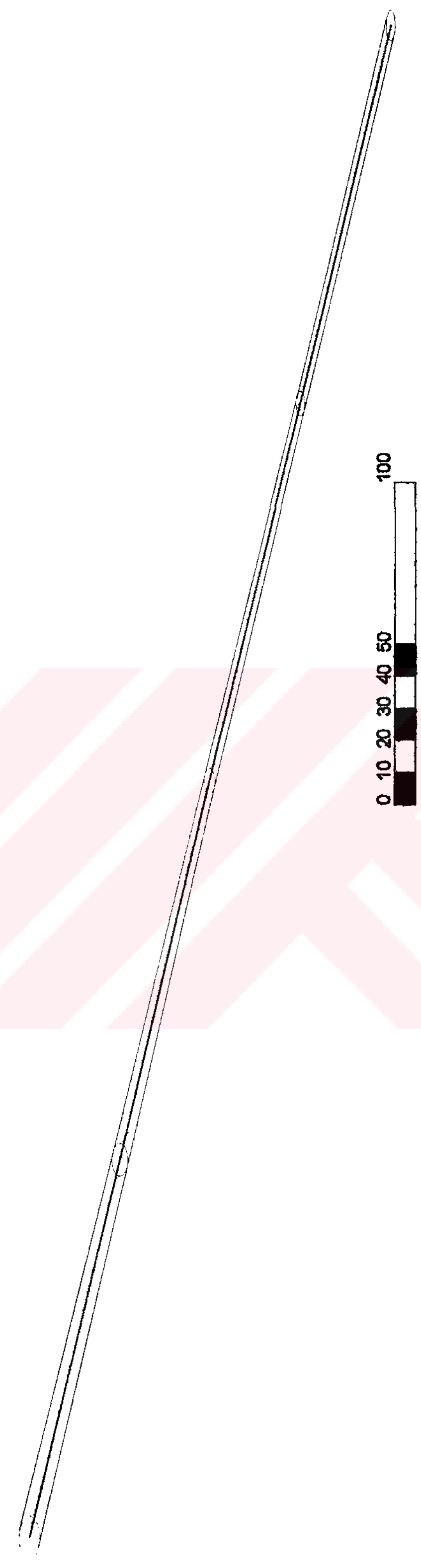

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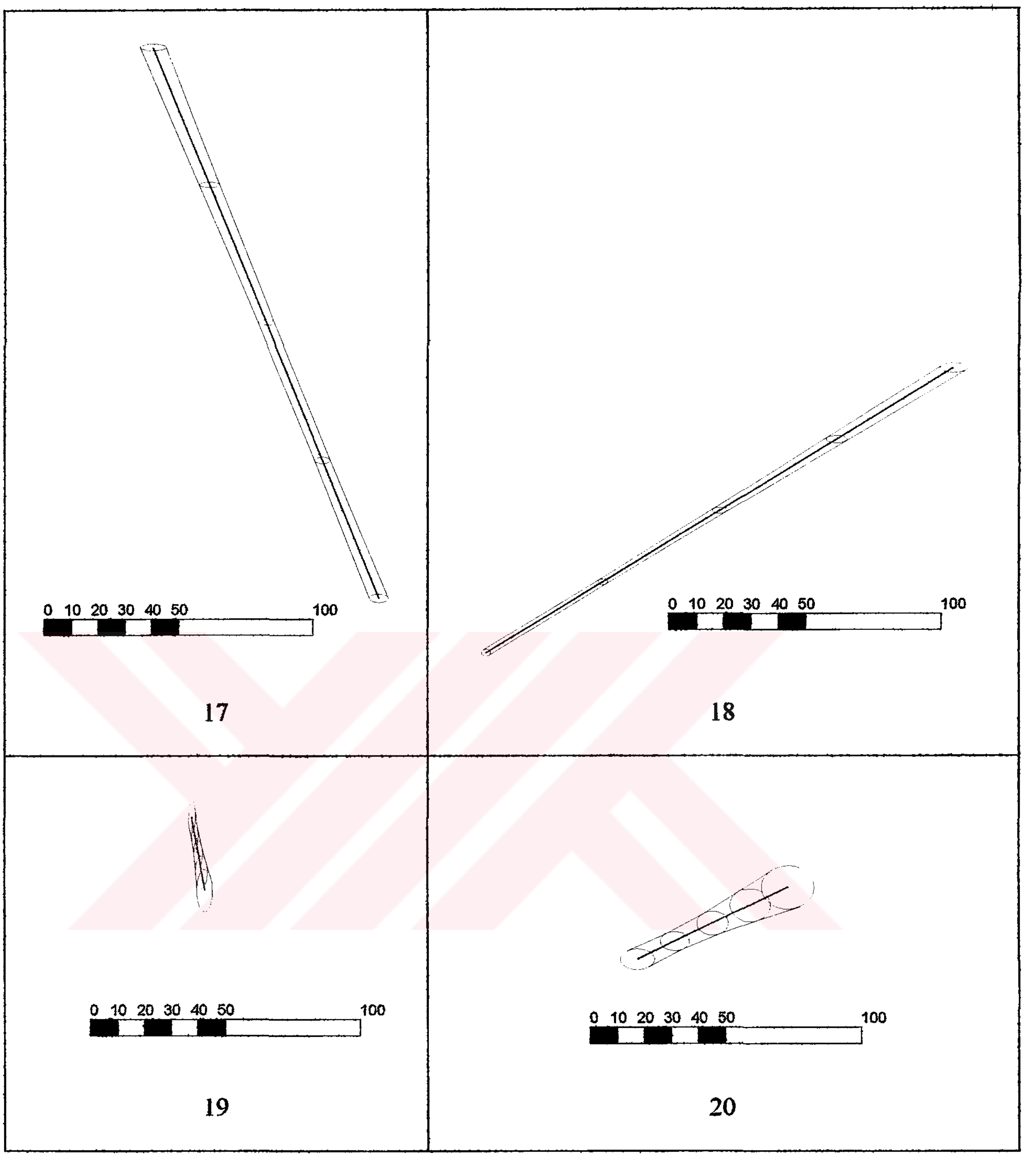
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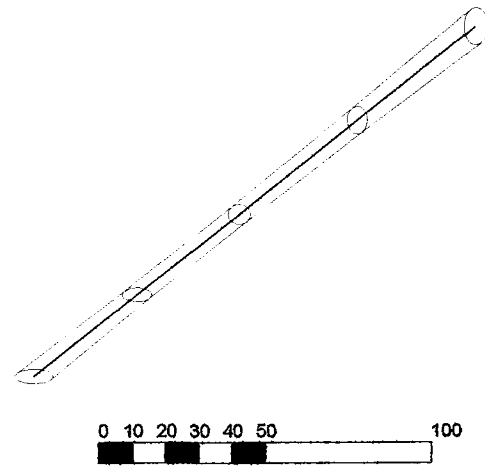
