Remote Sensing for Urban Sprawl Detection on Istanbul

Quantification and Detection of Key-Actions with Integrated GIS

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PhD Thesis

REMOTE SENSING FOR URBAN SPRAWL DETECTION ON ISTANBUL

Quantification and Detection of Key-Actions with Integrated GIS

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Introduction and Thanks

Istanbul belongs to the most fascinating cities in the world, its flair, its history but also its socioeconomic problems aroused my interest in this mega-city. In the year 1998, during a research project on urban sprawl on Bratislava and Prague, I made a business-trip to Ankara and visited Istanbul as well. Already from the plane the enormous size of the city was visible, even the huge amount of construction sites showing the dynamic of the urbanisation process.

Following a discussion with the JRC in Ispra, led to the launch of an EC-funded project under MOLAND for Istanbul, where I signed the contract. During the following 18 months, with the help of the ITÜ, I did the land-use change detection on this city, starting with first interpretations of the extracted data.

Besides the project’s main task, many aspects have been analysed which encouraged me to frame this additional work in a PhD Thesis.

Many colleagues and friends have guided me through the project and the completion of this study. They supported me in very different ways and helped when necessary. Thanks to everybody for supporting me.

I would like to pay special thanks to my colleagues in the Joint Research Centre in Ispra, who first followed my idea to analyse the urbanisation on Istanbul and finally launched and financed this project. Especially Carlo Lavalle and Luca Demiceli, who supported me in this study and arranged a contract including the possibility of using the data for this study.

I would like to thank Prof. Werner Fricke for his supervision and his warm welcome with this theme when I asked him to be my “Doctor-Father” in 2002. He remained patient when I confronted him with a huge amount of papers in the last half year.

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May 2005 Gerhard Kemper

Declarations:

I declare that I am the sole author of the submitted dissertation and that I have not made use of any sources or help from other sources I have referred to.

I also declare, that I have neither applied for a permission to enter the examination procedure at other institutions nor I have presented the dissertation to another faculty in its current or any other form in another examination procedure.

Speyer, May 2005

Dipl.-Geogr. Gerhard Kemper

Summary

The study presented is based on the result of the project MOLAND for Istanbul, which was carried out in the Year 2001 and 2002 for the Joint-Research-Centre of the European Commission in Ispra / Italy. First of all, a background chapter aims to give an introduction of the Project MOLAND (Monitoring Land-Use Dynamics) and its goals. The objectives of this study will be presented. To understand this rapidly growing Metropolis Istanbul in its complexity, the main geographic and socio-economic facts, for Turkey itself and also for the Marmara-Region and Istanbul, are described. Beside existing natural resources, other aspects like migration, economics, industrialisation, tourism and other aspects will be analysed in order to understand Istanbul and its interaction with the Turkish hinterland. A short historical survey of the actual problems in Istanbul will close this chapter.

A chapter on the methodological work is antecedent to the analyses. At first, the problems of the land-use detection will be highlighted, because this kind of classification can be squeezed into individual structures in a legend, which is finally necessary to compare the results. Thus, the legends of CORINE and MOLAND will be presented by examples. Frequently used classes of this study will be explained then. Thereafter, the application of Geographic Information Systems will be discussed which is essential for such analyses. Data models, formats, and the combination of various data into a Data-Warehouse will be introduced.

Finally, the acquisition of the data and the sources used in this study will be described. Based on the availability of these data, the years 1945, 1968, 1988 and 2000 have been selected for the analysis. Topographic maps have been used as georeference for all data. For the 1940ies and the year 1968, aerial images have been organised. For the years 1987/88 KFA and KVR satellite photographs have been acquired and for the reference year 2000 IKONOS and IRS Satellite scenes have been put at our disposal by the JRC. Supplementary data and their use like geological maps, terrain models, thematic maps, statistics and others will be mentioned. The methodical steps are described in detail in the Satellite-image georeferencing procedure, in the photogrammetric processing and orthophoto-production on the aerial images and the other steps in data preparation. The final extraction of the land-use pattern, which was made in combination with vectorisation and interpretation, will also be explained. Beside tests of an automated classification by using cluster-analyses, the manual method is critically validated and problems and frequently used classes are then presented. Another important methodological step is the down dating of the reference data in order to get land-use information of the historical years. The mixed data processing, which will play a role in the further interpretation, will also be described. Since third parties were also involved in the digitising work during the project, special attention had to be paid as far as the definition of a standard operation procedure is concerned.

In the third chapter, the exact study area, as well as analyses of the geometric and thematic accuracy of the data produced, is described. In the following, the land-use databases with their placement, size and use is presented. In addition, the transportation network, which has been extracted, will be described. Land-use maps do this for each year along with summarized statistics for these data.

In chapter four, the data are analysed in a first approximation, also developments and trends, based on increasing classes or lost areas are carried out. Using examples like aerial photos and satellite images and their interpretation, the land-use change of agricultural area to urban fabric is demonstrated. It is to be seen that there is an enormous urban sprawl based on the loss of agricultural area. In addition, the coastline and lagoons have been modified and special infrastructural areas support this urbanisation process.

The facts described in the previous chapters are explained in more detail by spatial statistics and combined analyses. With analyses of the direct exchange of areas and changes of single classes within a group, i.e. the residential areas, such a multidimensional dynamic can be monitored. Single classes are observed in more detail in this chapter i.e. there is shown a trend to more dense residential areas. In combination with demographic data and with the use of modelling procedures a trend of “fewer people per flat” can be observed, which reflects the

social change in ISTANBUL: A comparison of the Asiatic and the European side of Istanbul points out the importance of the two Bosporus Bridges for the urban sprawl. This infrastructural project initiated an extreme urban sprawl on the Asiatic side, mainly residential areas. In this chapter, statistical trends presented as statistical diagrams of maps with growth-axes of the urbanisation of Istanbul will be discussed.

In chapter six, Istanbul will be compared to the world's biggest agglomerations and the development from 1950 up to the near future (2015) prognosticated. With today's moderate growth-rate of 2%, Istanbul is ranking clearly behind other big agglomerations in South America, China or India, but still much higher than west European cities, which have low or sometimes negative rates. In a second step, Istanbul will be compared with the other 24 MOLAND-cities and the time-spatial development will be analysed. Not in all monitored aspects is Istanbul the dramatic outsider. Nevertheless, the urbanisation is far higher than in other MOLAND-cities. Finally, Istanbul will be compared to other neighbour metropolis and Turkish cities. The similarity to non-European west-Mediterranean cities is clearly figured out. Compared to other Turkish cities, Istanbul does not have the highest growth-rate anymore. Other cities benefit from industrialisation, tourism and migration from the eastern and northern Anatolian hinterland, which still in process.

Along with a summarized interpretation, the usability of the data is discussed. Mainly from the scientific point of view, there are many possibilities to cooperate, especially on the basis of long-term sponsored projects. Consumers, i.e. water suppliers, local authorities, organisations, service-companies are interested in these data, but data integration, and a development of strategies still has to be improved. As an example for the use of data in a crisis management system, the collected data has been used to develop a Tsunami-risk map, which integrates terrain model and actual coastline in order to provide information for planning purposes.

Finally, the methodological steps will be critically analysed using cost benefit and processing time balancing aspects. Unsolved problems will also be discussed. Possibilities and limitations of these data and analyses as well as their further use will be openly discussed. Less considered methods, which should be taken into account more strongly in the future, will be mentioned.

Zusammenfassung

Die vorliegende Arbeit basiert auf dem Projekt MOLAND für Istanbul, welches in den Jahren 2001 und 2002 für den Joint Research Centre der Europäischen Kommission in Ispra/Italien durchgeführt wurde. Zunächst wird in einem Hintergrund-Kapitel eine Einführung zum Projekt MOLAND (Monitoring Land-Use Dynamics) und seinen Zielen selbst gegeben, danach werden die weiteren Ziele der vorliegenden Arbeit definiert. Um die rasch wachsende Metropole Istanbul im Kontext zu begreifen, werden die wichtigsten geographischen und sozioökonomische Gegebenheiten zunächst für die Türkei dann auch speziell für die Marmara-Region und Istanbul skizziert. Neben der naturräumlichen Ausstattung werden auch Aspekte wie Migration, Wirtschaft, Industrialisierung, Tourismus und anderes angesprochen um Istanbul mit seinem Hinterland in Wechselwirkung zu verstehen. Ein kurzer geschichtlicher Abriss und eine Aufstellung der aktuellen Probleme schließt dieses Kapitel ab.

Ein methodisches Kapitel ist der eigentlichen Analyse vorangestellt. Hier wird zunächst auf die Problematik der Landnutzungserfassung eingegangen, da jede Form einer solchen Klassifizierung ein Einpressen individueller Strukturen in ein festes Schema darstellt. Dies ist aber hinsichtlich von Vergleichen eine Notwendigkeit. Es werden dahingehend auch die CORINE und MOLAND Legenden mit Beispielen erläutert und die in dieser Studie genutzten häufigen Klassen dargestellt. Danach wird auf die Nutzungsmöglichkeiten von Geographischen Informationssystemen eingegangen, welche für solche räumlichen Analysen von großer Bedeutung sind. Datenmodelle, Formate und die Kombination unterschiedlichster Quellen in einem „Daten-Warenhaus“ werden vorgestellt.

Schließlich wird auf die Datenbeschaffung und die genutzten Quellen eingegangen. Basierend auf deren Verfügbarkeit ergaben sich schließlich so die untersuchten Jahre 1945, 1968, 1988 und 2000. Neben topographischen Karten, die als Georeferenz dienten, wurden für die 1940er Jahre und 1968 Luftbilder beschafft, für 1987/88 KFA und KVR Satellitenphotos gekauft und für das Referenzjahr 2000 IKONOS und IRS Satellitenszenen vom JRC zur Verfügung gestellt. Auf weiterführende Daten und deren Nutzungsmöglichkeiten, z.B. Geologie, Geländemodelle, Thematische Karten, Statistiken usw. wird ebenfalls eingegangen. Detailliert werden die methodischen Schritte der Satellitenbild-Georeferenzierung, der photogrammetrischen Auswertung und Orthorektifizierung der Luftbilder und auch die weiteren vorbereitenden Arbeitsschritte vorgestellt. Die Methodik zur eigentliche Auswertung bzw. Interpretation der Daten erfolgt ebenfalls in diesem Kapitel, da Vektorisierung und Zuweisung der Nutzung in einem Prozess erfolgten. Neben Versuchen der automatischen Klassifizierung mittels Clusteranalyse wird auch diese manuelle Methode kritisch hinterfragt und Probleme aber auch häufig genutzte Klassen vorgestellt. Ein weiterer wichtiger methodischer Schritt ist die Rückdatierung (down-dating) der Referenz-Daten zur Erzeugung der historischen Landnutzungsdaten. Kurz wird auch auf die gemischte Datenverarbeitung eingegangen, welche in der späteren Analyse eine Rolle spielt. Da bei der manuellen Bearbeitung der Daten auch Dritte im Rahmen des Projektes beteiligt waren, wird auf eine Definition der notwendigen Arbeitsschritte besonderer Wert gelegt.

Im drittel Kapitel wird zunächst das genaue Untersuchungsgebiet definiert und eine Betrachtung der geometrischen und thematischen Genauigkeit durchgeführt. Dann werden für alle Jahre die extrahierten Landnutzungsklassen in ihrer Lage, Größe und Nutzung präsentiert und auch das ebenfalls erfasste Verkehrsnetz betrachtet. Dies erfolgt sowohl in Form von Karten als auch kumulativer Statistiken für die gewählten Untersuchungsjahre.

Im vierten Kapitel werden dann die Daten zunächst im Überblick analysiert und Entwicklungen anhand von Flächenzuwächsen oder Verlusten bilanziert. Anhand von Beispielen mit Luft- und Satellitenbildern und der entsprechenden Auswertungen wird der Landschaftswandel vom ländlichen Raum zur Grosstadt verdeutlicht. Bereits hier wird der enorme Zuwachs städtischer Strukturen vorwiegend zu Lasten der Landwirtschaftsflächen deutlich. Auch die Küstenlinie und Lagunen werden überplant und besondere infrastrukturelle Einrichtungen wie der Flughafen tragen zur Urbanisierung bei.

Räumliche Statistiken und kombinierte Analysen vertiefen in Kapitel 5 die vorangegangenen Feststellungen indem direkt die umgewidmeten Flächen extrahiert werden und auch Strukturänderungen innerhalb von Gruppen, z.B. der Wohngebiete festgestellt werden. Detaillierter werden nun einzelne Klassen analysiert und so z.B. der Trend zu dichterer Wohnbebauung herausgestellt. In Verbindung mit demographischen Daten werden unter Zuhilfenahme von Modellansätzen Analysen der Wohndichte durchgeführt, die den Trend zu „weniger Personen auf gleicher Wohnfläche“ herausstellen. Ein Vergleich der Entwicklung der Asiatischen und der Europäischen Seite Istanbuls stellt die Schlüsselfunktion der Bosporusbrücken heraus. Diese infrastrukturelle Maßnahme initiierte ein urbanes Wachstum enormer Dimension auf der Asiatischen Seite Istanbuls, vor allem bei der Wohnbebauung. Ferner werden in diesem Kapitel auch Entwicklungstrends sowohl statistisch als auch kartographisch dargestellt und Achsen der möglichen künftigen Ausdehnung Istanbuls aufgezeigt.

In Kapitel 6 wird Istanbul zunächst mit den weltgrößten Agglomerationen verglichen und die Entwicklung von 1950 bis in die nahe Zukunft (2015) prognostiziert. Mit einer heute moderaten jährlichen Wachstumsrate von 2% steht Istanbul deutlich hinter anderen Agglomerationen in Südamerika, Indien und China zurück, jedoch auch noch deutlich über den niedrigen oder sogar negativen Raten westeuropäischer Großstädte. In einem zweiten Schritt wird Istanbul auch mit den bereits untersuchten 24 MOLAND-Städten verglichen und deren zeit-räumliche Entwicklung gegenübergestellt. Dabei ist nicht in allen Aspekten die Entwicklung Istanbuls als dramatisch anzusehen wenngleich der Verstädterungsprozess den der anderen Agglomerationen weit übertrifft. Istanbul wird schließlich auch mit benachbarten Metropolen und anderen türkischen Städten in Vergleich gesetzt. Dabei wird die Ähnlichkeit der westmediterranen, nicht europäischen Ballungszentren festgestellt. Bezogen auf die Türkei ist Istanbul nicht mehr die wachstumsstärkste Stadt. Andere Städte profitieren weiter von der Industrialisierung, dem Tourismus und der Migration aus dem Hinterland, besonders Ost- und Nordanatolien, welche nach wie vor anhält.

Neben einer zusammenfassenden Interpretation wird auf Nutzungsmöglichkeiten der Daten eingegangen. Vor allem auf wissenschaftlicher Seite bestehen mögliche Kooperationen auch mit Interesse weiterführender finanziell unterstützter Projekte. Endnutzer, z.B. kommunale Organisationen. Ämter, Behörden sowie Dienstleistungsbetriebe wie die Wasserversorgung sind grundsätzlich an den Daten interessiert, an eine Datenintegration und Entwicklung von Strategien hierfür müsste aber noch gearbeitet werden. Als Beispiel für Nutzung im Krisenmanagement wird basierend auf den gewonnenen Daten eine Tsunami-Gefährdungskarte entwickelt, welche Geländemodell und aktuelle Küstenlinie nutzt um planungsrelevante Hinweise zu geben.

Abschließend werden die methodischen Schritte kritisch hinsichtlich Kosten-Nutzen-Zeitaufwand diskutiert und offene Probleme angesprochen. Möglichkeiten aber auch Limits zur weiteren Nutzung der Daten werden offen diskutiert und auch zu gering berücksichtigte Methoden, welche es in Zukunft stärker zu integrieren gilt, erwähnt.

Özet

Bu çalışma, 2001 ve 2002 yıllarında Ispra/İtalya'da bulunan Avrupa Komisyonu, Ortak Araştırma Merkezi (European Commission, Joint Research Center) için gerçekleştirilen MOLAND projesinin İstanbul uygulamasından oluşmaktadır. Öncelikle MOLAND (Monitoring Land-Use Dynamics) projesi ve amaçları hakkında bir giriş yapılacak ve ardından da bu çalışmanın diğer amaçları tanımlanacaktır. Hızla büyümekte olan İstanbul metropolünde bu büyümeyi anlayabilmek için, önemli coğrafi ve sosyo-ekonomik bilgiler öncelikle Türkiye, sonrasında da Marmara bölgesi ve İstanbul kenti için verilecektir. İstanbul ve ardülkesinin değişim etkisinin anlaşılması amacıyla doğal özelliklerinin yanısıra, göç, ticaret, endüstrileşme, turizm ve diğer etkenlerde tartışılacaktır. Bu bölümün sonunda, kısa tarihi bir özet ve güncel sorunların ortaya konması anlatılacaktır.

Analizlerin yapıldığı bölümden önce, metodolojinin anlatıldığı bir bölüm yer almaktadır. Öncelikle arazi kullanımının belirlenmesindeki sorunlar üzerinde durulmuştur.çünkü her bir sorunlu sınıflandırma, çalışmanın sonucunda sonuçları karşılaştırmak için kullanılacak olan lejantta ayrı bir yer almıştır. CORINE ve MOLAND Projelerinin lejantları örneklerle açıklanmış ve bu çalışmada kullanılan sınıfları ortaya konulmuştur. Ardından,bu çalışma gibi mekansal analizlerin çok önemli olduğu çalışmalarda büyük önem taşıyan coğrafi bilgi sistemlerinin kullanım olanaklarından bahsedilmiştir. Veri modelleri, formatları ve farklı kaynaklardan gelen verilerin kombinasyonları bir veri modelinde ortaya konulmuştur.

Son olarak, veri toplanması ve kullanılan veri kaynakları anlatılmıştır. Bu verilerin erişilebilirliği gözönüne alınarak, 1945, 1968, 1988 ve 2000 yılları analiz için seçilmiştir. Verilerin georeferanslandırılmasında kullanılan topoğrafik verilerin yansıra 1940 ve 1968 yılları için hava fotoğrafları elde edilmiş, 1987/88 yıllları için KFA ve KVR uydu fotoğrafları ve referans yılı 2000 için JRC aracılığı ile sağlanmış olan IKONOS ve IRS uydu görüntüleri kullanılmıştır. Jeoloji haritaları, arazi modelleri, tematik haritalar ve birtakım istatistiktilerin ek veri olarak kullanılmaları da araştırılmıştır. Uydu görüntülerinin georeferanslandırılması, hava fotoğraflarının fotogrametrik değerlendirme ve ortorektifikasyonunun yanısıra hazırlanmıi çalışma adımlarının tüm metodolijik aşamaları detaylı olarak anlatılmıştır. Vektörizasyon ve yorumlamanın kombinasyonu şeklinde sonuçlandırılmış olan arazi kullanımın belirlenmesi işlemi de bu bölümde açıklanmıştır. Cluster analizi kullanılarak otomatik sınıflandırmanın yanında, kullanılan mauel sınıflandırma Diğer önemli bir metodoloji ise tarihsel yıllardaki arazi kullanımını elde edebilmek için gerçekleştirilen, referans verisinin ters yönde güncellenmesi (down-dating) olmuştur. Yorumlama için önemli rol oynayan karmaşık verinin işlenmesi de burada açıklanacaktır. Üçüncü grupların da sayısallaştırma işlemine dahil olmasından ötürü, standart işlem prosedürünün tanımlanması için özel bir çaba sarfedilmiştir.

Üçüncü bölümde, öncelikle tüm çalışma bölgesi tanımlanmış, geometrik ve tematik doğruluk için bir yaklaşım gerçekleştirilmiştir. Ardından tüm değerlendirme yılları için elde edilmiş tüm arazi kullanım sınıfları konumları, büyüklükleri ve kullanımları ile gösterilmiş ve bu bilgilere ulaşım ağı da dahil edilmiştir. Bu, her değerlendirme yılı için arazi kullanım haritaları formunda ve bu verilerin özetlenmiş istatistikleri şeklinde yapılmıştır.

Dördüncü bölümde verilerin ön analizi gerçekleştirilmiş ve gelişimlerin alansal kazanımlar veya kayıplar da dikkate alınarak bilançosu çıkartılmıştır. Tarım alanlarından yapılaşmış alanlara doğru değişim, hava fotoğrafları ve uydu görüntülerinden örnekler sunularak açıklanmıştır. Bu aşamada tarım arazilerinden yapılaşmış alanlara değişimin büyüklüğü gözler önüne serilmektedir. Bunun yanında kıyı çizgisi ve lagular da değişimler göstermiş, ayrıca havaalanı gibi özel altyapı birimleri de inşaa edilmiştir.

Beşinci bölümde yer alan mekansal istatistikler ve kombine analizler, önceki bölümde elde edilmiş sonuçları daha da derinleştirmektedir. Meskun bölgeler gibi, tekil sınıflar içerisindeki alansal farklılıklar ve değişimlerin analizi ile çok boyutlu dinamik de belirlenebilmektedir. Bu bölümde tekil sınıflar daha detaylı olarak ele alınmış, bu şekilde yoğun meskun bölgelerdeki eğilim de gösterilmiştir. Demografik verilerle bağlantılı olarak, mesken yoğunluklarının analiz modeli gerçekleştirilmiş ve İstanbul'un sosyal değişimini yansıtan "birim mesken katına daha az birey" eğilimi ortaya çıkartılmıştır. Asya ve Avrupa yakalarının karşılaştırılması, Boğaz

köprülerinin anahtar fonksiyonlarını ortaya çıkartmaktadır. Bu altyapısal özellik, Asya yakasında özellikle meskun alanların çok büyük boyuttaki gelişimini sağlamıştır. Bu bölümde ayrıca istatistiksel ve kartografik olarak gelişim eğilimleri de ortaya konmuş ve olası gelişim yönleri de gösterilmiştir.

Altıncı bölümde, İstanbul öncelikle dünyanın büyük yerleşimleriyle karşılaştırılmış, ve 1950'den yakın geleceğe kadar (2015) olan gelişim gösterilmiştir. %2'lik büyüme oranıyla İstanbul, açıkça Güney Amerika, Çin ve Hindistan'daki diğer büyük yerleşimlerin ardında sıralanmakta, ancak genellikle düşük veya negatif büyüme oranlarına sahip Batı Avrupa şehirlerinden önde gelmektedir. İkinci aşamada İstanbul'un 24 diğer MOLAND şehirlerinin zamana bağlı olarak mekansal gelişmelerinin karşılaştırması yapılmıştır. İstanbul'un her açıdan en dramatik durumda olmadığı, ancak şehirleşmenin tüm diğer MOLAND şehirlerine göre farklı şekilde büyük olduğu belirlenmiştir. Son olarak İstanbul, yakın metropoller ve diğer Türk şehirleri ile karşılaştırılmıştır. Avrupa dışındaki Batı Akdeniz şehirleri ile olan benzerlikler saptanmıştır. Diğer Türk şehirlerine göre İstanbul en yüksek büyüme oranına sahip değildir. Diğer şehirler endüstrileşme, turizm ve halen devam etmekte olan Doğu ve Kuzey Anadolu'dan gelen göçlerin etkisi altındadır.