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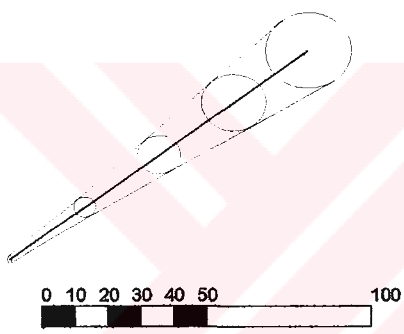
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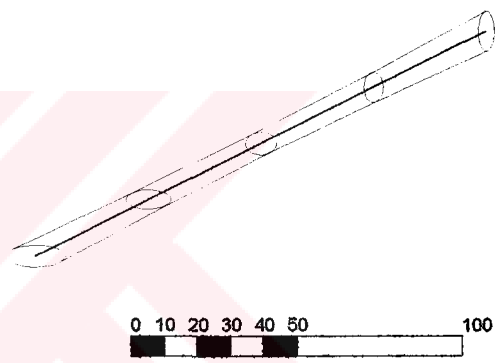
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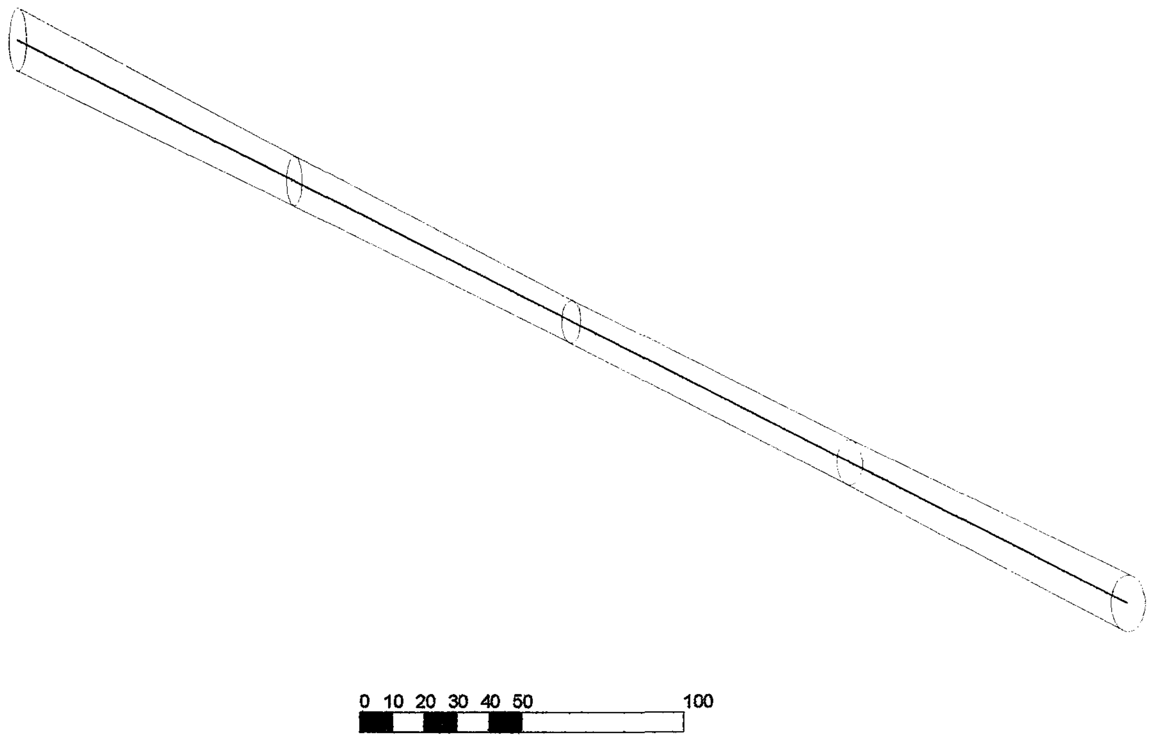