Özetlenen yorumların yanında, verilerin kullanılabilirliği de tartışılmıştır. Genellikle bilimsel açıdan özellikle devam etmekte olan finans destekli projeler için birçok işbirliği olanağı bulunmaktadır. Su şebeke kuruluşları gibi altyapı kurumları, kamusal organizasyonlar, kamu kurumları gibi son kullanıcılar bu verilere ilgi duymaktadır. Ancak veri entegrasyonu ve strateji geliştirilmesi için çalışmalar yapılması gerekmektedir. Örnek olarak, afet yönetim sistemi içinde kullanılabilmesi için, elde edilen veri, planlama amaçlı bilgi elde etmek amacıyla, arazi modeli ile güncel kıyı çizgisinin bir enegrasyonu olan Tsunami risk haritasının elde edilmesinde kullanılmıştır.

Son olarak, metodoloji adımları, maliyet-kazanç ve işlem-zaman açısından analiz edilmiştir. Çözülemeyen sorunlar da tartışılmıştır. Veri ve analizlerin limit ve olanaklarının yanısıra, bunların ilerideki kullanımları açıkça tartışılmış, kullanılmayan ancak gelecekte entegre edilmesi gereken metodlardan da bahsedilmiştir.

AGENDA

1 Background

1.1 MOLAND-about the project

The Directorate General (DG) for the Joint Research Centre (JRC) of the European Commission (EC) is performing the pilot project Monitoring Land-use Dynamics (MOLAND). Their goal is to study the dynamics of urban areas to assess their progress towards sustainability and their impacts on regional developments. The project, which measures the dynamics of cities and areas in Europe through the creation of land use and transport network databases, covers also wider issues linked to sustainable development, and aims to create a network of partners and collaborators within and outside Europe. MOLAND addresses specifically the issues mentioned in the European Spatial Development Perspective (ESDP) that are related to urban and regional development and those linked to sustainable land use management. MOLAND is of direct relevance to several environmental topics at the EU level, such as the actions on sustainable urban development and related communications, and the initiatives on Environmental Impact Assessment and on Strategic Environmental Assessment. MOLAND contributes to the preparation and definition of the Thematic Urban Strategy of the sixth Environmental Action Plan of the European Union, following the guidelines set by the EC Directorate General on Environment. MOLAND aims to provide an integrated methodology based on a set of spatial planning tools that can be used for assessing, monitoring, and modelling the development of urban and regional environments. The project allows quantitative and qualitative comparisons at Pan-European level, among areas subject to transformation due to policy intervention. A further characteristic adopts a methodology that simultaneously addresses the EU perspective on the one hand, and the regional/local dimension on the other. Currently, a total of 40 urban areas have been analysed in Europe and a wider network of links is being created in collaboration with existing organisations such as EUROCITIES, METREX and others.

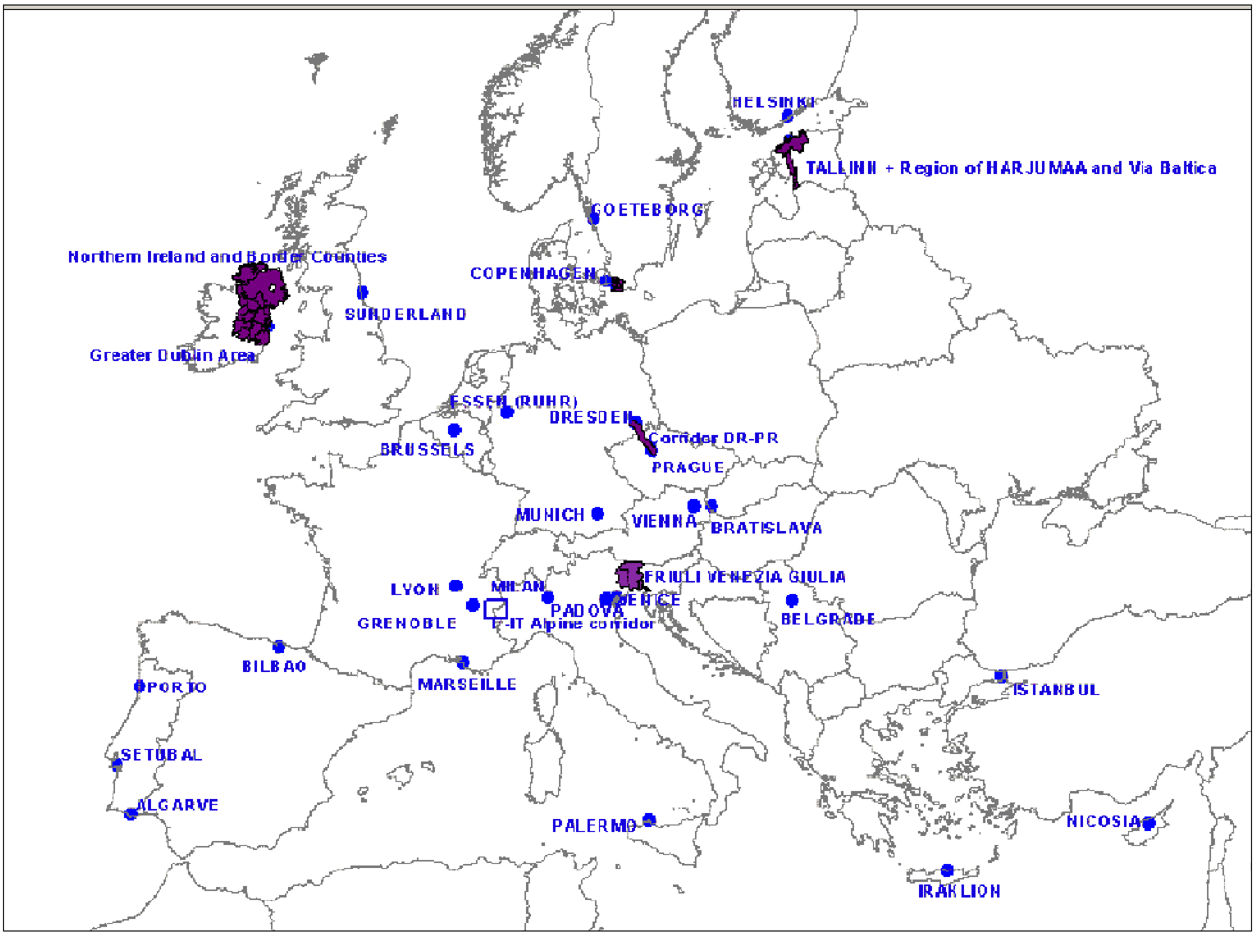


Figure 1: *The covered cities and regions under MURBANDY and MOLAND (JRC, http://MOLAND.jrc.it)*

MOLAND was initiated in 1998 (under the name of MURBANDY – Monitoring Urban Dynamics), in support of the preparation of the European Spatial Development Perspective (ESDP). MURBANDY aimed to monitor the development of urban areas and to draw some conclusions on trends at a European scale. This work was extended (under MOLAND) to the computation of indicators (following the requirements of EUROSTAT, European Environment Agency and others), and to the assessment of the impact of anthropogenic stress factors (with a focus on expanding settlements, transport and tourism) in and around urban areas, and along development corridors. The primary role of the MOLAND Project is to provide scientific and technical support to the European Commission's various Directorates-General (DGs), services, and associated bodies, which are responsible for the conception, development, implementation, and monitoring of EU policies related to urban and regional development. At present, the main EU policy areas that are supported by MOLAND include the following: the 6th EC Environment Action Programme's proposed Thematic Strategy on the Urban Environment, for DG ENV (Environment); indicators for Sustainable Urban and Regional Development, for DG ENV, EUROSTAT, and the EEA (European Environment Agency); the ESDP, for DG REGIO (Regional Policy); Impacts of the Structural and Cohesion Funds, for DG ENV; Strategic Environmental Assessment (SEA) of the Trans-European Transport Networks (TEN-T), for DG TREN (Energy and Transport).

From a technical point of view, MOLAND has three specific aims:

- to produce quantitative information on the evolution of land use and transport networks, from the year 1950 onwards, in study areas subject to infrastructure changes (e.g. urbanisation, construction of transport links);
- to develop methods for performing a harmonised analysis of historical trends, including socio-economic aspects, impact of legislation, landscape fragmentation, etc.;
- to develop models for the harmonised simulation of future European-wide scenarios, at local and regional scales.

The implementation of MOLAND is divided into three phases. Central to the methodology is the creation of detailed GIS databases of land use types and transport networks for the study areas, at a mapping scale of 1:25.000. The databases are typical of 4 periods (early 50s, late 60s, 80s, late 90s), or of two periods (mid 80s, late 90s) in the case of large areas. For each study area the reference land use database (late 90s) is created from interpretation of satellite imagery, most commonly from the IRS and in a few cases from the IKONOS satellites. SPOT images sometimes complement the available imagery. The three historical databases are created from the available data (aerial photographs, military satellite images, etc.) for these periods. MOLAND adopts the CORINE land cover legend, with a fourth, more detailed level of nomenclature needed for the scale used.

In the second phase of MOLAND, various spatial analysis techniques are applied to the land use and transport databases, and associated socio-economic data, in order to compute different types of indicators of urban and regional development. These indicators are used to assess and compare the study areas in terms of their progress towards sustainable development. Analysis of the fragmentation of the landscapes is also carried out. The land use and transport databases have also been used for a strategic environmental assessment (SEA) of the impact of transport links on the landscape.

In the third phase of MOLAND, an urban growth model is applied. This model, which is based on spatial dynamics systems called "cellular automata", takes as input the MOLAND land-use and transport databases, as well as maps of land use suitability and zoning status, and simulates future land-use development under the input of urban and regional planning and policy parameters. Here the aim is to predict future land-use development under existing spatial plans and policies, and also to compare alternative possible spatial planning and policy scenarios, in terms of their effects on future land use development.

Key objectives in MOLAND are to quantify the changes in land use patterns, to explain the trends of growth for the selected urban areas, and to help in identifying strategies for sustainable urban and regional development. The extensive data created within MOLAND leads to a series of unique land-referenced data. This data is used to build, and particular, to test specific spatially referenced indicators. Such indicators serve several purposes:

- Provide a better understanding of complex territorial problems
- Provide a sufficiently complete basis for the approaches to urban and regional spatial planning (particularly regarding sustainable land use management)
- Help city managers and decision-makers in defining local policies
- Provide regional/national authorities and international institutions with detailed territorial-referenced information at local and European levels.

The indicators are designed to be robust in space and time, as well as flexible enough to accommodate the urban and regional different structures. At the same time, such indicators offer a degree of standardisation that allows comparisons between different European urban areas. A further key peculiarity of the approach is the multi-temporal perspective for assessing past and future trends.

Any indicator would be furtile if the data to calculate were arduous or even impossible to obtain. In practice, the failure of several attempts to set up indicator development strategies on the basis of theoretical analyses was mainly due to the lack of basic information. MOLAND directly produces indicators according to a precisely defined strategy. Moreover, the flexibility of the methodology also allows developing indicators according to different user needs.

Linking the issue of developing a core set of urban and regional sustainability indicators to data availability is, therefore, important. On the other hand, once the data availability has been checked, it is often difficult to find out a coherent framework of sustainable development indicators, due to the impossibility of cross-linking different series of parameters. The main problems arise when the spatial dimension is not taken into account in indicator computation.

A common approach to measure sustainability consists of developing indicators for facilitating assessments of certain situations and related trends. In some cases, the aim is to allow comparisons and benchmarking. There are certain acknowledged “rules” for selecting indicators. One rule, whose importance is often underestimated, is that the boundaries (i.e. the physical limits) of the considered system have to be defined first. The basis of the strategy of MOLAND is the idea that, without a spatial approach, any indicators set aiming to address sustainability would be incomplete.

Previous works addressing sustainability through the development of indicators did not adequately take into account spatial parameters, the importance of which is basic to any studies on urban and regional development. For instance, nowadays any work focusing on urban sustainability must address transportation capacity. Assuming that the appropriate carrying capacity or the ecological footprint of a certain area is also determined based on territorial parameters, a spatial approach has to be satisfactorily considered.

The MOLAND methodology adopts a spatial approach, defining the urban system as that portion of land covered with continuous artificial surfaces, including a surrounding buffer area. The various sets of indicators for urban and regional sustainability are, therefore, differentiated according to the spatial dimension. If a standard geographic unit for different urban systems can be fixed, deriving spatial referenced indicators that allow comparisons amongst systems that then become feasible. For this reason, the geographic unit of analysis must be clearly specified, because shifting units can affect the results. By necessity, the data on which the indicators are based on must be territorially differentiated.

A core set of urban and regional indicators, which includes land use and socio-economic information, has not yet been precisely defined and agreed at international level. Furthermore within the project the definition of specific indicators for the sustainability in urban areas, as a system connected to regional backgrounds, is one of the most investigated topics.

The technical framework for providing such a quality of information has never been previously developed on a large scale so far. As stated by Bittermann and Haberl: “good concepts and theoretical foundations for spatially relevant pressure indicators are lacking throughout the bulk of the international indicator literature”. MOLAND addresses these deficiencies and offers a new point of view by linking “classical” socio-economic indicators to territorial parameters.

Particular effort is devoted to the development of easily handled indicators, since potential users of these results include city managers, local administrators, and planners, right up to international bodies. Such users may also be willing to have a comprehensive framework of the situation. Due to the complexity of the urban systems and the quantity of data managed, the number of indicators has to be reduced to the minimum. Furthermore, in order to attain all the sectors that need to be considered, MOLAND targets a set of cross-sectoral indicators - with a focus on pressure indicators.

The user, in this way, should be able to handle more information with a manageable effort. The indicators developed under MOLAND can be divided into two main categories:

Spatially referenced indicators providing information on different land use types and changes;

Cross sectoral spatially referenced indicators to target and evaluate more complex processes for landscape changes (e.g. fragmentation). Socio-economic data, prepared in a spatially disaggregated format, are included in this category to cover topics of relevance for different policies (environment, transport, social cohesion, etc.). The aim here is to address carrying capacity and general urban and regional sustainability issues.

The urban and regional growth model that is used in MOLAND is based on spatial dynamics systems called “cellular automata”. The model takes five types of digital maps for the geographical area of interest as input:

- actual land use types presented in the area;
- inherent suitability of the area for different land uses;
- zoning status (i.e. legal constraints) of the area for different land use;
- accessibility of the area to the transport network;
- socio-economic characteristics (e.g. population, income, production, employment) of the area.

The information on land use types and transport networks is derived from the detailed GIS databases that were produced for each of the study areas, as part of MOLAND. The output from the urban growth model is maps of predicted land use development over twenty years.

The underlying spatial dynamics of the MOLAND urban and regional growth model are determined by so-called “transition rules”, which specify the interaction between neighbouring land use types.

By modifying the input data (e.g. zoning, suitability, transport links), the MOLAND urban and regional growth model can be used to explore, in a realistic way, alternative future scenarios of land use development. The following types of spatial planning and policy “interventions” – with sample “real” applications – can be easily simulated with the model:

- Addition / removal of transport links: This can be used for a Strategic Environment Assessment (SEA) of the Trans-European Transport Network (TEN-T).
- Modification of land use zoning: This can be used to assess the effects on land use development prohibiting the development of artificial surfaces in natural areas.
- Modification of land use suitability: This can be used to assess the effects on land use development of decreasing the flooding risk, due to infrastructure improvements.
- Modification of socio-economic data: This can be used to assess the effects on land use development of a changing economic climate (e.g. decreased industrial production).
- Modification of model’s transition rules: This can be used to capture the particular cultural characteristics of an area (e.g. in certain areas, close to water might be considered attractive for residential areas).

The alternative spatial planning and policy scenarios are presented to the MOLAND urban and regional growth model in the form of digital data sets of the transport networks, socio-economic data, land-use zoning status, and land use suitability. Based on these scenarios, and on the actual land use types at the start of the forecasting period, the model then predicts the likely future development of land use development, for each year over the next twenty years. In order to compare the alternative predicted land use maps produced by the model, in terms of the long-term sustainability of the input land use planning and management parameters, various indicators – including those describing landscape fragmentation – are computed and analysed.

Currently, the MOLAND urban and regional growth model is being calibrated for MOLAND’s extensive Europe-wide network of cities and regions, using the MOLAND land-use and transport databases, as well as the ancillary data-sets acquired from local authorities. The latest version of the model also incorporates data, describing the socio-economic properties of the area, and will be used to simulate the interactions between the cities and their surrounding regions. This so-called “macro-model” is being tested on the four new “extended” MOLAND study areas, where extensive regional changes in land use are likely to occur as a result of major economic and infrastructure developments (e.g. the Dresden-Prague transport corridor).

The issues dealt with by MOLAND require a concrete and active involvement of regional and local authorities. This is for two main reasons.

In the field of Regional policy, the subsidiarity principle reaches its full dimension: local/regional bodies implement with almost full autonomy directives and measures for regional developments decided by the EC. This is particularly true for structural funds related to urban and local infrastructure (ports, airport etc.) and for the application of SEA at local/regional level. The debate has also been at the centre of the ESDP, and will have to be solved in the establishment of ESPON.

From a purely technical point of view, there is only at the adequate local level is there a need for information to fully assess and analyse the impact of measures taken or planned.

In the frame of the activities of the project, particular efforts have been dedicated to establish links and contacts with national, regional and local authorities. These contacts have resulted in formal collaborations either following already established mechanisms in the EC (such the Working Groups in DG ENV, projects funded in the INTERREG Programme, the fifth RTD Framework Programme, etc.) or following establishing bi-lateral agreements.

An active collaboration has been initiated with EUROCITIES (originated in the frame of the working groups set by DG ENV) to network cities and local administration. This will result in a series of proposals for thematic network to the EC, in which the partner-cities will aim to adopt the MOLAND methodology as much as possible.

The ‘instrument’ to formally set up a large thematic network on the issue of urban (and regional) sustainable development is provided by the European Research Area, which will drive the research activities of the European Commission. It is essential to extend the scope of such network to ‘institutional users’ (e.g. local administration, EC services etc.) and to institutes and organisations with a specialisation and tradition in the various fields related to the “urban affaire”.

To manage data-acquisition and data pre-processing, this work was given by tenders to external service providers. The preparation and acquisition of the data for the Istanbul-area was given to an external operator as well. The company GGS (Geotechnik, Geoinformatik & Service) as the main contractor to the JRC/IES has already undertaken the work on MURBANDY for the areas of Bratislava and Prague. The Technical University of Istanbul (ITÜ) was partner in the consortium lead by GGS.

The consortium formally acquired the data at the military geodetic institution in Ankara. This way was needed to get access to the military restricted data (maps and aerial photos) and it was the fastest and the least expensive one. The German company Atalay-Consult, a partner-company of ODOPEM, supported all this complex network of Turkish contracts.

All arrangements of aerial photos, topographical maps, and DEM were made by the ITÜ. The processing of the data (georeferencing, vectorisation and interpretation) was also done there, because all named data are secret and cannot leave the country or this institute. Beside me, (Gerhard Kemper / GGS) 1-3 people of the ITÜ worked for this project in the Photogrammetric Laboratories in ITÜ between March 2001 and April 2002.

The Company Odopem arranged the ancillary data sets also in co-operation with ITÜ. These data are not a matter of secret and in that case, this data has been processed by GGS in Germany.

The interpretation of the land-use data in combination with statistical analyses and trend estimations was done at GGS. In addition, the reports, data-conversations etc, was done by GGS.

1.2 Objectives of this studies

Before I discuss the objectives, I would like to clarify why Istanbul was chosen as the object for this study. Before the JRC launched the project MOLAND Istanbul via a Tender, the city was already a focus of my interest. Following a visit in the year 1999, just after finishing similar projects for Bratislava and Prague, the dynamic of this “Megacity” became apparent in an impressive way. The idea to undertake a similar project for Istanbul was immediately born in my mind. Istanbul, with its extreme size and dynamic, seemed a perfect object for such a Remote Sensing project. I discussed my ideas with the JRC and, at the end of the year 2000, Istanbul was placed on the tenders list for MOLAND. Istanbul is an interesting object for several reasons.

Istanbul, formerly Constantinople and Byzantium, is the only city in the world that sits astride two continents – Europe and Asia. Istanbul is the largest city in Turkey and is the country’s chief commercial and cultural centre. Istanbul is an important crossroad between the orient and occident, the northern Europe and the Mediterranean, and a gateway to the Islamic world. With the finest natural harbour in the region, it is an important trade hub. The city is the capital of Istanbul Province, which is bound on the north by the Black Sea, on the south and southwest by the Sea of Marmara, on the east by Kocaeli Province, and on the west by Tekirdag Province. The Bosporus, linking the Black Sea and the Sea of Marmara, separates Istanbul’s European and Asian sections. The actual city covers an area of 1991 km² (after MS-Encarta 1998), while the metropolitan area occupies 5712 km². In 1994, Istanbul’s official estimated population was 7,615,500; some unofficial estimates were much higher, however, reflecting the increasing influx of people from other countries and rural parts of Turkey. Within the Istanbul metropolitan area, there has been considerable migration from crowded central Istanbul to the Asian side of the Bosporus and also to various suburbs. Bakirköy, located west of “Stambul”, is Istanbul’s largest suburb. The biggest growth, however, took place along the Marmara-seaside on the Asian as well as on the European side. Today the greater Istanbul area has an unofficial population of 16-18 Mio. The extremely rapid growth, and the enormous size, makes Istanbul a perfect site for Remote Sensing projects, while other methods have difficulties to adapt to this dynamic growth.

1) The first objective of this thesis is the methodological and scientific guidance of the project with a critical discussion of the work. This was already one of my main tasks for the entire duration of the project. It is mainly a technical objective. Nevertheless, the variations of operators influence the result a lot.

1a) The preliminary definition of suitable data-sources, the data processing, and the extraction of land-use data out of the remotely sensed data is a vital piece of work due to its influence on the final result. To achieve enough details without losing the overview makes this work very complex. The scale of the study had to be selected according to the defined aim. The complexity of relations between land-use patterns and their spatial determinants influences the scale of analysis which itself causes the results. The spatial resolution is often in focus of interest, but that is only one aspect of scale effects. 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 land-use to its determining factors, and more specifically land-use patterns, 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 determined. With decreasing resolution and increasing extent, it becomes increasingly harder to identify key processes.

1b) Geodetic task lies in the definition on the most suitable coordinate system and the needs to transform all data into this target system. Data of satellite imagery had to be converted, geocoded and adapted for further processing. Methods of stretching, colour-composition and pan-sharping had to take place. Each type of satellite imagery needs specific steps in processing to point out a most suitable workflow. Analyses of the geometric accuracy have been done to validate the quality of the extracted data. The processing of aerial images needed a kind of detective's work in photogrammetry in order to receive the expected data, especially the camera-parameters for digital operations.

1c) The legend and how to interpret the type of land-use class is not an easy task either. Many lively discussions have been undertaken with the JRC to reach a good and reliable result. The knowledge about previous projects (MURBAND for Prague and Bratislava) already gave an indication of which class should be adapted or should become integrated into a newer or updated legend list. Other methods like automated classification algorithms, will be discussed as well in this study and its limits will be pointed out.

1d) Land-use interpretation is closely linked to the operator and because of that, it is difficult to be validated. Which variation will we achieve by different operators and how can this problem be handled? How can we solve 3-dimensional variations of spatial use? This is a difficult problem – already known in geo-scientific analyses that have also met this project.

1e) The interpretations have been done in GIS – interactive as vector data with the remotely sensed raster-data in its background. Which tools are suitable and which accuracy can we achieve in information and geometry? How can we digitise the results in topological GIS environment and which strategy helps with the down dating for the historical years and how to validate the results?

2) The second main objective of this thesis is the interpretation and analysis of data, which were not a primary task in the MOLAND-project. Nevertheless, first interpretations have been already done in the project. To find a suitable strategy in such complex data needs scientific creativity.

2a) The logic task in this study is to receive an overview on the urban sprawl dynamic. To combine statistical and mapped information is one's aim. To detect where and when the biggest change took place was interpreted out of these results. The analysis where and when exchange of land-use classes appeared is also a focus of this study.

2b) A further analysis by the help of trend-analyses using extrapolation with different statistical methods has solved the next task – how and in which direction the city will grow in future. This analysis also points out the upcoming problems of the city – to get the uncontrolled sprawl of Istanbul under control most quickly.

2c) To understand the reason of this growth can only partly be analysed by this remote-sensing strategy. But with the combination of spatial data and other empiric information, first correlations can be undertaken. Specific things can be pointed out like the sprawl–jump across the Bosporus and the change of living density within the centre. It correlates with statistical data and qualitative information reasonably well.

2d) To compare Istanbul with other cities, processed under MURBANDY and MOLAND, might help to find similar phenomena. Is Istanbul comparable with the sprawl of other cities? Did this growth in Istanbul happen at the same time and with the same intensity as in others? What is specific and what is common? Are these mechanisms already detected and adjustable for Istanbul as well?

2e) If we understand the why's of this rapid urbanisation, we might be able to define forecast strategies. It needs to be discussed whether this is realistic or not. Sometimes it is necessary to establish scenarios to highlight the ongoing problems. The necessity for changes has to be accepted by the population, but first of all the planners and decision makers must be aware of it.

3) As an outlook to the future, a third main objective is to make use of this study for integrated planning and management purposes for the city. Methods, strategies and “gates” to get access to this study for planners are important.

3a) The results of land-use 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

It is an important task to point out where and how these data can be integrated into an existing subject. Some of them are obvious; others might be more or less latent. However, if we aim at undertaking an integrated planning, we have to fit in with the data wherever it makes sense.

After developing new technologies in the field of geosciences during the last few years, the lack of information can be reduced more easily. Using technologies such as aerial photogrammetry, remote sensing and GPS enable the generation of new approaches.

For big cities like Istanbul, there exists the big problem to control, plan and analyse the urbanization. All these urbanization activities are the job of local authorities; nevertheless, scientists have to develop new methods and techniques to support the decision makers.

3b) But which tools should enter the wide range of the planner’s world? Istanbul is similar to other big cities in its planning and managing strategies. A common overview is missing; no organisation or computer-system is able or willing to use this data. Too many different software-tools, system-designs, and needs exist beside each other. It will never be possible to solve all applications with one system only. To find a key to make these systems communicate successfully will be discussed. Mainly, the implementation of a multi-scaled GIS with innovative access and control mechanisms will be pointed out.

1.3 The Republic of Turkey

The Republic of Turkey placed between 36-42° north and 26-45° east, is a Eurasian country that spans two continents.

Turkey is a large, roughly rectangular peninsula situated bridge-like between southeastern Europe and Asia. The country has functioned as a bridge for human movement throughout history. Turkey extends more than 1,600 km from west to east but generally less than 800 km from north to south. With an area of 814,587 km², the Republic of Turkey has more extensive land than its neighbours, except Iran. 3% of the area is located in Thrace in Europe, and the remaining 97%, which is referred to as Anatolia, is located in Asia.

The European Turkey (Thrace) encompasses 3 % of the total area, but is home to more than 10 % of the total population. The Bosporus Strait (Istanbul Bogazi or Karadeniz Bogazi), the Sea of Marmara (Marmara Denizi), and the Dardanelles Strait (Çanakkale Bogazi) separate Thrace from the Asian portion. The Asian part of the country is known by a variety of names: Asia Minor, Asiatic Turkey, the Anatolian Plateau, and Anatolia (Anadolu). The term *Anatolia* is most frequently used in specific reference to the large, semiarid central plateau, which is rimmed by hills and mountains that in many places limits access to the fertile, densely settled coastal regions. Astride the straits separating the two continents, Istanbul is the country's primary industrial, commercial, and intellectual centre. However, the Anatolian city of Ankara, which Atatürk and his associates picked as the capital of the new republic, is the political centre of Turkey and has emerged as an important industrial and cultural centre.

1.3.1 Borders:

Eight countries and six bodies of water bound Turkey. Surrounded by water on three sides and protected by high mountains along its eastern border, the country generally has well-defined natural borders.

Figure 2: *Turkey and its borders (www.notebooktravel.co.uk)*

Its demarcated land frontiers were settled by a treaty early in the 20th century and have remained stable since that time. The boundary with Greece (206 km) was confirmed by the Treaty of Lausanne in 1923, which resolved persistent boundary and territorial claims involving areas in Thrace and provided for a population exchange. Under the agreement, most members of the sizable Greek-speaking community of western Turkey were forced to resettle in Greece, and the majority of the Turkish-speaking residents of Greek Thrace were removed to Turkey. The 1923 treaty also confirmed Turkey's 240 km boundary with Bulgaria.

Since 1991, more than 500 km of boundary with the former Soviet Union, which was defined in the 1921 treaties of Moscow and Kars, has formed Turkey's borders with the independent countries of Armenia (268 km), Azerbaijan (9 km), and Georgia (252 m). A treaty confirmed the 499 km boundary with Iran in 1937. Turkey's two southern neighbours, Iraq and Syria, had been part of the Ottoman Empire up to 1918. According to the terms of the Treaty of Lausanne, Turkey ceded all its claims to these two countries, were organized as League of Nations mandates under the governing responsibility of Britain and France, respectively. Turkey and Britain agreed on the 331 km boundary between Turkish and Iraqi territory in the 1926 Treaty of Angora (Ankara). Turkey's boundary with Syria (822 km) has not been accepted by Syria. As a result of the Treaty of Lausanne, the former Ottoman Sanjak (province) of Alexandretta (present-day Hatay Province) was ceded to Syria. However, France agreed in June 1939 to transfer Hatay Province to Turkish sovereignty, despite the strong objections of Syria's political leaders. Since achieving independence in 1946, Syria has harboured a lingering resentment over the loss of the province and its principal towns of Antakya and Iskenderun (formerly Antioch and Alexandretta). This issue has continued to be an irritant in Syrian-Turkish relations.

The seas that surround the country on three sides are the Black Sea, the Aegean and the Mediterranean. The length of the coastline is 8,333 km.

Throughout history, Turkey, due to her location, her important strategic position, and her extensive coastline, which make her a neighbour to the entire world, has been a centre of major trade and migration routes. The Marmara Sea and the straits are important maritime passages that provide access to the Black sea and to the world. The Marmara Sea, which is located completely within national boundaries, opens onto the Black Sea via the Bosporus and to the Aegean and the Mediterranean via the Canakkale Strait.

1.3.2 Geology:

Turkey's varied landscapes are the product of complex earth movements that have shaped Anatolia over thousands of years and still manifest themselves in fairly frequent earthquakes and occasional volcanic eruptions. Except for a relatively small portion of its territory along the Syrian border that is a continuation of the Arabian Platform, Turkey geologically is part of the great Alpine belt that extends from the Atlantic Ocean to the Himalayan Mountains. This belt was formed during the Tertiary Period (about 65 million to 1.6 million B.C.), as the Arabian, African and Indian continental plates began to collide with the Eurasian plate, and the sedimentary layers lay down by the prehistoric Tethyan Sea buckled, folded, and contorted. The intensive folding and uplifting of this mountain belt was accompanied by strong volcanic activity and intrusions of igneous rock material, followed by extensive faulting during the Quaternary Period, which began about 1.6 million B.C. This folding and faulting process is still ongoing, as the Turkish and Aegean plates, moving south and southwest respectively, continue to collide. As a result, Turkey is one of the world's most active earthquake and volcano regions. Tectonically Turkey is situated in the Alpine-Himalayan zone, which is one of the world’s most active seismic regions. The North Anatolian fault, which extends from one corner of Turkey to the other, is one of the primary faults in the country. There are many active faults along this area.

Earthquakes range from barely perceptible tremors to major movements measuring five or higher on the Richter scale. Earthquakes measuring more than six can cause massive damage to buildings and, especially if they occur on winter nights, numerous deaths and injuries. Turkey's most severe earthquake in the twentieth century occurred in Erzincan on the night of

December 28-29, 1939; it devastated most of the city and caused an estimated 160,000 deaths. Starting with Erzincan there have been eight major earthquakes along this North Anatolian fault. These tremors have occurred systematically, starting from the east and continuing along the fault to the west. The August 1999 earthquake and the November 12, 1999 Düzce earthquake occurred in the East Marmara section of the North Anatolian fault. The results of these earthquakes, which occurred in one of the most densely populated regions of Turkey, are more than 18.000 killed people and about 100.000 houses that were destroyed or damaged. The Marmara earthquake, the magnitude was 7.4, was qualified as the "disaster of the century". It was the most devastating earthquake in Turkey since the 1939 Erzincan earthquake. The Marmara earthquake was followed on May 1, 2003 by the Bingöl earthquake with a magnitude of 6.4. This devastating earthquake destroyed a great number of buildings in the centre of Bingöl. Earthquakes of moderate intensity often continue with sporadic aftershocks over periods of several days or even weeks. The most earthquake-prone part of Turkey is an arc-shaped region stretching from the general vicinity of Kocaeli to the area north of Lake Van on the border with Armenia and Georgia.

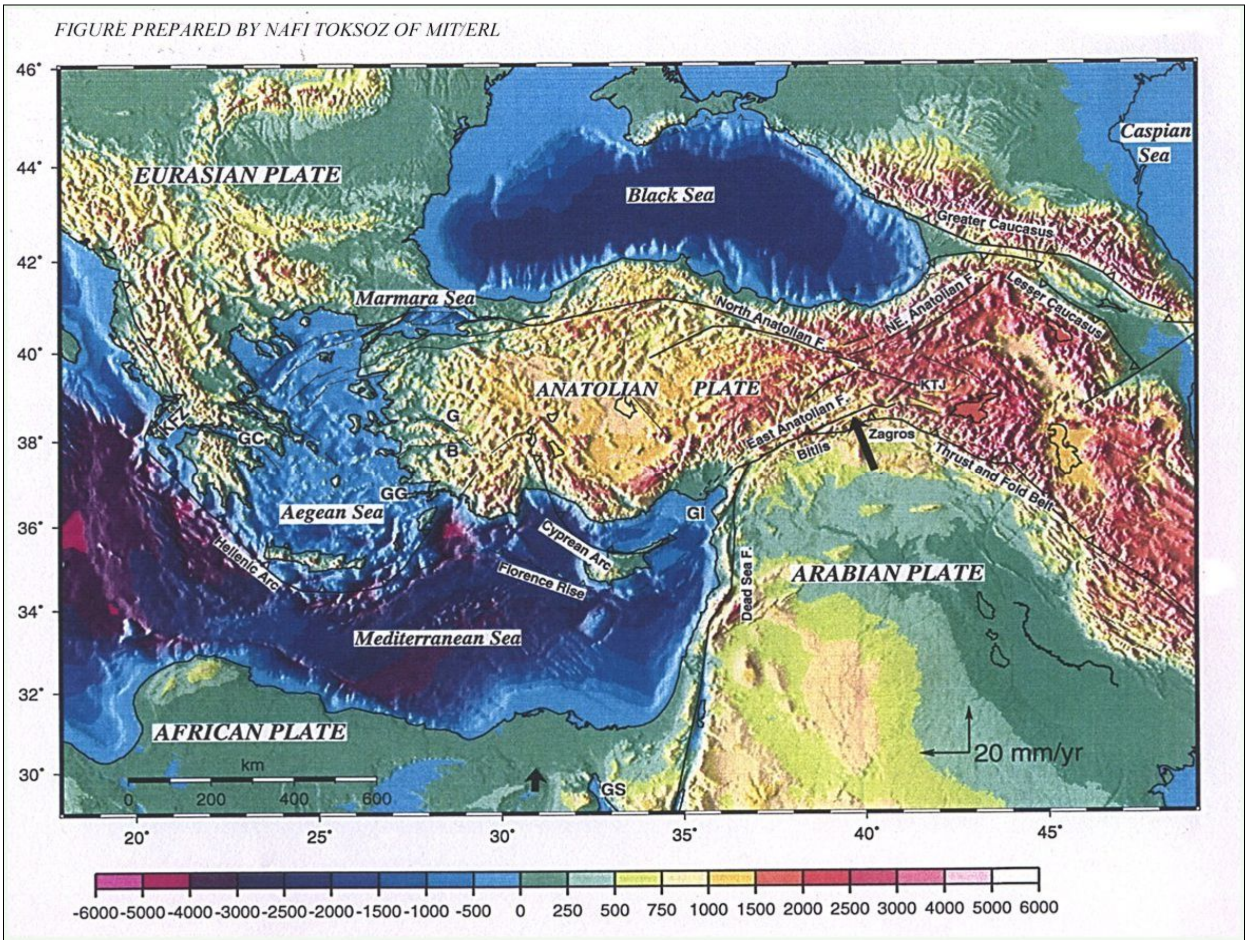


Figure 3: *The faults and tectonic structures of Turkey; (Institut faste jords fysikk (www.ifjf.uib.no)*

Turkey's terrain is structurally complex. A central massif composed of uplifted blocks and down folded troughs, covered by recent deposits and giving the appearance of a plateau with rough terrain, is wedged between two folded mountain ranges that converge in the east. True lowland is confined to the Ergene Plain in Thrace, extending along rivers that discharge into the Aegean Sea or the Sea of Marmara, and to a few narrow coastal strips along the Black Sea and Mediterranean Sea coasts. Nearly 85% of the land is placed at an elevation of at least 450m; the median altitude of the country is 1,128m. In Asiatic Turkey, flat or gently sloping land is rare and largely confined to the deltas of the Kizilirmak River, the coastal plains of Antalya and Adana, and the valley floors of the Gediz River and the Büyükmenderes River, and some interior high plains in Anatolia, mainly around Tuz Gölü (Salt Lake) and Konya Ovasi (Konya

Basin). Moderately sloping terrain is limited almost entirely outside Thrace to the hills of the Arabian Platform along the border with Syria.

More than 80% of the land surface is rough, broken, and mountainous, and therefore is of limited agricultural value. The terrain's ruggedness is accentuated in the eastern part of the country, where the two mountain ranges converge into a lofty region with a median elevation of more than 1,500 meters, which reaches its highest point along the borders with Armenia, Azerbaijan, and Iran.

1.3.3 Terrain:

Turkey’s terrain has got a true mosaic in terms of geology and geomorphology formed by many essential events. The country possesses all types of geological formations of variations eras. The topography is varied, having high elevations and high mountains. There are high mountain ranges in the north and south. These mountains generally extend parallel to the coast. The North Anatolian Mountains span the Black Sea Region and the Taurus Mountains in the south determine Turkey’s high elevation. The highest point of the North Anatolian Mountains is the Kackar Peak. Ilgaz and Köroglu mountains are the second and third in height. The Samanli Mountains, Uludag, Istranca Mountains and Tekirdag are located at the Marmara Region; the Kozak, Yunt and Aydin mountains in the Aegean Region; Mount Kizildag, Mount Hasan, and the Idris, Elma and Ayas mountains are located in the Central Anatolia Region; and the Karacdag, Raman and Sof mountains are located in the South-eastern Anatolian Region. The 5.137 m high Agri Mountaing (Mount Ararat), is Turkey’s highest mountain and is situated near the point where the boundaries of the four countries meet. Mount Süphan, which is a dormant volcanic mountain near Ararat, is located in the Eastern Anatolian Region beside Nemrut and Alacadag.

These mountains in Turkey cover an extensive landscape, but there are also many plains, plateaus and depressions. The large plains in the central part of Anatolia separate the mountain ranges to the north and to the south. The arable plains, suitable for agriculture and farming, are the Bafra, Carsamba and Merzifon plains in the Black Sea Region, the Konya Plain in the Central Anatolian Region; the Bakicay, Gediz, Büyük Menderes and Kücük Menderes plains in the Aegean Region; the Cukurova Plain in the Mediterranean Region; and the Mus Plain in the Southeast Anatolian Region.

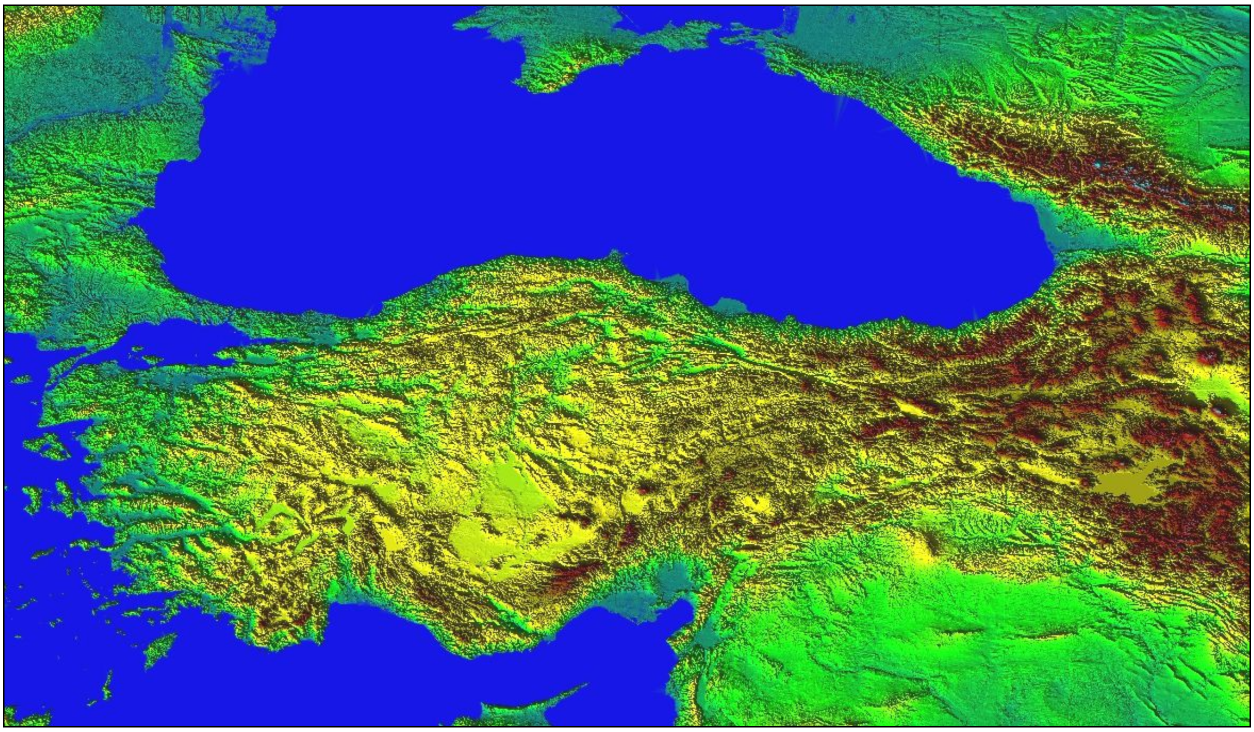
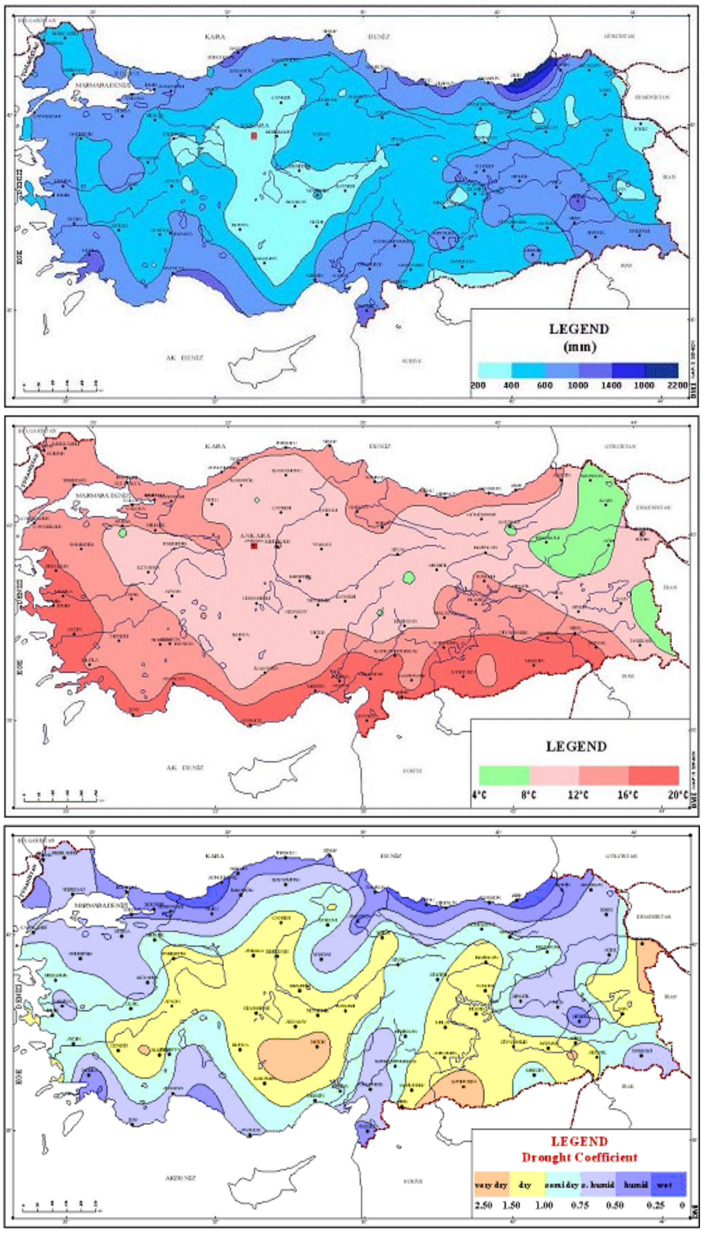


Figure 4: *Digital terrain model (DTM) of Turkey, derived from the global terrain model*

1.3.4 Climate:

Turkey, located in a moderate climate belt, has got four seasons. There are different climate regimes in Turkey, because the mountains are parallel to the coast. The 4 criteria of climatic change can be used perfectly to describe Turkey's climates: North to south, west to east, central to periphery, and low altitude to high mountains. The coastal regions have a moderate maritime climate, while the central regions, surrounded by mountains, have a continental climate. The Mediterranean region expires hot and arid summers, while in the winter it is mild and rainy. Turkey is big enough to have different climates for each region.



The country can be divided into seven climatic similar regions. The Aegean and Mediterranean coasts have cool, rainy winters and hot summers with humidity above the average, almost no snow and sometimes frost on cold winter nights. In Istanbul, the Marmara and Thrace you can expect snow from December to February. It snows a year no more than three or four times in Istanbul. In addition, if it does snow, it will melt away the next day with the shining sun. Annual precipitation in those areas varies from 580 to 1,300 millimetres, depending on regional effects. Generally, rainfall is less to the east.

The Black Sea coast receives the most amount of rainfall within all the regions. It even rains in summer times in high mountains. The eastern part of that coast averages 1,400 millimetres of rain annually and is the only region of Turkey that receives rainfall throughout the year.

Figure 5: *Climatic maps of Turkey, the upper map shows the annual precipitation, the middle one the average temperature and the map down shows the computed Drough Coefficient according the Aydeniz Formula. (all data from www.meteor.gov.tr)*

The Eastern part of Turkey is hot and dry in the summer. Winters are fiercely cold with frequent, heavy snowfall. On some days, people cannot get out of their homes for several days under heavy snowstorms until the rescue teams arrive. Temperatures may go down to -30º C or -40º C and snow may stay up to 120 days on mountainous areas. Spring and autumn are mild, but sudden changes in temperatures can occur.