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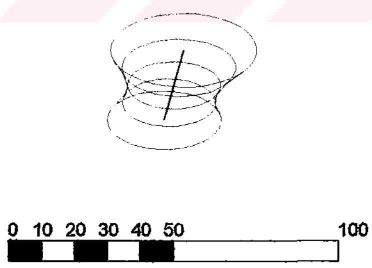

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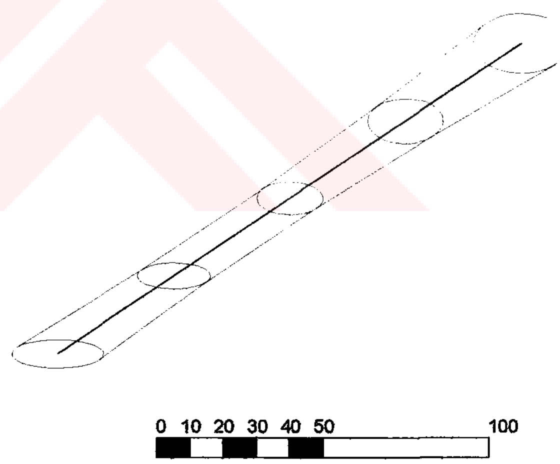

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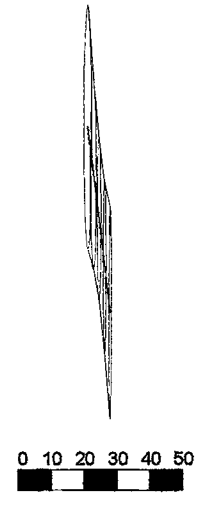

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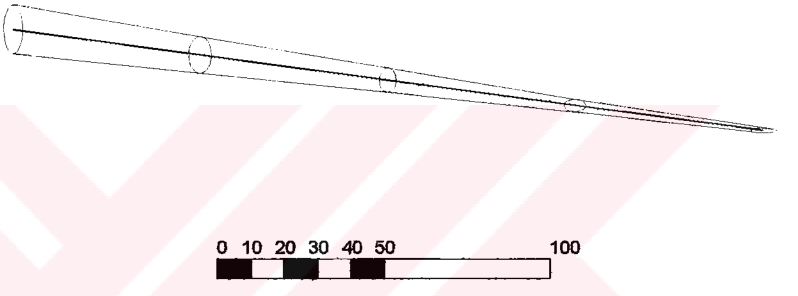

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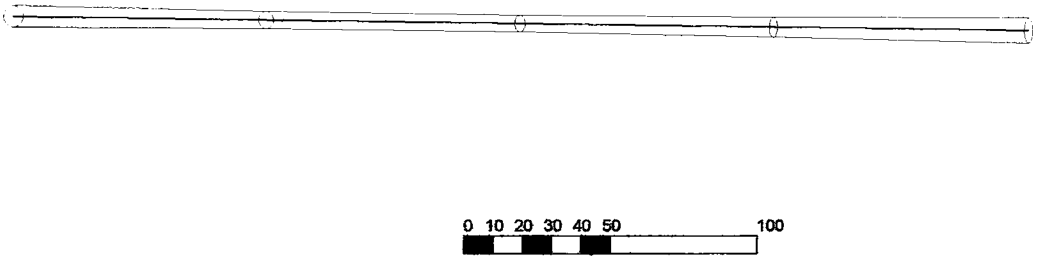

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BIOGRAPHY

T. Murat Çelikoyan was born in Ankara in 1973; he concluded his primary education in Ankara and he continued his high school education in Ankara Anatolian High School. He was graduated from the Istanbul Technical University, Department of Geodesy and Photogrammetry Engineering in 1997 and awarded MSc degree in Geodesy and Photogrammetry Engineering program of I.T.U Institute of Science and Technology. He started his doctorate at the same program in 1999. He is currently working as a research and teaching assistant in Division of Photogrammetry of I.T.U. Faculty of Civil Engineering.