The Southeastern Anatolia is the driest region. It has a similar climate to the eastern part of Turkey but it is hotter and extremely dry. Central Anatolia and Cappadocia can be bitterly cold in winter, but it is not as cold as the Eastern part of Turkey. In summers, the weather is clear and warm and in spring and autumn, it is mild. The Konya Plateau is the driest region. The average temperature of the capital city, Ankara, is 0 degrees in January and 23 degrees in July. The capital city averages 350 mm of precipitation annually.

The climate of course varies according to local effects like mountains, plains, orientation of the valleys and the hydrological situation of the geology (cast-caves), lakes, rivers and the vegetation on the soil as well.

1.3.5 Hydrology:

Because of the mountainous structure of Turkey, there are many rivers and lakes. These rivers flow into the seas, which surround Turkey, and some reach other seas after leaving Turkey's borders. There are long rivers like the Euphrates, Tigris, Kura, Aras and Coruh, which originate in Turkey, but flow into the seas in neighbouring countries. A large number of rivers are used to generate energy and provide irrigation and drinking water. The two major rivers are the Firat (Euphrates) and the Dicle (Tigris), which provide fresh water to Turkey as well as many of the countries of the Middle East. On the Euphrates River, the Atatürk Dam, the Keban Dam, and the Karakaya Dam have a capacity of over 21,500 of megawatts of hydroelectric power. 11% of Turkey's total area consists of lakes (9.423 km²) and wetlands. The lakes around the Marmara Sea are the Sapanca, Iznik, Ulubat, Manyas, Terkos, Kücük Cekmece and Büyük Cekmece lakes. Central Anatolia's lakes are shallow and very salty.

1.3.6 Geographical Regions and Provinces

Figure 6: *The Landscape-Regions of Turkey (www.state.gov.tr)*

At the conclusion of the first Geography Congress, which convened in Ankara in 1941, Turkey was defined by seven geographical regions. These regions represent the physical structure of the country, mostly defined by the geomorphologic and geological basement, to be seen by the topography and finalised by the climatic diversification.

The Black Sea, the Marmara, the Aegean, and the Mediterranean Region, are named after their seaside. The Central, East and Southeast Anatolian Regions were named in accordance with their geographical location in Anatolia. The borders of the geographical regions in Turkey are not in close conformity with the provincial borders.

The 1982 constitution retains Turkey's centralized administrative system. Each province is administered by a governor appointed by the Council of Ministers with the approval of the president. The governors function as the principal agents of the central government and report to the Ministry of Interior. The constitution grants governors extraordinary powers during a state of emergency, powers similar to those of military authorities in areas under martial law. The constitution also stipulates that the central administration oversee elected local councils in order to ensure the effective provision of local services and to safeguard the public interest. The minister of interior is empowered to remove from office local administrators who are being investigated or prosecuted for offences related to their duties.

Figure 7: *The Administrative Districts of Turkey (http://f5apm.free.fr)*

Early in 1995, Turkey was divided into seventy-six provinces. Each province was further subdivided into an average of about eight districts. Each district was segmented into an average of 493 sub districts. Each provincial capital, each district seat, and each town of more than 2,000 people is organized as a municipality headed by an elected mayor. Government at the provincial level is responsible for implementing national programs for health and social assistance, public works, culture and education, agriculture and animal husbandry, and economic and commercial matters.

As chief executive of the province and principal agent of the central government, each governor supervises other government officials assigned to carry out ministerial functions in his or her province. Civil servants head offices of the national government that deal with education, finance, health, and agriculture at the provincial level. In each province, these directors form the provincial administrative council, which, with the governor as chair, makes key administrative decisions and, when necessary, initiates disciplinary actions against errant provincial employees.

1.3.7 Land-Use

Turkey's land surface totals 78 million hectares, of which 48 million hectares were used for agriculture in 1991. There were 24.2 million hectares in field crops, of which 5.2 million lay fallow. Another 3.7 million hectares were in use as vineyards, orchards, and olive groves, and 20.2 million hectares were covered by forests and other woodlands. Other land areas counted for about 29 million hectares; included in this was land classified as lakes, marshes, wasteland, and built-up areas. Another category included 9 million hectares of pastureland.

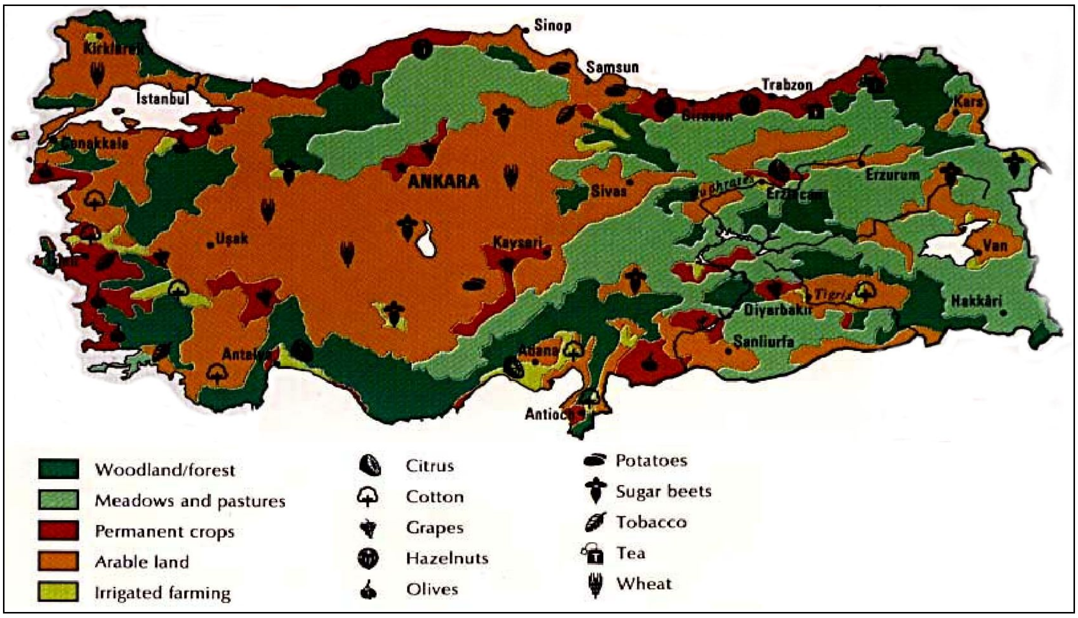


Figure 8: *Land-Use map of Turkey, modified from "atlas of the middle east" (www.lib.utexas.edu)*

During the 20th century, population pressure resulted in the expansion of farmland. The cultivated area increased from about 8 million hectares in the 1920s to nearly 19 million hectares in 1952 and to almost 28 million hectares by 1991. Using Marshall Plan credits that first became available in 1948, Turkey began to import large numbers of tractors, which made it feasible to expand cultivation of marginal lands, especially on the Anatolian Plateau. Although total production grew rapidly, average yields did not. In 1970, nearly all arable land was under cultivation.

Cultivation increased primarily at the expense of meadows and grasslands, which diminished from about 46 million hectares in the mid-1920s to about 14 million hectares in the mid-1980s. Although cultivation of the larger area made greater agricultural production possible in the short term, it created long-term problems for livestock production. It also resulted in the destruction of tree cover and the ploughing of marginal fields that were too steep and that received barely sufficient rainfall even in normal years. By the early 1960s, government agents were encouraging farmers to practice contour ploughing and to take other measures to minimize erosion, but to little effect. By the late 1970s, more than half the country's land was judged to have serious erosion problems, and some plains regions were experiencing dust-bowl conditions. All of Turkey was affected, with the mountainous eastern provinces hit hardest. Some areas lost all topsoil and could only support few plants.

In the 1970s, the government conducted land-use studies and found that more than one-fifth of the land should have been used differently to achieve optimum long-term production. Misuse was greatest in rain-fed cropped fields, but some grazing land and wasteland were found better suited to other uses such as cropping and forestry. Turkey's unusually high proportion of fallow land also limited production; in 1981 the government began encouraging double cropping and the planting of feed crops on fallow fields. The government was also considering a broad land-use policy. However, reform proved difficult because of government inefficiency and the lack of alternative crops in areas cut off from markets, where farmers had little choice but to use their land to grow grain to feed their families. Expansion of the road network, irrigation facilities, and extension services continued to offer hope for eventual improvements in land use.

1.3.8 Agriculture

Turkey consists of 30% arable land, 4% with permanent crops, 12% meadows and pastures, 26% forests and woodlands and 28% for other uses. Agriculture, the major occupation in Turkey, continued to be a crucial sector of the economy in the mid 1990ies, although industrial production was already increasing at this time. Turkey's fertile soil makes the country self-sufficient in terms of food. Turkey's variety of microclimates and adequate rainfall allow the growing of a broad range of crops. Farming is conducted throughout the country, although it is less common in the mountainous eastern regions, where animal husbandry is the principal activity. In the mid-1990ies, crop cultivation accounted for about two-thirds and livestock for one-third of the gross value of agricultural production.

The overall income deriving from agriculture fell from 50 % in 1950 to around 15 % in 1993. During the same period, the sector grew only about 1 % faster than the country's population, and per capita food production declined in absolute terms. The relatively poor showing of the agricultural sector reflected in part government policies that had made rapid industrialization a national priority since the 1930ies. In addition, farmers were slow to adopt modern techniques, with agricultural output suffering from insufficient mechanisation, limited use of fertilizer, excessive fallow land, and unexploited water resources. The result has been low yields.

Despite the relative decline in agricultural activities in the 1980ies, the sector played an important role in foreign trade. Turkey is competitive in many agricultural products. The main export markets are the European Union, the United States and the Middle East, importing primarily fresh fruit, vegetables, and meat. At the end of the 1980ies, agricultural exports accounted for nearly 60 % of the total value of exports, in the early 1990ies just 15 %.

Since 1980, the government has been encouraging investments in packaging, processing, livestock, and slaughterhouses, as well as imported new seed varieties. These efforts had caused a modest impact on overall production by the mid-1990ies.

The failure to exploit the country's great agricultural potential has contributed to Turkey's periodic economic crises and poses serious problems for future development. Glaring inequalities of income between urban and rural residents, and among segments of the farm population, have created social tensions and contributed to emigration from rural to urban areas. Malnutrition continues to threaten segments of the rural population, especially children. The Kurdish insurgency in eastern Turkey has added to problems in some rural areas. Rising incomes in the urban areas have caused increased demand for more "exotic" foodstuffs, especially meat and poultry. Since 1984, Turkey has liberalized its policy on food imports, partly to meet this urban demand and partly to offset domestic price pressure. Many previously banned luxury food imports and imports that compete with domestically produced staples are permitted for these reasons; in turn, the growth of these imports has contributed to pressures on foreign trade accounts. Overall, agricultural output needs to increase along with the rest of the economy to maintain adequate supplies for industry and exports. Longer-term economic growth prospects and macroeconomic stability, therefore, depend on the performance of Turkey's agricultural sector and rural incomes.

Getting enough water to crops is a major problem for many farmers. The bulk of the agricultural land is on the Anatolian Plateau, which receives less rainfall. Although rainfall on the plateau varies considerably among its regions, on average, it is barely adequate over large areas. In addition, the amount and period of rains vary sharply from year to year, causing sharp fluctuations in harvests. Since World War II, officials have stressed irrigation as a means of increasing and stabilizing farm output, and irrigation projects have consumed more than half of public investment in agriculture.

In the mid-1980s, private irrigation reached up to 1 million hectares. Development of large-scale irrigation had been delayed until the 1960s. Public-sector irrigation systems, built and operated by the General Directorate of State Hydraulic Works tend to be large and costly. Most of them provide water for entire valleys, and some large projects combine with water supplies for urban areas, protection from flooding, hydroelectric power, and irrigation. Irrigation projects are dispersed throughout the country, but the majority is concentrated in the coastal regions of the

Aegean and Mediterranean seas, where the longer growing seasons are particularly favourable to crops. Water provided by public irrigation water was available to 3.7 million hectares in the mid-1990s, although the area irrigated with public water totalled about 3 million hectares.

Animal husbandry plays an important role. Livestock products contributed more than 33% of the agricultural output in the mid-1990s. Despite growing demand for animal products in Turkey's cities as incomes rose, the number of livestock stagnated in the 1980ies and fell in the early 1990ies. Although yields were growing, traditional methods kept the livestock industry from achieving its considerable potential. The oil boom in the Persian Gulf, however, led to an expansion of export markets and to major investments in the meat industry of the eastern Turkish towns of Erzurum and Van. In 1992, meat exports totalled 140 million USD; exports, however, were being hurt by the UN embargo on Iraq. Wool is also a significant export.

Many farms are too small to support a family and too fragmented for efficient cultivation. Tenancy arrangements foster neither long-term soil productivity nor the welfare of tenants. In many areas, the rural poor are becoming poorer while land better suited for grazing continues to be converted to grain fields. At the same time, many large landholdings have been turned into productive modern farms that contribute to the country's improved agricultural performance. Major irrigation projects in the Euphrates River Valley and elsewhere offer the prospect of increasing the supply of productive land. The declining population growth rate has reduced the pressure for land reform, and industrialization offers an alternative for landless farm workers, who prefer city life to that of rural areas.

1.3.9 Forestry

Although a big part of Turkey's area is forested, lumbering is not important because most of the trees have no commercial value. The trees are primarily cut for fuel. Therefore, forestry contributes little to the economy, but it holds potential for future development. In the early 1990s, Turkey's forests covered an estimated 20.2 million hectares (26%). Official statistics indicate that forests have doubled in size since 1950; that does not reflect actual growth but continuing survey efforts and the inclusion of less productive wooded areas under the forestry administration. The most productive lumber area is the Black Sea region, followed by central, western, and southern Anatolia, where mostly pinewood is produced. The forests in the eastern part of the country are in poor condition and yield little besides firewood. Many forests are over mature because of poor management and infrequent cutting, and thus only about 20% of the total forested area is commercially exploitable.

By the mid-1950ies, the state had taken over all forest areas from private owners. Compensation was largely in the form of access to fuel wood at low prices. The one-third of the rural population that lives in or near forests includes many of the country's poorest families. The bulk of their income comes from farming; forest products provide supplemental income and fuel. The main objective of forest management is control of traditional logging and grazing rights; the lack of alternative fuel supplies makes it impossible to stop illegal wood harvests in state forests.

The General Directorate of Forestry in the Ministry of Forestry has assumed responsibility for logging and reforestation operations and for reducing erosion. Whereas wood production has been substantially below potential, partly because of a lack of equipment and roads, reforestation efforts increased Turkey's wooded area by about 2% between 1977 and 1981. During the early 1980ies, annual wood production averaged 5.2 million m^3 of lumber. By 1991, production had risen to about 6.5 million m^3.

Another important industry in Turkey is raising livestock. The grasses of the high plateau provide food for cattle, sheep and goats. Turkey is a major producer of mohair.

1.3.10 Fishery

Since Turkey is surrounded by water on many sides, fishing is a major industry. Most of the fish come from the Black and the Mediterranean Seas. Despite the country's long coastline and large freshwater bodies, fishing is an underdeveloped industry. The tonnage of the fishing fleet has increased, but in the early 1990ies, it still included about 7,000 traditional boats, some 1,500 of which without motorization. The annual catch rose from around 430,000 tons in 1981 to about 625,200 tons in 1988, but declined to about 365,000 tons in 1991. Frogs' legs, snails, shrimp, and crayfish are exported to Europe.

1.3.11 Population

Turkey’s population counts 68,893,918 inhabitants (July 2004). Turkey's first census of the republican era was taken in 1927 and counted a total population of about 13.6 million. Less than seventy years later, the country's population had more than quadrupled. Between 1927 and 1945, growth was slow; in certain years during the 1930s, the population actually declined. Significant growth occurred between 1945 and 1980, when the population increased almost 2.5 times. Although the rate of growth has been slowing gradually since 1980, Turkey's average annual population increase is relatively high in comparison to that of European countries. Turkey's population at the end of 1994 was estimated at 61.2 million. This number represented an 8.4 % increase over the 56.5 million enumerated in the census, conducted in October 1990. The State Institute of Statistics (SIS) has estimated that since 1990 the country's population has been growing at an average annual rate of 2.1 %, a decrease from the 2.5 % average annual rate recorded during the 1980s. Turkey's population in 1985 was about 50.7 million, and in 1980 about 44.7 million. In the 14 years from 1980 to 1994, the population increased nearly 37 %.

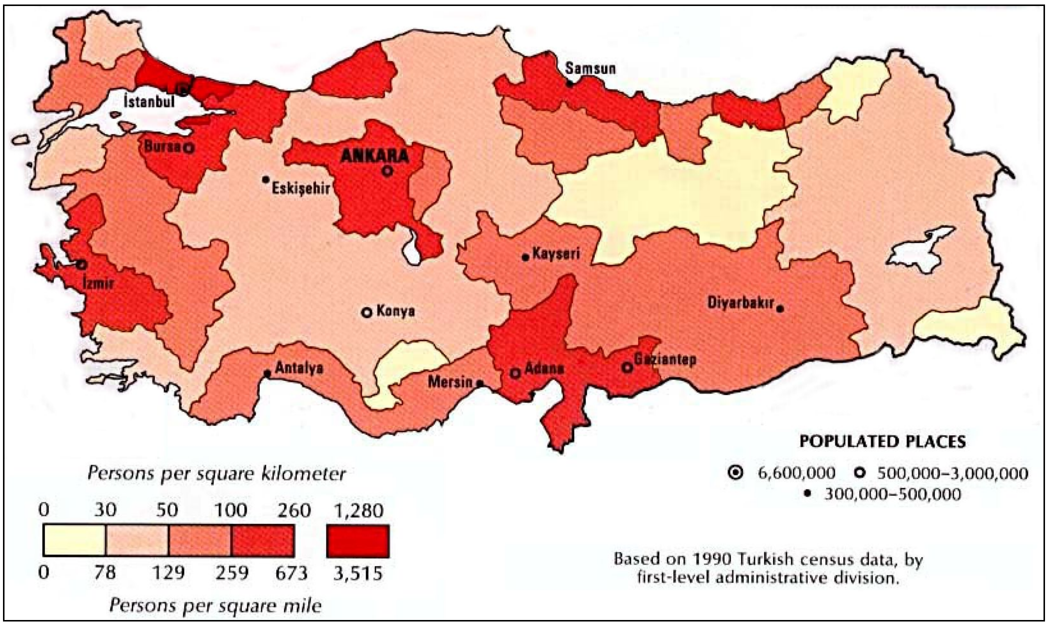


Figure 9: *Population-Density of Turkey, modified from “atlas of the middle east (www.lib.utexas.edu)*

According to the 2000 census, the population of Turkey amounted to 67.844 million. While the annual population increase was 2.49 % in the period 1980-85 and 2.17% in the period 1985-90, this value dropped to 1.83 % in the 1990-2000 period. This value is expected to drop further to 1.45 % in the period 2000-2005. About 50.5% of the population was male, and 49.5 % female. The average life expectancy for females of 72 years was greater than the corresponding figure for men of 68 years. The birth rate was 2.8 %; the death rate was 0.6%.

Population density has increased along with the rapid growth rate. Turkey had an average of only 27 inhabitants per km² in 1950; this has nearly tripled to 72.5 people per km² by 1990. Population density was estimated at 78.5 people per km² at the end of 1994. According to the 1990 census, the most densely populated provinces are Istanbul with 1,330 persons per km²; Kocaeli with 260, and Izmir with 220. The most lightly populated provinces are Tunceli and Karaman, with 17 and 24 persons per km². Turkey's overall population density was less than 1/2 the densities in major EU countries such as Britain, Germany, and Italy.

Since the 1960s, Turkey has been considered to be among the countries, which register the greatest progress in urbanisation. In 1990, about 50% of the population was classified as rural. This represents a decline of more than 30% since 1950, when the rural population accounted for 82 % of the country's total. In 1990, the rural population lived in more than 36,000 villages, most of which had fewer than 1,000 inhabitants.

The 2000 census indicated that 44 million people live in provinces and administrative centres, and 23.7 million in districts and villages. In the 1975 census, it was noted that 58 % of the population resided in rural areas and 42 % in cities. By 1995, more than 65 % of Turkey's population lived in cities with 10,000 or more inhabitants. The urban population has been growing at a rapid rate since 1950, when it accounted for only 18 % of Turkey's total. The main factor in the city’s growth was the steady migration of villagers to urban areas, a process that was continuing in the 1990s. The trend toward urbanization was revealed in the 1990 census, which enumerated more than 17.6 million people, that is more than 30 % of the total population, as living in 19 cities with populations then of more than 200,000. In 2000 census, the number of people living in cities had increased to a total on 64 % and remaining 36 % in the rural areas.

Out of the 81 provinces in the country, the 3 most densely populated are Istanbul with an population of (officially) 10 million, Ankara with a population of (officially) 4 million, and Izmir with a population of 3.4 million.

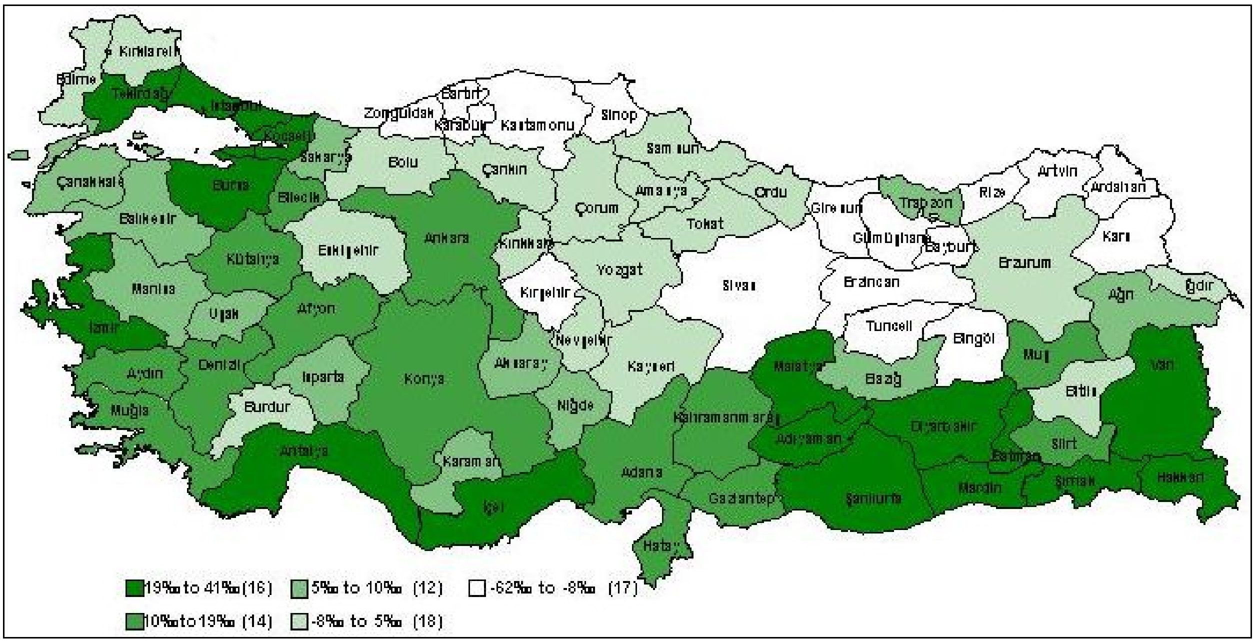
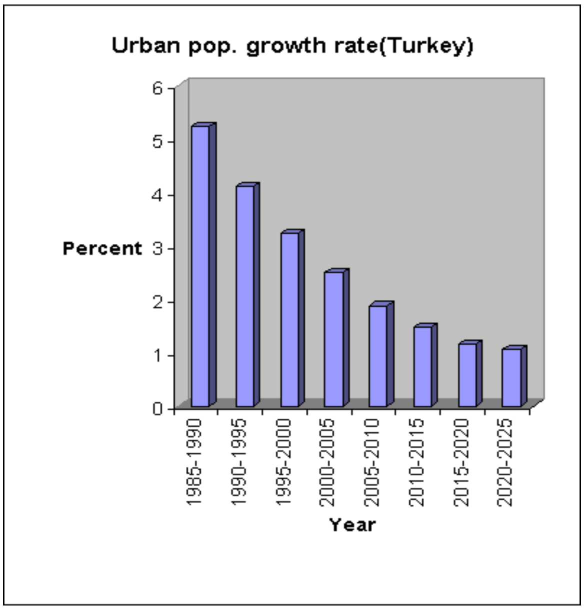


Figure 10: *Annual Population Growth-Rate of Turkey’s cities, modified after:(www.culture.gov.tr)*

Although overall population density is low, some regions of Turkey, especially Thrace, the Aegean and Black Sea coasts, are densely populated. The uneven population distribution is most obvious in the coastal area stretching from Zonguldak westward to Istanbul, then around the Sea of Marmara and south along the Aegean coast to Izmir. Although this area includes less than 25 % of Turkey's total land, more than 45 % of the total population lived there in 1990. In contrast, the Anatolian Plateau and mountainous east account for 62 % of the total land, but only 40 % of the population resided there in 1990. The remaining 15 % of the population lived along the southern Mediterranean coast, which makes up 13 % of Turkey's territory. The three provinces counting the greatest increase in population growth rate are Antalya, with a 4.18 % increase, Sanliufa, with 3.66 % increase, and Istanbul with 3.31 % increase. Tunceli has the lowest population growth rate among the provinces with a decrease of 3.56 %. These changes in the regional distribution of the population in Turkey resulted from migration from the eastern and northern regions to the western and southern metropolices.



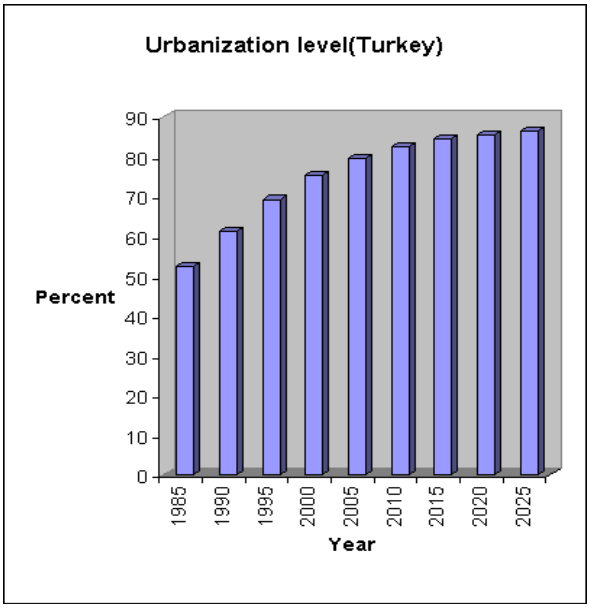


Figure 11: *Trend-analyses on the census data: (www.unhabitat.org)*

Turkey is a country with a young population. The 0-14 age group represents 30 % of Turkey's population, the 15-64 age group 64.4 %, and the 65 + age group 5.6 % of the population. Compared with the European Union, the 0-14 age group in EU countries with 17.2 % is approximately half of that of Turkey. Conversely, the 65 + age group in EU countries with 15.7 % is almost three-times of that in Turkey

Turkey's population rate has been influenced by the fact that Anatolia has been a transit route throughout history. Numerous civilisations were established in Anatolia at different time-periods. Such a blend of cultures inherited by the Republic of Turkey contributes to a sense of unity.

About 80% of the people in Turkey are Turkish. 19% are Kurdish and the other 1% are mainly Arabs, Greeks and Americans. About 98% of the people in Turkey are Muslims. The other 2% are mostly Catholic, Jewish, and other Christians.

1.3.12 Migration

During 1915-1925, the country experienced large population transfers by substantial movement outward of minority groups and an influx of refugees and immigrants. The first major population shift began in 1915, when the Ottoman government, for a variety of complex and in some instances contradictory reasons, decided to deport an estimated 2 million Armenians in eastern Anatolia. The movement of Greeks out of Turkey, which began during the 1912-13 Balkan Wars, climaxed in the 1920s with an internationally sanctioned exchange of population between Turkey and the Balkan states, primarily. In accordance with the 1923 Treaty of Lausanne, Turkey accepted approximately 500,000 Muslims, who were forced to leave their homes in the Balkans, in exchange for nearly 2 million Greeks, who were forced to leave Anatolia. By special arrangement, Greeks living in Istanbul and Turks living in the Greek part of Thrace were exempted from the compulsory exchanges.

After 1925 Turkey continued to accept Muslims speaking Turk languages as immigrants and did not discourage the emigration of members of non-Turk minorities. More than 90 % of all immigrants arrived from the Balkan countries. Between 1935 and 1940, approximately 124.000 Bulgarians and Romanians of Turkish origin immigrated to Turkey. Between 1954 and 1956, about 35,000 Muslim Slavs immigrated from Yugoslavia. In the 55-year period ending in 1980, Turkey admitted approximately 1.3 million immigrants; 36 % came from Bulgaria, 30 % from Greece, 22.1 % from Yugoslavia, and 8.9 % from Romania. These Balkan immigrants, as well as smaller numbers of Turkic immigrants from Cyprus and the Soviet Union, were granted full citizenship upon their arrival in Turkey. The immigrants were settled primarily in the Marmara and Aegean regions (78 %) and in central Anatolia (11.7 %).

The most recent immigration influx was that of Bulgarian Turks and Bosnian Muslims. In 1989 an estimated 320,000 Bulgarian Turks fled to Turkey to escape a campaign of forced assimilation. Following the collapse of Bulgaria's communist government that same year, the number of Bulgarian Turks seeking refuge in Turkey declined to under 1,000 per month. In fact, the number of Bulgarian Turks who voluntarily repatriated (125,000) exceeded new arrivals. By March 1994, 245,000 Bulgarian Turks had been granted Turkish citizenship. However, Turkey no longer regards Bulgarian Turks as refugees. Beginning in 1994, new entrants to Turkey have been detained and deported. As of December 1994, an estimated 20,000 Bosnians were living in Turkey, mostly in the Istanbul area. About 2,600 were living in camps, the rest was dispersed in private residences.

In 1994 the government claimed that as many as 2 million Iranians were living in Turkey, a figure that most international organizations consider to be grossly exaggerated. Turkey is one of the few countries that Iranians may enter without first obtaining a visa; authorities believe that the relative ease of travel from Iran to Turkey encourages many Iranians to visit Turkey as tourists, or to use Turkey as a way station to obtain visas for the countries of Europe and North America. Consequently, as many as 2 million Iranians may transit Turkey per year. Specialized agencies of the European Union and the United Nations that deal with issues of migrants and refugees believe that the number of Iranians who live in Turkey, and do not have a residence in Iran or elsewhere, is close to 50,000.

In the 1960s, working-age Turks, primarily men, began migrating to Western Europe to find employment as guest workers. Many of these Turkish workers eventually brought their families to Europe. An estimated 2 million Turkish workers and their dependents resided in Western Europe in the early 1980s, before the onset of an economic recession that led to severe job losses. Germany initiated the program of accepting Turkish guest workers. In the 1990s, Germany adopted a policy of economic incentives to encourage the voluntary repatriation of Turkish workers. At the end of 1994, an estimated 1.1 million Turks continued to reside in Western Europe as semi permanent foreigners. About two-thirds of these Turkish migrants lived in Germany, and another 10 % in France. Other European countries with sizable Turkish communities included Austria, Belgium, the Netherlands, Sweden, and Switzerland. In addition, at least 150,000 Turks were working in Saudi Arabia and other Arab oil-exporting countries of the Persian Gulf.

1.3.13 Language

Turkish is the language of 90% of the population of Turkey. The Caucasian and Kurdish dialects, Greek, Ladino and Armenian are among the other 70 languages and dialects spoken in the country. The Turkish spoken Turkey is an agglutinative language. It is the modern form of the Ottoman Turkish, which, until the beginning of the 20th century, had borrowed many words from Arabia and Persia. Modern Turkish, along with the Turkish spoken Azerbaijan and Turkoman Turkish, is derived from the Oghuz dialect, which has been spoken since the 11th century.

The communities, which speak Ural-Altaic tongues, are spread from Central Asia towards the east and northwest and especially to the west. After the adoption of Islam, the influence of Arabic and Persian on the Turkish language was quite significant. Turkish is the seventh most spoken language in the world today. More than 200 million people speak Turkish. The Turks, who used many written languages from the 8th century up until today, mostly used the Göktürk, Uigur, Arabic and Latin alphabets. Mustafa Kemal Atatürk believed that it was necessary to benefit from western culture in order to attain a contemporary level of civilisation in modern Turkey. 1928 he adopted the Latin alphabet that was prepared according to the vocal harmony of the Turkish alphabet rather than the Arabic one.

The second major step in the Language Reform was the founding of the Turkish Language Research association in 1932. The work of the Association produced positive results by deleting Arabic and Persian words. Today, the Turkish Linguistic Society continues these activities with a reactivated statute within the structure of the Atatürk Cultural, Linguistic and Historical Supreme Council, established in 1983. The most important result of the constructive studies related to the Turkish language is the fact, that the ratio of use of Turkish words in the written language, which was 30-40 % before 1932, is now 75-80%. This fact is the most important proof that the people, whom it has made for, have embraced the Language Reform.

1.3.14 Transportation

Turkey has an extensive transportation system of railroads, highways, and airlines. There are over 8,671 km of railroad tracks, which are run by the Republic State Railways. 2,122 km of them are electrified; the others are of standard gauge.

There are over 385,960 km of roads, of these are paved 131,226 km including 1,749 km of motorways. The other 254,734 km (1999) are unpaved. In 1996, for every 1000 residents, there were 55 automobiles. Busses still offer a convenient means of transportation for many people travelling across the country.

Navigable waterways count 1,200 km (2003), pipelines for gas 3,177 km, such for oil 3,562 km (2003). 87 of the 120 Airports have paved runways. 16 of them have a runway with a length of more than 3 km length, suitable for international flights. The Turkish Airlines offers domestic and foreign services.

Coastal shipping allows connections between major and minor seaports of Turkey. Nine are big industrialised ports; Istanbul and Izmir are the leading ones. Ships provide a means of transportation for people as well as for transporting goods.

1.3.15 Industrialisation

Turkish modernizers have built an industrial system that helped to restore the country's economic power. Until 1980, the result was a striking unfolding of industry. Between 1950 and 1977, it grew at an annual average rate of 8.6 %, expanding its share of GDP from 12 % to 25 %. Despite the retrenchment of the early 1980s, the recovery of the industrial sector, with an annual growth rate of 5.9 % between 1987 and 1992, restored the sector to its pre-1980 proportion of more than 23 % of GDP in 1993. By the early 1990s, the only individual industries accounting for more than 5 % of industrial output were food-processing, petroleum, textiles, iron and steel.

The country's first factories processed food, such as sugar and flour, and nondurables like textiles and footwear. Next came intermediate industrial products, including iron and steel, chemicals, cement, and fertilizer. By the end of the 1970s, the country was developing capital goods industries and high-technology products.

The rapid industrialization minimized the attention given to efficiency, and excessive protection forestalled competition that would have promoted efficiency; selling in the protected home market was much more attractive than attempting to export. Moreover, the rise of assembling industries, which assembled such products as motor vehicles, consumer durables, and electronic goods primarily using imported components, meant that industrial growth required ever more imports. The capital-intensive nature of many industrial investments caused employment in industry to grow relatively slowly, contributing to structural unemployment. Dependence on petroleum imported made the country vulnerable to increases in oil prices.

By the end of the 1970ies, industry had reached a turning point. In the short run, the sector needed to overcome shortages of energy, imported machinery, parts, and processing materials that had caused a decline in industrial output during the last years of the decade. In the end, to become more efficient and to enable increased exports, the industrial structure had to be adjusted in accordance with the country's comparative advantages. In effect, industry would have to transfer resources out of uncompetitive industries to favour those that could compete in world markets. The difficult adjustment process started in the early 1980s, and substantial progress was made. Under the new outward-oriented development strategy, industry was to be the leading sector of the economy.

Many of the problems of import substitution had not yet been overcome by the mid-1990s. Much progress had been made in spurring private-sector-led industrialization, particularly in light manufacturing and export promotion. Light manufactures and iron and steel accounted for an increasing proportion of exports. Moreover, foreign investment in the industrial sector had begun to have a positive impact. A great part of the industry was still dominated by the public sector in early 1995 and private-sector companies still depended on crucial inputs from public-sector industries.

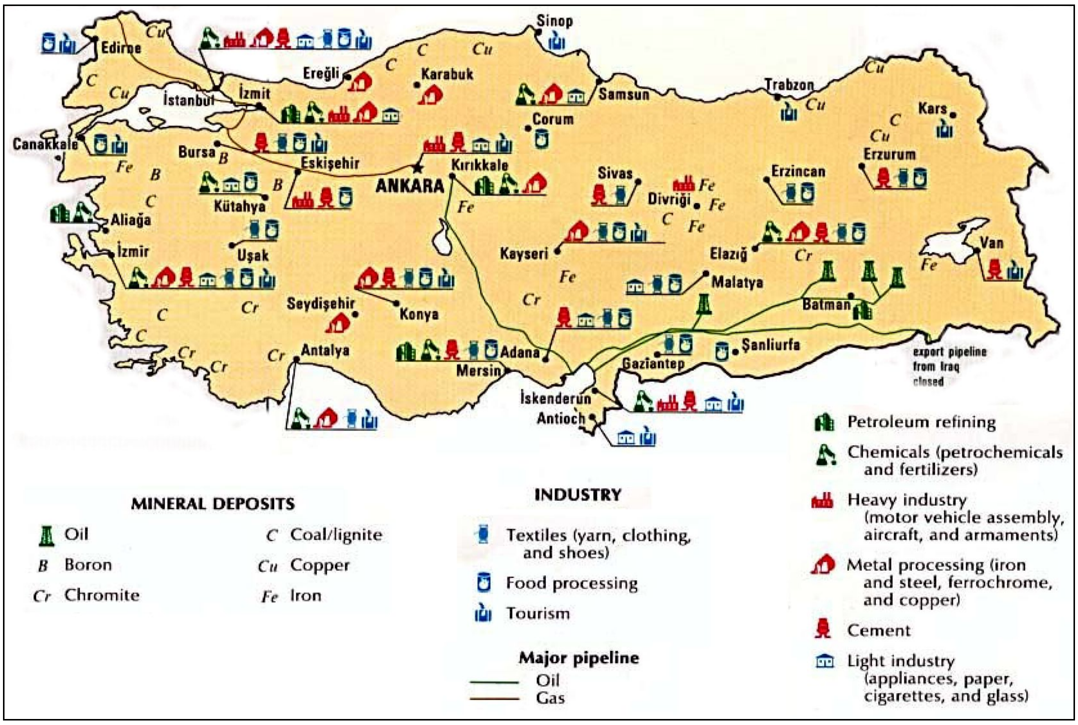


Figure 12: *Industrial places in Turkey, modified after the “atlas of the middle east (www.lib.utexas.edu)*

1.3.16 Energy

Turkey is endowed with energy and mineral resources. The mountainous terrain provides hydroelectric sites, most being far from the main population and consumption centres. The country has substantial exploitable lignite resources and small reserves of hard coal, petroleum, and natural gas. Commercially exploitable deposits of many minerals have been located, but the territory has been surveyed only partially. The demands of industrialization and urbanization nearly tripled energy consumption in the 1960s and 1970s. In 1960, more than half of the primary energy came from non-commercial sources, mainly firewood, but also manure and other agricultural wastes. These sources plus domestic coal and lignite, accounted for more than 80% of all primary energy; oil supplied only 18%. By 1980, oil supplied about 47% of the primary energy, coal, and lignite about 21%, hydroelectric power 8%, and non-commercial sources only 23%. By 1992, 43.5% of energy came from petroleum, 31.1% from lignite and hard coal, 4.1% from hydroelectric power, 6.9% from natural gas, and 14.4% from other energy sources, including solid fuels, geothermal, solar power, and wind power.

During the 1970s, the demand began to exceed, and by the late 1970s, the power gap began to constrain industry. After 1977 rotating blackouts affecting industrial, commercial, and residential consumers were necessary to meet demand. By 1979, the shortage of foreign exchange had restricted imports of crude oil that fuel for cars, trucks, and tractors had to be rationed. In the mid-1980s, the administration launched the build, operate, and transfer system, under which foreign investors provide the capital and technology to build plants, operate them for a number of years with guaranteed revenues, and finally transfer the units to the government after the investment has been fully returned. The Atatürk Dam was a major project designed to increase electricity output.

Although Turkey's energy resources remained underdeveloped in early 1995, the country had relatively good energy production potential. One estimate places the economically feasible hydroelectric potential at around 29,500 megawatts, which would allow annual production to reach roughly 100,000 gigawatt-hours. Lignite is the second most important potential source of energy, with proven and probable deposits put around 6.4 billion tons. However, Turkish lignite, containing high amounts of water and sulphur, is hard to burn and pollutes the air. Turkey's proven and estimated petroleum stocks are equivalent to about three years' consumption. Proven reserves are estimated at about 16 million tons, and enhanced oil-recovery techniques may allow extraction of another 30 million tons. Proven reserves of natural gas total about 12.4 billion m^3 and reserves of hard coal about 1 billion tons. Turkey's geothermal resources are considerable, but they have not yet been systematically explored.

Imports of petroleum averaged more than 15 million tons per year in the early 1980ies and increased to about 23 million tons in the early 1990ies. Most of Turkey's oil fields are located in southeastern Anatolia near the borders with Iran, Iraq, and Syria.

Several foreign concerns started exploration after a governmental liberalization package went into effect, but up to the mid-1990s, no major finds had been reported. By the early 1990ies, output had increased to nearly 4.4 million tons. Total Turkish production in 1993 of about 78,600 bpd met 17% of the country's 458,000-bpd needs.

Five refineries with a total capacity of about 713,000 bpd meet most of the country's need for petroleum products. Until early 1995, about 85% of refinery capacity was in public hands in four refineries.

Natural gas became important in the 1980s. Gas tapped in Thrace was piped to the Istanbul region and used to produce electricity, thereby reducing the need for energy imports from Bulgaria. In 1986, Turkey began the construction of a pipeline to carry Soviet natural gas from the Bulgarian border to Ankara; the line was completed in the late 1980ies. Since 1990 also natural gas from Algeria was purchased that helped to balance Turkey's large purchases from the Soviet Union.

Policy makers in the early 1970ies had targeted lignite as the most abundant domestic source of hydrocarbons, and production grew rapidly from 7.9 million tons for the 1970-75 period to more than 31 million tons in 1985. The great depth of the country’s deposits hampers coal production. Hard coal output fell from around 6.5 million tons in 1976 to about 3.8 million tons in 1983, and unit costs exceeded those of coal imports. Therefore, Turkey began to import coal for use in power plants. In 1992, Turkey produced about 12 million tons of coal and imported a net of about 4.2 million tons.

The Turkish Electricity Authority is responsible for most electric power production and its distribution. Upgrading of the national distribution grid began in the 1980s, and by 1985, about 70% of Turkey's villages were receiving electricity. By the mid-1990s, no village was without electricity. Demand for electricity increased rapidly because of industrial growth. By 1985, thermal plants produced 53% and hydroelectric plants produced the rest. In the early 1980s, shortages of electricity had to be covered with imports from Bulgaria and the Soviet Union.

Sources for generating electricity varied. By 1992, electricity generated by coal accounted for 36% of total installed capacity, with hydroelectric plants 40%. The rest was generated by using petroleum products.

In 1994, the General Directorate of State Hydraulic Works was building or planning to build about 300 hydroelectric plants. The hydroelectric program, the Southeast Anatolia Project, which includes dams on the Tigris and Euphrates rivers, increased Turkey's irrigable land about 25% and its electricity-generating capacity about 45%.

Industry is the major consumer of energy and industrial consumption is expected to grow. The most energy-intensive sectors of industry probably could reduce demand significantly if required to do so. However, the government needs to audit major energy users to discover which could cut back consumption. A shift in relative energy prices to reflect long-run costs might induce industrial restructuring that would consider Turkey’s energy endowment. Moreover, energy policy makers need to improve management of firewood and agricultural wastes, which continue to play an important role in the rural energy economy.

1.3.17 Mining

Turkey's most important minerals are chromites, bauxite, and copper. The country also exploits deposits of other minerals such as iron, manganese, lead, zinc, antimony, asbestos, pyrites, sulphur, mercury, and manganese. Mining contributed slightly fewer than 2% of GDP in 1992, but the sub sector provides the raw material for such key manufacturing industries as iron and steel, aluminium, cement, and fertilizers. Turkey exports a variety of minerals; the most important are blister copper, chrome, and boron products. Minerals accounted for an average of about 2% of export earnings in the mid-1990ie. The public sector dominates mining, accounting for about 75 % of sales.

1.3.18 Manufacturing

Turkey's manufacturing industry is diverse and growing. Public-sector entities dominate manufacturing, accounting for about 40% of value added. A number of large conglomerates that have diversified across several industries dominate private-sector firms.

The manufacture of textiles is Turkey's largest industry, very competitive in international markets, and the most important foreign-exchange earner. Domestic cotton and wool provide much of the raw material, but synthetics production has also expanded. The textile sector contributed 20% of total manufacturing output and employed 33% of all workers in the mid-1990ies. Factories controlled by the country’s largest SEE, Sumerbank, and a number of private firms. Installed capacity is around 33% of that of the EU in terms of cotton spinning and around 11% of EU woollen yarn and textiles.

Textile exports grew rapidly after 1980; between 1987 - 1992 textile exports values expanded at an annual rate of 19%. By 1992, textiles accounted for 35% of total exports. Investment in increased capacity in the 1980ies resulted in increased exports of finished products and ready-made garments.

Agro processing is one of the most dynamic branches of Turkish industry, supplying both domestic and export markets. Main product lines are sugar, flour, processed meat and milk, and fruits and vegetables. Processed food exports grew at a rate of 8% per year between 1987 - 1992, and accounted for 9% of total exports.

SEEs are the most important producers of intermediate goods, although private firms are also active. The iron and steel sector became more competitive in Middle Eastern markets. Two-thirds of Turkey's steel is produced by three public sector steel mills, which remain subsidized. Private plants tend to use scrap as a raw material and to export to neighbouring countries.

Capacity use in the iron and steel sector increased rapidly in the 1980ies and early 1990ies. Total output of crude iron grew from about 3.1 million tons in 1985 to 4.5 million tons in 1992. Steel ingot output rose from about 7 million tons in 1987 to 10.3 million tons in 1992. Such exports accounted for 10% of total exports.

The demand for cement increased in the late 1980ies and early 1990ies as a result of an upswing in domestic construction stimulated by infrastructure and housing projects, especially by the enormous urbanisation process. Intensive Limestone-mining can be found around all bigger cities if the geological situation gives the opportunity for it. The cement industry consists of a large SEE and a number of smaller companies. Until 1970, the country imported most of its cement, but it has since become self-sufficient. Total output increased from 22.7 million tons in 1987 to 28.5 million tons in 1992. Exports of cement, especially to the Middle East, grew rapidly in the early 1980s because of the construction boom in these regions.

The chemical industry is concentrated in a few large state enterprises and some 600 private enterprises. Chemicals produced in Turkey include boron products, caustic soda, chlorine, industrial chemicals, and sodium phosphates. The high quality of the country's minerals gives it a comparative advantage in several products. Chemical exports increased during the second half of the 1980ies, but fell sharply in the early 1990ies, mainly because of increasing competition and lower prices elsewhere. In the late 1980ies, petrochemical production, started with a refinery plant. 12 plants, 7 sub plants, a thermal power station, and a water supply dam supply small private-sector plants, which in turn manufacture finished products. The sector's goal is to make the country self-sufficient in petrochemicals rather than to export.

Turkey's automobile industry, established in the mid-1960ies, was gradually exposed to imports after 1980. Although the sector recovered from low production levels after 1983, domestic producers remain weak. Car output rose from 55,000 units in 1985 to 300,000 units in 1993. Including trucks, buses, and tractors, Turkey produced about 345,000 units in 1992. Some 60,000 vehicles were imported in that year. The Turkish automobile industry in 1995 consisted of three producers, each affiliated with a foreign manufacturer.

1.3.19 Finance

Most state-owned banks were established to finance particular industries, whereas private banks generally have intimate connections with large industrial groups. The Central Bank of Turkey often provides credit to other banks. Banks, in turn, funnel credit to industries or groups they serve. The amounts available to particular sectors of the economy thus depend largely on the resources available to the institutions for that sector, rather than on market assessments.

In 1993, legislation started to bring the Turkish banking sector into line with European standards on capital adequacy and other prudential ratios.

The banking system in early 1995 consisted of the Central Bank and 58 banks, including 21 foreign banks, divided between Ankara, where most state-owned banks are located, and Istanbul, the centre for most privately owned banks.

After the passing of the Capital Markets Law in 1982, a Capital Markets Board was established to issue regulations for institutions marketing bonds and other financial instruments. The Istanbul Stock Exchange (ISE) reopened in December 1985. With the rise of "emerging market" funds, trading on the ISE expanded rapidly in the early 1990ies. Foreign investment accounted for 25% of the daily trading volume. In early 1994, the stock market crashed in the wake of the currency and balance of payments crisis. Plans for privatisation of SEEs were expected to revive the stock market, if foreign investment and confidence in the government's attempts to stabilize the macroeconomic situation increased.

The government of Turkey has a strong influence on the economy. It owns several important industries. In the mid-1990ies, the economy was so poor that the inflation rate reached 150%. The government's answer was to increase the price of goods produced or sold by government enterprises. Their major trading partners are Germany, United States, Italy, France, Saudi Arabia and Great Britain. The Turkish currency, the Turkish lira, took 1.2 million equal to one € in April of 2002. In December 2004, the currency was 1.8 million for one €. Beginning of 2005, new money became available with a suitable ratio to world leading currencies. Six numbers were deleted. Since Beginning of 2003, the inflation rate fell and made the Turkish lira to a reliable currency.

1.3.20 Tourism

Turkey's long and varied seacoast, high mountains and lakes, and its many historical, religious, and archaeological sites give the country tourist potential. Until the 1980ies, Turkish tourism lagged far behind its counterparts in other Mediterranean countries, and visitors tended to stay for shorter periods. The government's promotion of tourism in the 1980ies led to a dramatic change. The number of visitors grew rapidly during the 1980ies and early 1990ies, and Turkey was able to appeal to tourists from many different countries. Including business travellers, Turkey hosted about 1.3 million visitors in 1983 and 2.1 million in 1984, whereas Greece during the same period received at least 6 million and Spain 40 million visitors annually. By 1987, visits to Turkey had increased to about 2.9 million, and by 1992 close to 7 million.

In the early 1980ies, most tourists came from European countries. In the late 1980ies, European tourists accounted for nearly 60%, by 1992 the proportion had fallen to 45%. The largest increase was registered in tourists from the republics of the former Soviet Union. By 1992, they accounted for 43% of tourists, whereas the Middle Eastern share had shrunk from 11% to 8%.

Regional origin is a good predictor of the type of tourism and destination. Middle-class Turks, who started to take vacations in the early 1980ies, usually prefer the beach resorts on the Aegean and Mediterranean seas. Tourists from Western Europe, Israel, and the United States tend to visit beaches and historical sites. East European tourists, particularly from the former Soviet Union, typically come to Istanbul or Black Sea towns to shop or barter goods. Tourists from Iran and other Middle Eastern countries generally take longer holidays in Istanbul and Bursa, also coming to shop in Turkey.

Tourism earnings reached 770 million USD in 1985 and jumped to 3.6 billion USD by 1992. The number of beds rose from 49,000 in 1980 to 206,000 in 1992. Istanbul, the main tourist centre, still lacks sufficient beds, however, and there is a tendency to concentrate on luxury hotels that are too expensive for middle-class tourists. Nevertheless, the mid-1990ies saw a noticeable improvement in the average spending per day by tourists: 141 USD compared with the world average of 70-100 USD. Shopping tours helped to raise the average significantly.

1.3.21 History

Turkey's first known human inhabitants appeared in the Mediterranean region 7500 BC. The first great civilization was that of the Hittites. They dominated Anatolia from the Middle Bronze Age (1900-1600 BC), clashing with Egypt under the great Ramses II and capturing Syria, but by the time Achaean Greeks attacked Troy in 1250 BC, the Hittite machine was creaking. A massive invasion of 'sea peoples' from Greek islands put untenable pressure on the Hittites and smaller kingdoms played at border bending until Cyrus, emperor of Persia (550-530 BC) swept into Anatolia. Alexander the Great, who conquered the entire Middle East around 330 BC, expelled the Persians. After Alexander's death, his generals squabbled over the spoils and civil war was the norm until the Galatians (Celts) established a capital at Ankara in 279 BC, bedding down comfortably with the Seleucid, Pontic, Pergamum and Armenian kingdoms.

Roman rule brought relative peace and prosperity for almost three centuries, providing perfect conditions for the spread of Christianity. The Roman Empire weakened from around 250 AD until Constantine reunited it in 324. He oversaw the building of a new capital, the great city which came to be called Constantinople. Justinian (527-65) brought the eastern Roman, or Byzantine, Empire to its greatest strength, reconquering Italy, the Balkans, Anatolia and North Africa. Five years after his death, Muhammed was born in Mecca and the scene was set for one of history's most astounding tales. The armies of Islam were threatening the walls of Constantinople (669-78), having conquered everything and everybody from there to Mecca, Persia and Egypt. The Islamic dynasties challenged the power and status of Byzantium from this time, but the Great Seljuk Turkish Empire of the 11th century was the first to rule what are now Turkey, Iran, and Iraq. The Seljuks were shaken by the Crusades and overrun by Mongol hordes, but they hung onto power until the vigorous, ambitious Ottomans came along.

The Ottoman Empire began as the banding together of late 13th century Turkish warriors fleeing the Mongols. By 1453, the Ottomans under Mehmet the Conqueror were strong enough to take Constantinople. Sultan Süleyman the Magnificent (1520-66) oversaw the apogee of the empire: beautifying Constantinople, rebuilding Jerusalem and expanding the Ottomap to the gates of Vienna. Nevertheless, few of the sultans succeeding Süleyman were capable of great rule and the Ottoman Empire's long, celebrated decline had begun by 1585. By the 19th century, decay and misrule made ethnic nationalism very appealing. The subject peoples of the Ottoman Empire revolted. After bitter fighting in 1832, the Kingdom of Greece was formed; the Serbs, Bulgarians, Rumanians, Albanians, Armenians and Arabs were all seeking independence soon after.

The European powers hovered vulture-like over the disintegrating empire, while within Turkey various disastrous attempts to revivify the country were undone by the unfortunate decision to side with Germany in WWI. In 1918, the victorious Allies set to carving up Turkey.

At this point Ottoman general Mustafa Kemal began to organise resistance, sure that a new government must seize the fate of Turkey for the Turkish people. When Greece invaded Smyrna and began pushing east, the Turks were shocked into action. The War of Independence lasted from 1920-22, ending in a bitterly won Turkish victory and the abolition of the sultanate. Mustafa Kemal undertook the job of completely remaking Turkish society.

Turkey's history is that of the republic established in 1923 under the leadership of Mustafa Kemal (1881-1938), called Atatürk, the "Father Turk." The creation of the new republic in the heartland of the old Islamic empire was achieved in the face of internal traditionalist opposition and foreign intervention. Atatürk's goal was to build a new country and society patterned directly on Western Europe on the ruins of Ottoman Turkey. He equated Westernisation with the introduction of technology, the modernization of administration, and the evolution of democratic institutions.

Atatürk's ideological legacy (Kemalism) consists of the "Six Arrows": republicanism, nationalism, populism, reformism, etatism, and secularism. These principles have been embodied in successive constitutions, and appeals for both reforms and retrenchment have been made in their name.

In the late 1940ies, Atatürk's long-time lieutenant and successor introduced democratic elections and opened the political system to multiparty activity. In 1950, the Republican People's Party was defeated at the polls by the new Democrat Party. The government attempted to redirect the economy, allowing for greater private initiative, and was more tolerant of traditional religious and social attitudes. In their role as guardians of Kemalism, military leaders became convinced in 1960 that the government had departed dangerously from the principles of the republic's founder, and overthrew it in a military coup. After a brief interval of military rule, a new, liberal constitution was adopted for the so-called Second Republic, and the government returned to civilian hands.

The 1960ies witnessed coalition governments until 1965 was led by the CHP. A new grouping, the right-wing Justice Party organized and recognized as the successor to the outlawed Democrat Party, came to power in that year. In opposition, the new leader of the CHP, introduced a platform that shifted Atatürk's party leftward. Political factionalism became so extreme as to prejudice public order and the smooth functioning of the government and economy.

In 1971, the leaders of the armed forces demanded appointment of a government "above parties" charged with restoring law and order. A succession of non-party governments came to power, but, unable to gain adequate parliamentary support, each quickly fell during a period of political instability that lasted until 1974. During the remainder of the 1970ies, a period marked by the rise of political extremism and religious revivalism, terrorist activities, and rapid economic changes accompanied by high inflation and severe unemployment. The apparent inability of parliamentary government to deal with the situation prompted another military coup in 1980. The new regime's National Security Council acted to restore order and stabilize the economy. A constitution for the Third Republic in 1982 increased the executive authority of the president to a seven-year term. General elections to the new National Assembly held the following year enabled to form a one-party majority government that promised to bring stability to the political process.

In two elections, in 1987 and 1991, Turkey demonstrated a commitment to pluralist politics and a peaceful transfer of power. The 1991 election ended the eight-year rule of Özal's Motherland Party and brought to power the True Path Party, headed by Süleyman Demirel. In 1993, Tansu Ciller became the first female prime minister of Turkey. In 1993, the Turkish Grand National Assembly elected Demirel Süleymanis to become the ninth President of the Republic of Turkey. In the November 2002, election of Turkey's 58th government, the Justice and Development Party (AK) captured 34.3%, making Abdullah Gul Prime Minister, followed by the Republican Peoples Party (CHP) with 19.39%. A special General Election was held again in the province of Siirt in March 2003, resulting in the election of AK's chairperson Recep Tayyip Erdogan to a seat in parliament, allowing him to become prime minister. AK and CHP were the only parties to surpass the 10% threshold required to hold seats in parliament. The elections resulted in 363 of the 550 seats going to AK, 178 seats to CHP, and 9 as independent. Due to a reshuffle in party affiliation, AK holds 367 seats, CHP holds 175 seats, five are independent, and three joined the True Path Party (DYP). In March 2004 nationwide local elections, AKP won 57 of 81 provincial capital municipalities and, with 41.8% of the votes for provincial council seats, consolidated its hold on power.

1.4 Istanbul and the Marmara-Region

The Marmara Region, placed at the northwestern corner of Turkey and straddles over Asia and Europe, covers 8.5% of the country with a surface area of 67,000 km². The population of the region constitutes one forth of the total population of Turkey.

The Sea of Marmara is named after the internal sea, which is surrounded entirely by land. This sea (11,474 km²) is 280 km long and 80 km wide, connected on the northeast with the Black Sea through the Bosporus and on the south-west with the Aegean, as apart of the Mediterranean Sea, through the Dardanelles. Istanbul is located at the entrance of the Bosporus into the Sea of Marmara. The sea has no strong currents and the tidal range is minimal. In ancient times, the sea was known as Propontis (fore-sea) from its position relative to the Black Sea. Its modern name is derived from the small island of Marmara or Marmora (ancient Proconnesus), famous for its extensive marble quarries.

The Marmara Region forms a passage between the Balkan Peninsula and the Anatolia Regions to the east, the Aegean Region to the south, and the Greece and Bulgaria to the northwest.

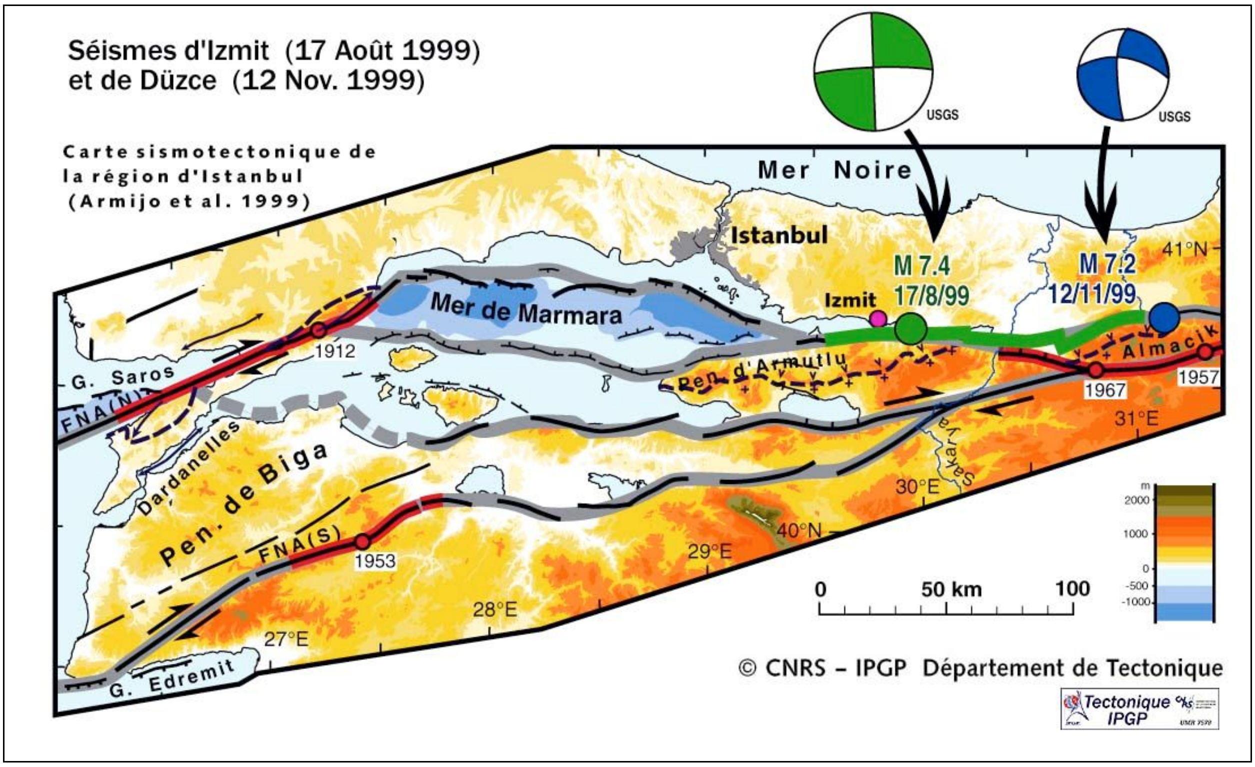


Figure 13: *Tectonic structures and faults of the earthquake risky Marmara Region (www.ipgp.jussieu.fr)*

Northwestern Turkey is a site of active tectonics and crustal movements by which the morphology, geology and hydrology of the region are significantly influenced. These geodynamic processes produce frequent earthquakes, thermal springs, and ore mineralization. The North Anatolian fault is running through the Marmara Sea. On August 17, 1999, a catastrophic earthquake occurred in the Gölcük-İzmit area. The primary earthquake measured 7.4 on the Richter scale. 17,118 people were killed and over 50,000 injured. Thousands of people remain missing and unaccounted for, and over 600,000 people were left homeless. Extensive human and property impacts related to the earthquake were experienced throughout Kocaeli, Sakarya and Istanbul provinces. Damage is estimated by government sources to be approximately 12 billion USD. The earthquake involved a right-lateral, strike-slip motion of the nearly vertical North Anatolian fault between Karamürsel and Gölyaka. The duration of the strong ground shaking was 37 seconds. Site visits to the Gölcük-İzmit area conducted in September and October 1999, demonstrated an extensive range of earthquake-related devastation: fault rupture, tectonic displacement, plus evidence of soil liquefaction, landslides, flooding, and fire.

The Marmara region is geologically divided into three parts, Istranca massif, Istanbul zone and Sakarya zone. Between Istanbul and Sakarya zone, the intra-pontid suture exists which roughly follows the northern strand of the North Anatolian Fault. The southern part of the Istranca massif is called Trakya basin. Cenosoic sedimentary rocks and quaternary alluvial deposits overlay it. Sedimentary rocks consist of sandstone, sandy-clay and limestone. The thickness of sediments in the Trakya basin reaches up to 6,000m. The Istranca Massif consists of sandstone, quartzite, shale, limestone, and Late Permian granitoid. Its contact with the Istanbul Zone further east is covered by the Eocene sediments. The metamorphic rocks of the Istranca Massif are composed of metagranite, micaschist, marble, calcschist, quartzite, and phyllite. The Istanbul Zone is characterized by a well developed, unmetamorphosed and little deformed continuous Palaeozoic sedimentary succession extending from Ordovician to the Carboniferous overlain with a major unconformity by latest Permian to lowermost Triassic continental red beds. The Istanbul Zone is very distinctive from the neighbouring tectonic units in its stratigraphy, absence of metamorphism and lack of major deformation. The Intra-Pontide Suture of Late Triassic-Early Jurassic age separates Istanbul and Sakarya Zones.

Figure 14: *The Bosporus connects the Black Sea with the Sea of Marmara that can be seen in the centre of this image. It was taken during the Shuttle Radar Topography Mission (SRTM). The large city of Istanbul, located on both sides of the southern end of the strait, is visible as a brighter (light green to white) area on the image due to its stronger reflection of radar-impulses. (www.jpl.nasa.gov)*

The European part comprises of rolling plains and low hills, while the Asian part includes low hills and higher mountains. The lands on both parts are excellent for farming, residency and industrial plants. The highest point is the Uludag near Bursa with 2,543 m. The terrain of Istanbul is hilly, facing the Bosporus. The mean average is ranging between the sea level and 540 m. The hilly plateau has got an average height of 190 m and is deeply cut by valleys, which lead perpendicular towards the Bosporus strait. This causes limits in the construction of a public transport system especially for subways and railroads. It also brings a disadvantage to manage the water supply and the construction of roads and buildings. In contrast, the southern part along the cost of the Marmara Sea is relatively flat. This makes this area suitable for agriculture and urban development.

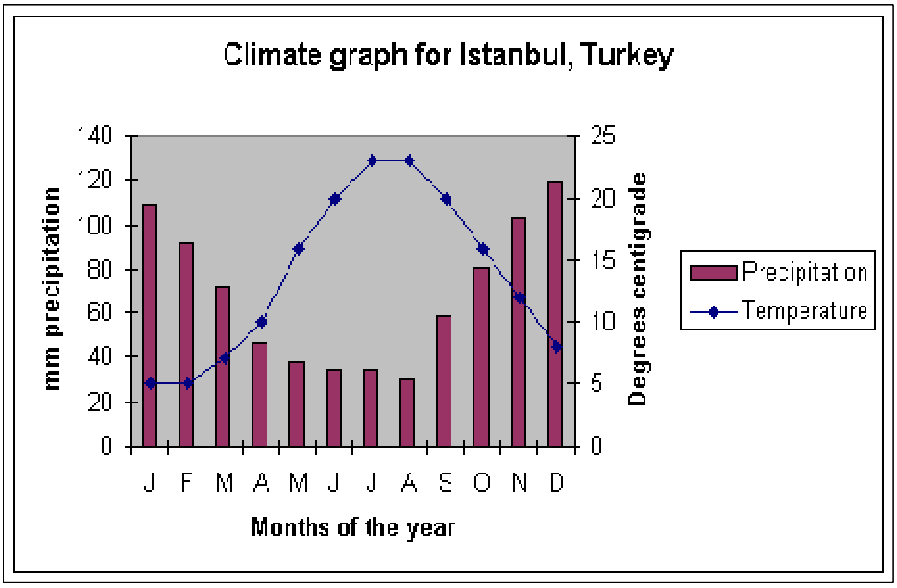


Figure 15: *Climate of Istanbul by annual distribution of rain and temperature (www.sln.org.uk)*

The sea mainly influences the climate of the Marmara Region. The different seas have various impacts on the climatic characteristics. The Black Sea influences the north of it, while the south is typical Mediterranean climate. Rainfall is enough to facilitate the growth a variety of fruits, while snowfall enlivens the winter season. The weather is variable and the Mediterranean climate competes with the northern Black-Sea weather conditions.

The climate of Istanbul is relatively mild and humid. The average temperature in Istanbul is 14°C, the annual rainfall reaches 677.2 mm. The average relative humidity is about 75%. But in the winter period the north-wind is able to deliver some days with strong snowfall which causes an entire traffic collapse on the hilly terrain. The annual number of days with snow is about 8. The location on the seaside causes the high humidity, but it is combined with a sufficient wind-circulation. Because of that, Istanbul's weather is not too much susceptible to smog compared to other mega-cities, especially, if one considers the large number of vehicles. The SO_2-concentration reached by 1991 a level of 213µg/m³, the limit of the international health organisations is set to 250. The particles reach a level of 102µg/m³, more than half of the limit of 200.

The potential natural vegetation is Mediterranean forest along the coastal area of the Marmara-sea, and can be defined as sub-Mediterranean along the Bosporus and the Black Sea coast. The mountains naturally carry broad–leaved forest. Only in the north of Istanbul some rests of the natural vegetation can be found, in the other areas agriculture and grassland demonstrate the long period of human settlement. The Marmara-Region is rich concerning the biodiversity, nevertheless the dense population and intensive land-use has repressed natural vegetation.

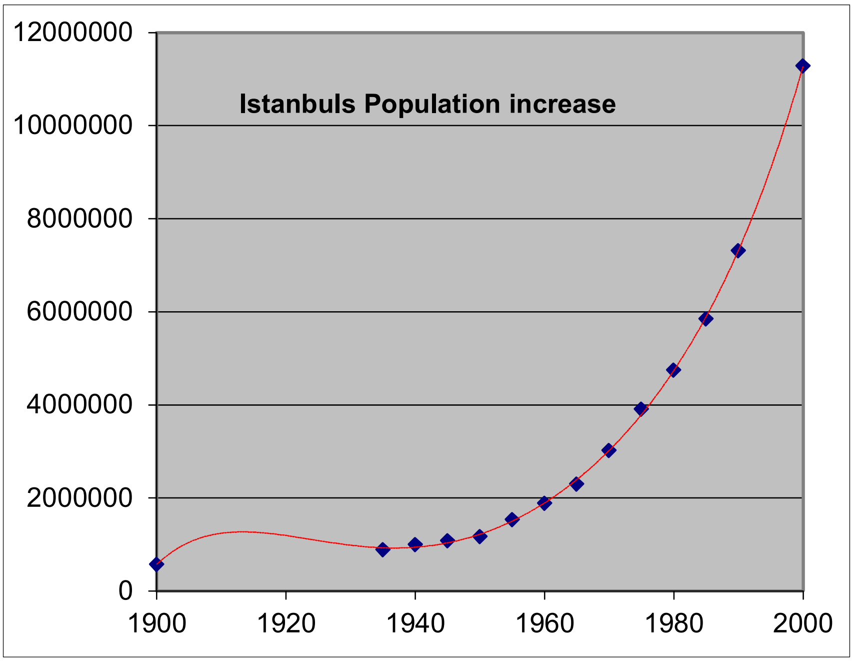


Figure 16: *The number of inhabitants of Istanbul since 1900. (different statistical sources)*

The population of the region has risen to 17,365,027 people according to the result of the 2000 census. 13,730,962 of them reside in cities and 3,634,065 in villages. Marmara is the region with the highest population increase, which reaches an annual growth rate of 2.67%. The constant migration to the region is the main reason for this. Migration from East Anatolia and the Balkans into the Marmara Region forced this dynamic process.

The people in the Marmara Region, which is Turkey's most industrialised area, are employed in industry, trades, and tourism. The most developed industrial zone in here is the Istanbul-Bursa, Izmit triangle. Among the industrial goods produced in the region are processed foods, textiles, ready-to wear clothing, cement, paper, petrochemical products, automobiles and spare parts, durable household items, railway cars and ships.

The advantageous location of the Marmara Region on the transportation routes, imparts a special trait to the region. The shortest highways connecting Europe and Asia pass through this region. These highways intersect with the waterways that connect the Black Sea countries with the Mediterranean. This location is the reason behind the development, the population density, and the wealth of the region. This region, where many great civilisations were born and flourished, comprised the migration routes of the tribes passing between the two continents. Tourism is also very developed in this region. Various educational institutions, press and information establishments, a cinema industry and theatres, intense cultural activities, and some of the world's most important works of architecture and art have their place within.

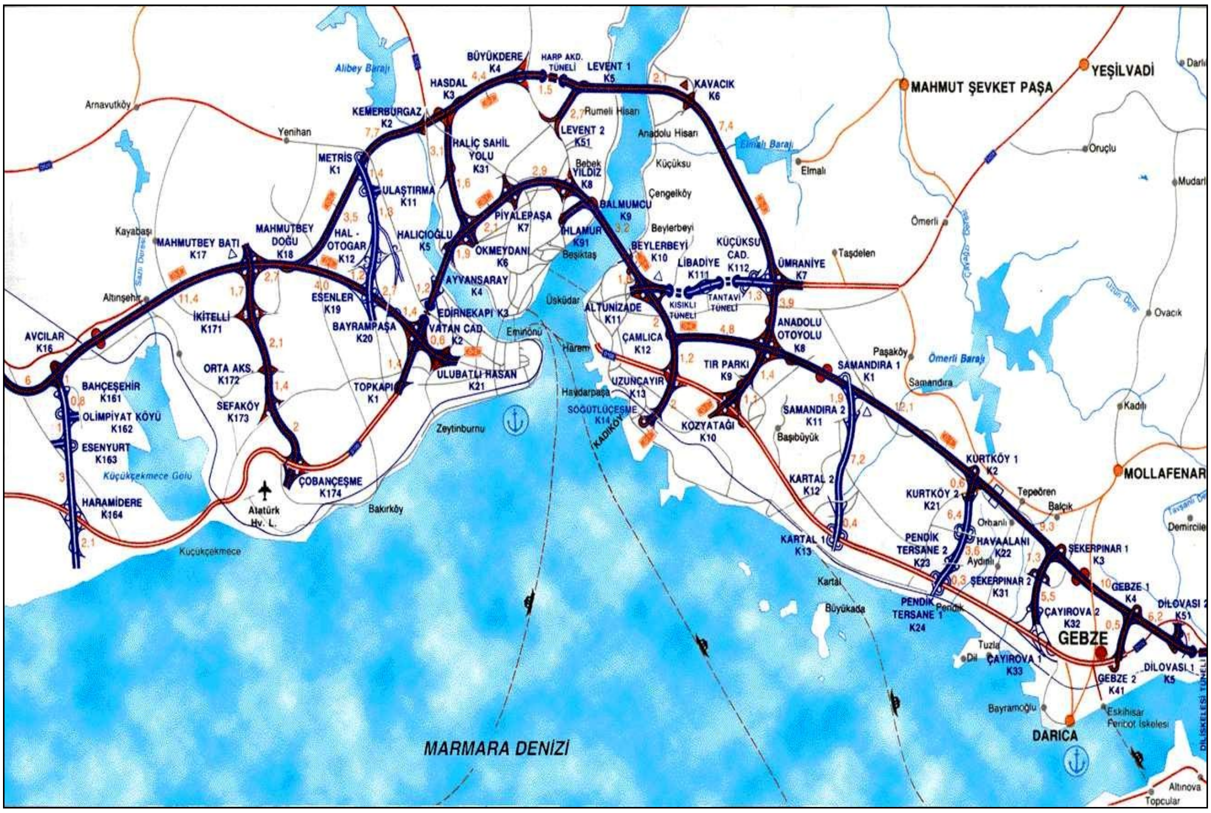


Figure 17: *Two main Ring-Highways connect the city's parts (www.tourizm.net)*

Istanbul, formerly Constantinople and Bycantinum, is the only mega-city in the world that sits astride two continents - Europe and Asia. Istanbul is the largest city in Turkey and the country's chief commercial and cultural centre. With the finest natural harbour in the region, it is an important trade hub. The city is the capital of Istanbul Province, which borders with the Black Sea in the north, with the Sea of Marmara in the south and south-west, with Kocaeli Province in the east and with Tekirdag Province in the west. The Bosporus, a narrow and deep strait that links the Black Sea and the Sea of Marmara, separates Istanbul's European and Asian sections. Two bridges connect Europe and Asia, The Bosporus Bridge (1973, the longest, part of the inner-city traffic ring) and the Fatih Sultan Mehmet Bridge (1988, part of the outer-city traffic ring) span the Bosporus. On top of that, a tunnel will be constructed. The bridges are not the only means to cross the Bosporus, numerous ferries do their job. The Bosporus leads north to the Black Sea and South to the Marmara Sea and via the Dardanelles to the Aegean and Mediterranean Sea. The European part of the city is divided into two parts by the Golden Horn, the town's historical port and smaller waterway; its only outlet is the Bosporus. Several bridges span the Golden Horn. South of the Golden Horn is the Old City, known as Stambul, the part where most of the Ottoman and Byzantine monuments are located.

The Old City is divided into several districts and enclosed by the Byzantine city walls, which stretch from the Marmara Sea to the Golden Horn and were under the reign of Emperor Theodosius II in the 5th century. North of the Golden Horn is the part of the city where foreigners settled since the middle Ages and which in the 19th century became the modern part of Istanbul. North of the Golden Horn the modern section, comprising the districts of Galata and Beyoglu (formerly Pera), is located. Important suburbs of Istanbul include Bakirköy, Zeytinburnu, Sariyr, and Kagithane in the European section. The Asian part of the town is also interesting with parts as Kadikoy, Uskudar, Selimiye and Kartal. Further there are other districts and suburbs, varying from the wealthy to the slums or Gecekondu's (built overnight) and anything in between. The most expensive parts to live are Levent and along the Bosporus (Bebek and the opposite site).

The city proper covers an area of 3,000 km², while the metropolitan area occupies 5,700 km², bigger than the Benelux countries. The European section of Istanbul is about the size of the Asian section and contains 60% of the city's population.

Istanbul has always been a populous city of its time, attracting a large number of people from the countryside as well as from the adjacent and remote areas of the world. Migration has always been a characteristic of the city from Byzantine to the modern times. According to the first official census of 1478 after the conquest, the city had a population of 70-80 thousand and in 1507 (only 54 years after the conquest) it became the world's largest city with a population of 1,2 million, as a result of peace and order reigned under the Ottoman rule, the delicate care the Ottomans shown for her sustenance and their successful settlement policy. These were decisive in making it not only the capital of the empire but also the capital of the world. At present, roughly 1 out of every 7 citizen in Turkey lives in Istanbul. Population boost, though creating urban problems like in other large cities all over the world, empowers the city with a unique strength and dynamism.

In 1997 Istanbul's official estimated population was 9,198,809 and makes the city the 24th largest city in the world; some unofficial estimates were much higher, however, reflecting the increasing influx of people from other countries and rural parts of Turkey. Within the Istanbul metropolitan area, there has been considerable migration from crowded central Istanbul to the Asian side of the Bosporus and also to various suburbs. Bakirköy, located west of the centre, is Istanbul's largest suburb. The biggest grow however took place along the Marmara-seaside on the Asian as well as on the European side. Today the greater Istanbul area has an unofficial population of 20 Mio. However, it is still not clear where and how many people lived at which time, the dynamics of the population movement is too strong and based on different regions (city or district). Therefore the published data differ strongly.

Of those 9 million the vast majority are ethnic Turks, some hundreds of thousands are of ethnic Kurdish origin, around a 20,000 of Jewish ethnic origin, a few thousand of ethnic Armenian origin with their own Patriarch and some 4,000 of Greek ethnic origin, with their Patriarch of the Greek Orthodox Church in Istanbul. The Turks you will find in all layers of the population. The inhabitants of ethnic Kurdish origin fall apart in several classes, the ones who stayed already rather long in Istanbul or were even born there, are well integrated. The others, who arrived not so very long ago and are still 'searching' their way. The latter you may meet frequently as carpet sellers in the Sultanahmet area. The ethnic Armenians are fairly rich and you'll find them mostly in trade. The Greeks are mostly found in trade and/or middle class.

Istanbul, though not the administrative capital of Turkey, is the economic and cultural heartland of modern Republic of Turkey in terms of decision-making and administration. Being the largest city and the seaport of Turkey and the hub of its industry, the largest companies, banks, insurance and stock exchange firms, advertising companies and mass media are all located in Istanbul.

1.5 Historical Background

The long history of this town began around 700 BC on the Asian site. Greek settlers established Chalcedon, at the location of what is now Kadikoy. In 657 BC, other Greek settlers, under the command of Byzas, settled on the European section at Seraglio Point (Sarayburnu), where a small fishing village was situated. The new settlement was named after its commander, Byzantium. Thanks to its unique location, the land bridge between Europe and Asia and the sea route between the Mediterranean and the Black Sea, the settlement prospered. It was ruled by the Persians at the turn of the 5^{th} century BC, for about 50 years, whereafter it was under control of the Athens and Sparta at different times. The town became part of the Roman Empire at the end of the 2nd century BC.

In 190 AD, the town was involved in bizarre events, which were part of the decline of the Roman Empire. In 192 AD, Emperor Commodes, known for his cruelty and follies, was killed. Emperor Pertinax who, due to his strict reforms, only ruled 68 days replaced him. The Praetorian Guard who feared the return of ancient discipline murdered him. Hereafter the Praetorian Guards decided to sell the Imperial Throne by public auction to the best bidder. A wealthy senator Didius Julianus bought himself the Imperial Throne. The Roman Army was furious and three generals (each head of three legions and each with a claim to the Imperial Throne) marched to Rome. General Septimus Severus arrived first at Rome's gates. Septimus Severus promised clemency to the Praetorian Guard, who complied with those easy conditions and handed Didius Julianus over, who was beheaded, as well as the two competing generals when caught later. Septimus Severus became the new Roman Emperor. Since Byzantium had chosen the side of another general (the governor of Syria), the walls of the city were razed in 196 AD. Later Emperor Septimus Severus had the city rebuilt and expanded.

The second decade of the 3rd century the Roman Empire was, for the sake of better administration, subdivided in four parts. Due to internal struggle for power, only two parts remained a European (capital Rome) and an Asian (capital Nicomedia). The European Emperor had the most powerful army, and the riches of Asia in mind. The European Emperor (Constantine) captured Byzantium in 323 and made the Asian Emperor resign. Attracted by the unique position of Byzantium and observing how well it was guarded against an attack by nature, Constantine made Byzantium his new capital in 326. The town was renamed Constantinople, new city walls, aqueducts and numerous buildings were constructed.

In 395 the Roman Empire was split up finally in a Western Empire (capital Rome), which was to end in 476 and an Eastern Empire (capital Constantinople). The Eastern Empire would be known to history as the Byzantine Empire. The zenith of the Byzantine Empire was under the reign of Emperor Justinian (527-565) who reconquered parts of the former Western Roman Empire. Justinian revised the law system, arts and architecture flourished. During this period, Constantinople had around one million inhabitants. Till the 7th century the Byzantine Empire was more Roman than Byzantine, but later Latin was gradually replaced by Greek and the empire became eastward orientated. From the 6th century till the 8th century the empire was under attack from invaders from the North as well from the Arabs, the latter besieged Constantinople twice around 700. The empire revived between the 8th century and 11th century, reconquered lost lands, arts and culture flourished again. However, the best times have passed over. The religious schism with the pope (1054), which made Constantinople capitol of the Greek Orthodox Church with its own patriarch, bereaved the empire of Western support. The Seljuk Turks defeated the Byzantines in 1074 and conquered nearly all of Anatolia.

The fourth crusade proved the final blow before the end. The crusaders, in urgent need of sea transport, made a deal with Venice. The Venetian fleet would carry the crusaders only if they would sack Constantinople. The town was seized in 1204 and stripped bare of its treasures, lots of it you'll find back in Venice. Countless relics were spread over Europe. Most known is the crystal tube with 'Christ's Blood', which is now in the Holy Blood Basilica in Bruges (Belgium). The Venetians were happy, for Constantinople would never become trade rival anymore. The crusaders had a clear conscience; they had destroyed the 'blasphemous' capitol of the Greek Orthodox Church. As an extra bonus they ruled the city nearly sixty years.

In 1261, the Byzantine Emperors returned, only to decline further and the town became a shadow of what it had been before. In 1345, one of the Byzantine Emperors asked the Ottomans for aid against a competitor and the Ottoman armies entered Europe. They got the emperor out of trouble and went back to Asia; the same kind of events repeated several times until 1353. In that year, the Ottomans crossed the Dardanelles and settled on the peninsula of Gallipoli. After that, things changed rapidly; in 1362, Adrianople (Edirne) was taken and became the new Ottoman capital.

Sultan Mehmet II (The Conqueror) decided to take the town. First, he had a mighty fortress (Rumeli Hisari) constructed at the narrowest point of the Bosporus in 1452. This cut the town's supply from the North. The conquest came in 1453, by use of modern artillery and a surprising way to control the Golden Horn. The Golden Horn was closed with an iron chain, so the Ottoman fleet could not get in to attack the weaker sea walls. The Sultan had a part of its fleet transported overland (by rollers and slides) out of the Bosporus into Golden Horn. Constantinople was taken on 29 May 1453, the last Byzantine Emperor died in the battle.

The town was renamed Istanbul and this name is most probably derived from the Greek 'eis ten poli' (in the town). Mehmet II was lenient, areas that did not resist its troops were spared, others were sacked, and their churches turned into mosques. Forcibly conversion to Islam did not happen. Christians (Roman and Orthodox), Jews, and Hindu's could freely practise their religion without any limitation. The patriarch of the Orthodox Church was greatly respected and honoured by the Ottomans. Istanbul became the Ottoman capital and Mehmet had a palace constructed on the grounds that are now occupied by the Istanbul University. Nothing is left of this palace. Later he had the building of the Topkapi Palace started. The Topkapi palace became the residence of the Sultans for nearly three centuries and was enlarged and changed during this period.

In 1517 Cairo, Sultan Selim I took Mecca and Medina and the Sultans took the title of Caliph. The Caliphate was actually an Arabic institution and means the representative of the prophet and guardian of the faith and the holy places (Mecca and Medina). The Caliphate can, to a certain degree, be compared with Papacy but is not recognised by all Muslims.

In 1520, the greatest Sultan came to the throne, Suleyman I (the Magnificent or the Lawgiver). Under his rule, the Empire reached its zenith. Suleyman I refined the law and tax system, developed free education, founded mosques with colleges, soup kitchens for the poor, libraries, and bathhouses and redesigned the Istanbul waterworks. Istanbul was the centre of Islam and the capital of a vast empire. The Ottoman Empire stretched from Algeria to Egypt, comprised the rims of the Arabic Peninsula, Syria, Iraq, Armenia, Georgia, all lands from the Crimea (including all territory around the Sea of Azov), to the Austrian border. The year (1566) Suleyman I passed away was also a watershed for the Ottoman Empire, hereafter decline started slowly and unnoticed at the beginning.

In the 19th century, notable reforms took place, based on Western lines. However, the empire had lost most of its power and former glory and the result was that the Empire became more dependent on foreign sources. For British, French, German, Austrian, and Dutch traders custom and tax barriers disappeared. With those measures, the Ottomans intended to promote modernisation and trade. As result, numerous banks, trade companies, were established etc. companies mostly in foreign hands. Those were the years that the modern city part north of the Golden Horn was created. The Sultans decided as well to live north of the Golden Horn and the Dolmabahce palace was built between 1831 and 1853. A direct railway between Vienna and Istanbul was opened in 1889.

Soon the Ottoman Empire was an open market for Western European products and a source of export for raw materials. The results for the artisans and peasants were negative. They could not compete with Western European products. The population of Istanbul started to rise nearly as fast as in other capital cities in Western Europe. The First World War proved fatal for the Ottoman Empire, it chose the side of the losers. On 13th November 1918, after an armistice was signed in October, the Entente fleet entered the Bosporus (the convoy was sixteen miles long). They did not occupy the town technically but practically they did. The Ottoman government fulfilled all the wishes of the Entente powers. The Entente did not only intend to divide the Empire, but as well had a division of Anatolia in mind.

The Ottoman General Mustafa Kemal (the victor of Gallipoli) started a struggle to rescue the Turkish part of the empire. Under the pretext of restoring order in Anatolia, he left for Samsung in 1919. He restored public order not the way the Entente powers expected him to do. He started to unite the forces in Anatolia for the sake of the Turks. The Sultan’s government (under Entente control) declared Mustafa Kemal a rebel and soon after the Entente took over parliament in Istanbul. Since neither the Sultan, nor the parliament in Istanbul had any control over the country, a Nationalist Parliament was established in Ankara.

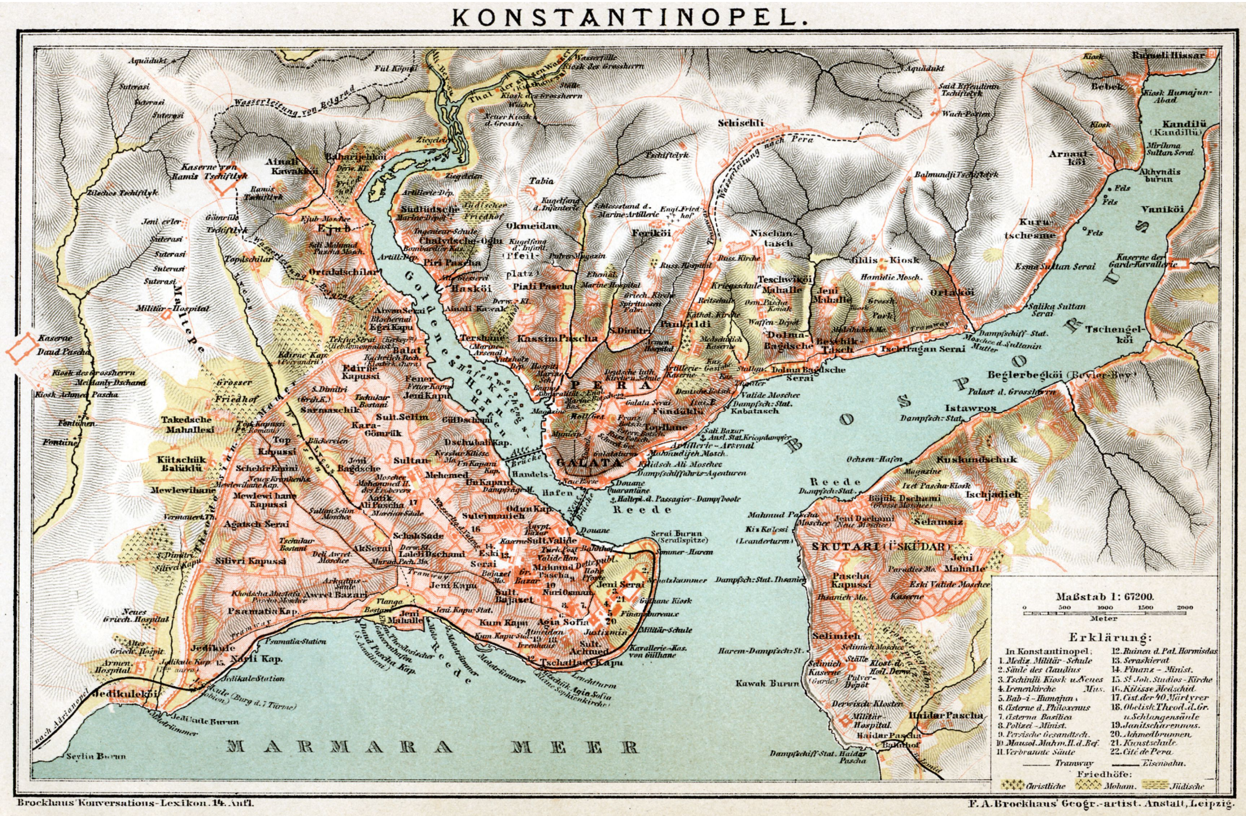


Figure 18*: Map of Istanbul around 1900. (Brockhaus Enzyklopädie , 14. Auflage)*

The incredible happened, with part of Anatolia occupied by the Italians, under attack from the French and Greeks, a new nation was born. The Nationalists inflicted heavy losses on the French and made them eager to negotiate. The Greeks, who had a new Hellenic Empire in mind, were totally defeated in 1922 and expelled from the country.

On November 17 in1922 the last Sultan fled the country aboard a British warship. On July 24 in 1923, the treaty of Lausanne was signed, between the Entente and the National Government in Ankara. In last days of September, the Entente forces left Istanbul saluting the Turkish flag. In October, it was decided that Turkey would become a republic and its capital would be Ankara. Ankara had a secure position against foreign armies and was the symbol of the Nationalist struggle. In 1924 the Caliphate, still in Istanbul, with as Caliph a cousin of the fled Sultan, was abolished. The religious courts were abolished and replaced by a Civil Code based on the Swiss Laws. Modernisation was on its way. The Republic of Turkey had been created out of the ruins of the Ottoman Empire. When the foreign embassies left to Ankara, Istanbul kept its importance for trade, industry and cultural life.

Since the 1950’s, the town's population has expanded, mainly due to the mechanisation of agriculture. The unrest in the Southeast of the country contributed to the expansion of the population as well. Since the 1970’s the infrastructure of the town has been under constant renovation, new roads, bridges have been built, tramways made, and an underground line is under construction. This had some negative side effects as it had in other towns in the world in similar way. Some new routes were cut through valuable architectural areas. However, the city council is on the way for plans of a third Bosporus Bridge or alternatively a tunnel, with less harmful results for the architectural and natural beauty of the town. Meanwhile, a Japanese consortium has started to build the tunnel underneath the Bosporus using pre-constructed double-tube compartments. More tramway lines and an underground railway (Taksim-Levent) are under construction. A traffic plan, to ban the car out of the centre, is on its way. Since the middle of the 1980's, industrial plants have gradually banned out of the centre and the Golden Horn area has been cleaned up.

1.6 Actual Problems

Being a city of the oriental hemisphere, Istanbul shows a lot of features of the Islamic-oriental culture (Ehlers 1993). Some of the main characteristics are a widespread and semi-public road and path network with many blind-alleys, the prevalence of houses with an inside-courtyard, bazaars, the coexistence of traditional districts and modern CBD's in the city centre and finally a very strong city spread, consisting of the strong population movement in Muslim cities and high internal migration figures, with fast growing marginal (suburban) settlements (Höhfelder 1995). Nevertheless it is astonishing that every 15th citizen of Turkey is a citizen of Istanbul at the same time (Çiğdem; Şen; Özbek 1998). The consequence of this development were several serious shortcomings in Istanbul as the government, the town council and the city planners could not handle the huge mass of immigrants. This problem existed since the Ottoman Empire. One evidence of the insufficiency of the town and their planners are numerous Gecekondu-estates (illegal residential buildings) which are built on state-owned ground in most cases.

Since the 1950s Istanbul has had to deal with the so called phenomenon of "Gecekondu-settlements" (Yüksek; Cebir 1996, 1998). These settlements arise of illegal house building (without estate or building permission) to outweigh the lack of housing capabilities (comparable to the illegal and spontaneous settlements in Latin America, the so-called *barrios, barriadas* or *favelas*; vgl. Bähr; Mertins 1995). In most cases, the settlements are later legalized by local politicians (Arslan; Schaffer; Klingshirn 1993). These settlements usually grow very fast and become extremely compressed thus preventing any kind of foresighted city planning (Ritter; Richter 1999).

Istanbul receives an estimated 500,000 immigrants each year from the rural areas of the country, most of whom become squatters. The old city is surrounded by Gecekondu settlements, which include 65% of all buildings in Istanbul. In these areas the dominant economic activities are as informal as the housing. Most of the Gecekondu settlements have gradually evolved from the original definition of "housing with poor conditions in order to survive" into areas where lower-middle-income apartments predominate. This evolution has not only made Gecekondu an economic investment, but also the subject of daily politics. Continuously, there have been populist attempts of various political parties to legalize these settlements. These attempts encouraged new Gecekondu investments, and in turn, the new Gecekondu areas came to depend on such populist policies, creating a vicious circle. Mainstream urban policies had the tendency to see both Gecekondu and their informal economic activities as unwanted. The organic tie between Gecekondu and politics, together with these unsuccessful urban policies, allowed urban politics to establish in Gecekondu areas before urban culture and economics. By 1994, their population had increased to the point where it constituted a majority, and Gecekondu areas began to determine local election results. By this token they ensured that urban policies would no longer exclude them. The rise of the Islamic Political Party in these areas is thus not coincidental, but strongly related with the internal dynamics of Gecekondu and informal economic activities.

After their legalisation, these Gecekondu areas have changed their style. Floors are added and the houses become more similar to normal residential buildings. The Gecekondu nowadays do not look anymore like primitive constructions, they are usually build solid with bricks and concrete, but of course during the weekend (over night) with the help of relatives and neighbours. Gececondu is no longer just a phenomena of the lower and middle class. Gecekondu residences on very high level appear as villas in protected areas of Istanbul. Such areas are more difficult to detect besides legally built residences. The sizes of the Gecekondu settlements differ strongly in literature and in publications. It shows the difficulty of the clear detection in the Istanbul area – in fact, it is a law-definition.

Even radical and extreme efforts (systematic demolition of new Gecekondu settlements) to contain this Turkish phenomenon of uncontrolled city proliferation - the so-called urban sprawl - were not very successful in the past. In order to have a long-term persistence of opposition against the very difficult Gecekondu-problem, the city council started the project of a municipal redevelopment ("Kentsel Dönüsüm Projesi") in 2004. Within the bounds of the plans, the council decided to pull down 85,000 Gecekondus and to resettle the occupants in meticulously planned accommodations. Under instructions by the department of property and expropriation, the section for house- and Gecekondu-building counted 85,423 Gecekondus in their investigation. At the beginning of the implementation 500 buildings in the areas of Armutlu, Sarigöl and Gazi Mahallesi were pulled down. Furthermore, 700 in the district of Gaziosmanpasa will follow, but the biggest pull-down-works are planned in Okmeydani. In spite of these and other uncounted efforts like five-year plans, overall plans or land utilization plans in order to canalize the uncontrolled settlements, in Istanbul can still be seen as a victim of unsystematic urban development (Görgülü 2002). The process of sub urbanization was not only implemented by the illegal Gecekondu settlements but also by the increased settlement of industrial areas as well as the formation of satellite towns like Ikitelli or Mahmutbey and the agglomeration of industrial estate along the Londra Asfalti.

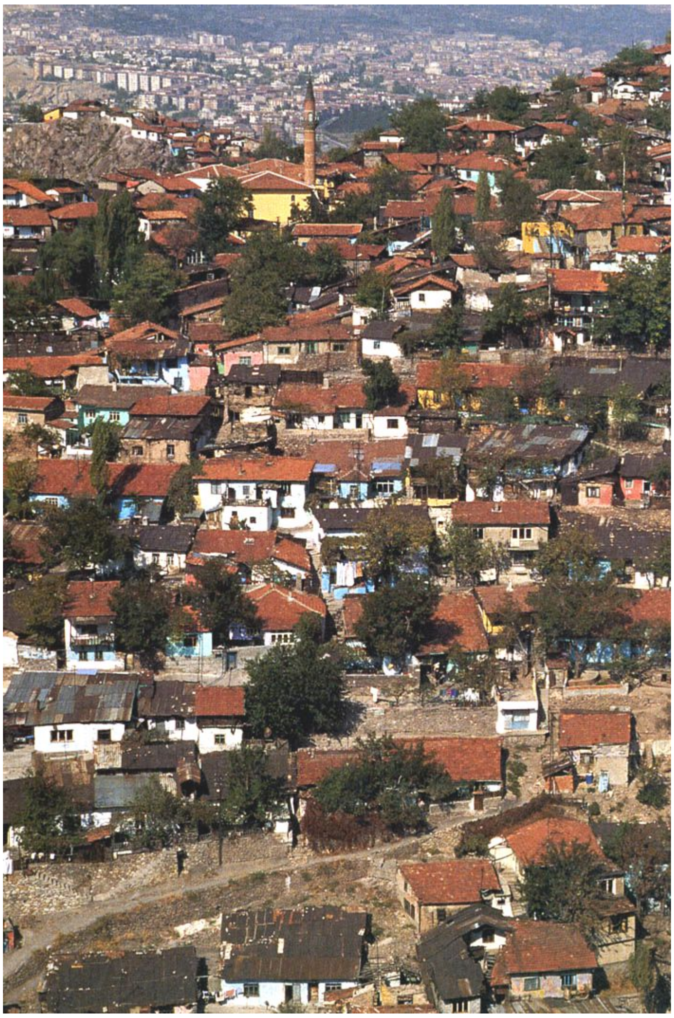


Figure 19*: Gecekondu-Settlement during the 80ies (A. Hottinger 1990).*

City planning in Istanbul is not only faced with the Gecekondu problem. There is not a lack of ideas and strategies for the city development, but still an integrated initiative of all authorities is missing. Local and regional authorities with different structures work besides each other and often with competitive strategies. A common database including software-tools and strategies for Istanbul is still missing. Local mayors follow own ideas, i.e. their building a residential area for 100,000 workers of Istanbul along the coast of the Marmara-Sea, just for weekends.

Istanbul grows rapidly in both dimensions, in space and in density (Kemper et al. 2002). The above-described urban sprawl is the visible result of striking and permanent structural alterations. Two main factors beside the numerous make it hard to control this process. Internal migration and globalisation and the rather frequent paradigm shift in Istanbul's economic and development policy, which increases the pressure for change and prevents sustainable development (Görgülü 2002) hamper the planner's work. The data needed for a sustainable city planning are usually too old; so far, master plans are running far behind reality. The acceptance by the citizens is low. Planning on actual data, presentation of the projects in the public and scenarios that make the people sensitive could help making sustainable steps toward an accepted and successful planning.

The traffic problem is one of the most difficult objects for the city planners in Istanbul. The hilly terrain and the Bosporus-straight make the design of a public transport system complex and expensive in its realisation. Most public transport is managed by busses, which compete with individual traffic by cars and mini-busses (Dolmush). Tram, still under construction, exists with just one line in the historical centre and as underground with a few stations to Levent. Railways have a small local importance and start or end at the Bosporus. Private cars and busses manage more or less the entire traffic, moving through, in and outside of the city. The 2 bridges, carrying the traffic from Asia to Europe and back, are crowded several hours per day. The most effective transport is the use of ferries cross and along the Bosporus, but it is limited on this area.

The traffic causes a high pollution with SO_2 (213 µg/m³ in 1991), particles (102 µg/m³ in 1991) and many other unhealthy components. This can be solved with a good public transport system only – as already mentioned a very difficult task. Istanbul is a strong industrialized area as well. By the transposition of factories to Istanbul's suburbs, the air-pollution of the inner city decreased significantly. The water pollution is another big problem of Istanbul. Especially in the Gececondu areas there is a lack of canalisation. Compared with other Mega cities in threshold countries, Istanbul has a relatively well working sewage system managed by a central organisation that even produces master plans. A big problem is the industrial wastewater input and the pollution by ships. The pollution in the Golden Horn is one of the most important environmental problems of Istanbul. Alluvium carried by Alibey and Kagithane creeks, and domestic and industrial wastewater discharges are the major sources of the pollution. In the upstream, a part of 3 to 4 km long, is almost completely filled with debris and organic solids. High anaerobic activities in the sediments are resulting in a heavy odor problem. A restoration feasibility project has been carried out for pollution prevention and evaluation of the restoration alternatives. Characteristics of water quality and bottom sediment were determined. Pollution prevention measures and the alternatives for the dredging and disposal of the bottom sediment were evaluated. Istanbul Metropolitan Municipality has already started the dredging work by early 1997 and has completed the diversion of all domestic and industrial wastewater discharges out of the Golden Horn. Still in the Marmara Sea, Black Sea, Bosporus and the Groundwater as well, pollution can be clearly detected. Still missing is a dense system for measuring and monitoring the pollution, both for air and water. In the last years several research programs to study the pollution have started i.e. the Beach Quality Monitoring (Convention for protection of the Black Sea against pollution), Water Quality Monitoring (impact of the land-based pollution on the Sea of Marmara, the Bosporus and the Black Sea) or Water Quality Monitoring in the Sea (Marmara, Bosporus and the Black Sea).

A sufficient supply of drinking water is not guaranteed at any time, especially in dry summer periods. Several dams have been built to collect water for Istanbul's increasing demand in potable water. Between the early nineties and today, the water consumption has tripled to more than 4 Million m³/d. As a major part of the ISKI (Istanbul Water Supply and Sewerage Administration) Master Plan all water and wastewater treatment plants as well as water distribution systems have to be improved and new water sources will be put into service.

The existing urban green spaces are not evenly distributed within the city. In almost every city quarter there is a deficit in the supply of urban green. The existing green areas are insufficient with regard to functional and visual attraction and very often have signs of overuse, like distressed meadows and bushes. There is a standing pressure on the existing urban green spaces for community housing and leisure within the city and the still remaining open spaces are heavily endangered. The uncontrolled expansion destroys fresh air zones in the western and eastern part of the city that are extremely important for the climate of the metropolitan area. It is almost impossible to protect alternative green zones from the urban sprawl. Consequences are smog, lack of oxygen, and infections of the respiratory tracts and climatic warming within the city.

Istanbul was never a classical city with a defined centre: the Bosporus and the Golden Horn divide the city into three almost independent parts, which lend the city visual and cultural abundance. Global economy rapidly transformed the city into a multi-centred and de-centred mega-space and an endless collage of urban, suburban, and rural settlements. Layers of macro and micro cultures co-exist in the city. Layers of prevalent traditional culture and resistant immigrant culture stand in ambiguous alliance with the dominant corporate culture. "Identity" and "being different" are floating/drifting concepts; "others" are present everywhere, not only as a result of immigration, but because the fermenting culture and the unpredictable daily life of the "others" constitute a crucial element of the so-called corporate economy. The city concentrates on diversity at a micro-level, even though the process of globalisation has introduced a strong unifying corporate culture, which dominates the newly developed business areas. Today's mixture of rural cultures with sophisticated international culture is creating a multiplicity and redundancy of "emergency identities" that unfold their new forms and dimensions accordingly. The same mixture creates surrealistic languages when these identities manifest their ideas, desires, and oppositions. However, the cultural mixing is a process beside a separation problem. It can be observed that national and international immigrants group together in urban areas, a problem that causes ghettos and social conflicts. There exist national, religion and international groupings of people. Migrants from eastern Turkey “rebuilt” parts of their villages with friends and relatives in Istanbul by Gecekondu settlements. Rich and poor people are neighbours, but in different quarters. The social and economic contrast is extreme in Istanbul.

Istanbul is the largest province of Turkey, both in terms of economic and social activities. The city constantly attracts migration as a result of vast employment opportunities. This situation causes problems that are difficult to solve in many aspects. Many schools are being introduced into service every year but the level of supply of education services is not sufficient. The number of vocational education institutions increases in parallel with the economic and social developments, but there has not been a good communication between industrial and educational institutions. There is currently difficulty in obtaining the related demographical and economic data of Istanbul since the results of the 2000 Population Census for Istanbul has not completely been published, yet. While there is a high potential of employment especially in industry and the service sector, an important part of the population comprises young and jobless people. Moreover, the majority of the jobless are permanently unemployed and unqualified. The situation is the same in the provinces surrounding Istanbul such as Tekirdağ, İzmir, Bursa and Sakarya. In other words, while there is heavy industrialisation around Istanbul, the problems of unemployment persists because of lack of a well-trained labour force needed by the industry. There are 2.1 million formal education students in Istanbul. Approximately 380,000 (18.1%) of these are enrolled in secondary education. 150,000 students (7.1%) out of the latter figure are students of vocational and technical education. These students attend 293 schools and are served by 7,317 teachers. In addition, there are 79,000 people attending courses in 51 non-formal education institutions including Adult Training Centres and Apprenticeship Training Centres. These figures prove that vocational education institutions in Istanbul are insufficient and the system needs to be strengthened. In this sense, Istanbul is a suitable regional centre.

Overpopulation leads to the increase of lease prices and prices for real estate. That enforces the process of social displacement. Mega-cities are more sensitive against social and economic triggers. Inflation of prices, dependence of the transport system causes the danger of social and economic collapses, like in any Mega-city. In this environment, crime has a fertile soil for development. Still the crime rate in Istanbul is relatively low, compared with other Mega cities. But unemployment, social drop down, drugs, underdeveloped social system can change the situation. There is still some cultural (either regional or religious) familiarity, which provides such effects. But there is a rise of informal economy and corruption.

It is nearly impossible to provide the necessary infrastructure for health standards and a decent quality of life (canalisation, schools, hospitals etc) and a sufficient supply with basic services and goods like water supply, health care etc... The uncontrolled development leads to high-density areas nearby geological sensitive territories with a high risk for earthquakes. Furthermore, the constructions of the houses in the Gecekondus are mostly not earthquake resisting. Strong risk against „Tsunamis“ exists along the shoreline of the Marmara-Sea. There is no adequate emergency plan or strategy for such cases. Scientific research has taken place but it was not put to practise. There is a big lack of basic data, which is not surprising if we are aware of the growth of Istanbul’s fabric. Istanbul is growing to the south mainly along the coast of the Marmara-Sea – that means closer to the main fault crossing the Sea just 60 km away.

The problem of the urban sprawl is realized neither by the mass of inhabitants nor by the decision-makers. Existing scenarios have been ignored and a common overview is still missing. Instead of thinking globally and dealing locally, most decision makers think locally and deal for the next election. Education and consciousness of the problems have not taken place up to now. This study might give a simple growth scenario and a dataset usable to provide a medium-scaled overview about Istanbul’s development. To fulfil this aim, Remote-Sensing is a technology, providing fast and accurate data for urban sprawl analysis.

2 Methodology

Humans have always wanted to know where they live. Research about our planet, its location, its shape and size has been done for 8000 years. 3000 BP, first maps and city plans were drawn. Furthermore, humans always want more information about their environment. They always want to learn more about the land where they live. This request did not only concern their current situation, but also about historical conditions of the environment. Depending on the scale, there is always something unsatisfying in accuracy or content.

Today, after the development of new technologies in the different geo-scientific disciplines, this lack of information can be compensated more easily. Using traditional and innovative technologies like aerial photogrammetry, remote sensing, GIS and GPS, new approaches have been generated. For Mega cities like Istanbul, it is still a big effort to control, plan and analyse the urbanization. To manage the urbanization is the job for local authorities, but scientists have to develop new methods and techniques to support these activities. Great effort has been taken in the definition of standards in land use classification, to make studies on various cities comparable.

Up to now, the urbanization of Istanbul has only been shown in general as figures and statistics but not as detailed geographical data. Exceptions exist for some small areas only, like sub cities or quarters of Istanbul. A few more detailed scientific studies have been done. However, they are not comparable with each other and cannot be connected to a wider analysis. Using these current conventional technologies, an approach has been generated and applied.

Referring the MOLAND, mentioned in chapter 1.2, there are three main steps.

- Change Detection
- Understanding
- Forecasting

A discussion about land-use detection has to take place, including classification methods and different interpretation legends. Each map is already an interpretation result and shows a kind of classification with limits in content and accuracy. For land-use detection, several techniques and methods have been used in this study. All of them are meaningful according to the aim. To make the results comparable, the MOLAND-Legend has to be introduced.

The extraction of data is done in a Geo-Information-System (GIS) and we have to handle a GIS-Warehouse in order to exchange data and make them available for other purposes too. It has to be discussed which system is suitable for this project, what the importance of geometry, database and topology in the vectors is. If we see GIS mainly as a vector based digital system, we have also to introduce raster-based tools for geocoding remotely sensed data like satellite images and aerial photos. On the aerial photos, digital photogrammetric work has to be done, including image-orientation, aero-triangulation, orthorectification and mosaicing.

The data-sources, suitable for the change analyse, will also be described. The availability, price and quality of such data sources and also the capability to handle them define their type and age. Each data-source needs a specific pre-processing to make them available for the GIS-analysis.

Defining the area of a mega city can be done according to different mathematical methods or descriptions or datasets already published. I have defined a core and a buffer zone, which have to be covered by the source-data.

To detect the CHANGE, the temporal analysis of four land use databases by mapping the historical development of the last 55 years and the actual situation on the base of aerial photographs and satellite data have been done. The final products are 1 “reference” and 3 “historical" land use databases for the urban and sub-urban areas. Each land-use database is derived by onscreen digitisation in the GIS into two line- and two area layers. The newest one, the reference land use database, is extracted out of high-resolution satellite imagery of the year 2000, which has been georeferenced to the topographical maps 1:25.000. The historical ones have been produced out of “historical data sets” like satellite-photographs, which have been georeferenced similar to the reference data, and aerial photos, which have been orthorectified by methods of digital photogrammetry.

Similar to topographical maps, other data-sources are available too. These are thematic maps, plans of the public transport system, master plans, other maps, economical data, demographic statistics, and analyses in literature. As far as suitable or available, they were taken into account. The processing of the data is sometimes difficult to make them comparable with the land-use data. The CHANGE data are related to them. This data are provided by the European and national statistical offices and by the local or regional offices. In the case of Istanbul, however, the official data and reality differ. The further goal was to combine the statistical data with the land use-database to receive spatial results. An introduction and the limits of a mixed data processing will be shown.

Finally, scenarios out of trend-analyses were undertaken and a virtual growth of the city was animated. Scenarios are able to visualise the problems of the city, while the urban sprawl is dramatically big. Data out of this project can be also a suitable base for emergency planning. Knowledge about GPS-GIS-connection on field-notebooks and wireless data transmitting of GPS-position to any headquarter is within the project-team and has already been discussed in order to set up additional projects. Especially in the field of earthquake monitoring and related planning, great efforts have been made in the western part of Turkey.

With the interpretation of the CHANGE-Data, key-areas of specific change can be detected and analysed. Such areas play a role for the development of the entire city and are result of a specific human impact. A number of environmental indicators are used to measure the sustainability of areas. They are related to political keys, such as law-restrictions. Especially in Istanbul, some changes (road-construction) initiated the growth of “Gecekondu” areas, which are very large nowadays.

According to our information, there are no detailed and complete studies, which would provide an overall picture of the spatial and time development of Istanbul. Studies available are named or implemented by the ancillary data sets and as far as possible integrated into spatial analyses. The use of the project data can be suitable in a large variety of applications, not only by the city of Istanbul, but also by the Ministry for Regional Development and the Ministry of Environment. The project could also contain some valuable information for the development of tourism and for potential investors. As mentioned above, it could also be part of the national earthquake management program. In this framework, the ancillary data-sets (i.e. geological maps) can provide a good base for this theme as well.

Another aim of this study is to give accurate values about both, the geometric and thematic result. Some approaches about thematic accuracy will be studied and the most suitable ones will be applied to the final results.

2.1 About land-use / land-cover detection

Although the terms land cover and land-use are often used interchangeably, their actual meanings are quite different. Land cover refers to the surface cover on the ground, irrespective of vegetation, urban infrastructure, water, bare soil or other. Identifying, delineating, and mapping land cover is important for global monitoring studies, resource management, and planning activities. The identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps.

Land use refers to the purpose the land is used for e.g. recreation, wildlife habitat, or agriculture. Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know current quantity of land is which type of use and to identify the land use changes from year to year. This knowledge will help to develop strategies to balance conservation, conflicts of use, and developmental pressures. Today, land-use studies analyse the removal or disturbance of productive land, urban encroachment, and depletion of forests.

It is important to distinguish between land-cover and land-use, and the information that can be ascertained from each. The properties measured with remote sensing techniques relate to land cover, from which land use can be inferred, particularly with ancillary data or priori knowledge.

Land-cover / use studies are multidisciplinary in nature, and thus the participants involved in this work are numerous and varied, ranging from international wildlife and conservation foundations, to government researchers, and forestry companies. Regional government agencies have an operational need for land cover inventory and land-use monitoring, as it is within their mandate to manage the natural resources of their respective regions. In addition to facilitating sustainable management of the land, land-cover and land-use information may be used for planning, monitoring, and evaluation of development, industrial activity, or reclamation. Detection of long-term changes in land cover may reveal a response to a shift in local or regional climatic conditions, the basis of terrestrial global monitoring.

Ongoing negotiations of aboriginal land claims have caused a need for more stringent knowledge of land information in those areas, ranging from cartographic to thematic information.

Resource managers involved in parks, oil, timber and mining companies, are concerned with both land use and land cover, e.g. local resource inventory or natural resource agencies. Environmental monitoring researchers, conservation authorities, and departments of municipal affairs will examine changes in land cover, with interests varying from tax assessment to reconnaissance vegetation mapping. Governments are also concerned with the general protection of national resources, and become involved in publicly sensitive activities including land use conflicts.

- Land use applications of remote sensing include the following:
- natural resource management
- wildlife habitat protection
- baseline mapping for GIS input
- urban expansion / encroachment
- routing and logistics planning for seismic / exploration / resource extraction activities
- damage delineation (tornadoes, flooding, volcanic, seismic, fire)
- legal boundaries for tax and property evaluation
- target detection - identification of landing strips, roads, clearings, bridges, land/water interface

This, along with the spatial and temporal analysis technologies i.e. Geographic Information System (GIS) and Global Positioning System (GPS), help with maintaining up-to-date land-use dynamics information for planning and a cost-effective decision. Land-use/ Land-cover change information has to play an important role on local, regional and on macro level planning. The planning and management task is hampered due to insufficient information on rates of land-cover/land-use change. The land-cover changes occur naturally in a progressive and gradual way; however, sometimes it may be rapid and abrupt due to anthropogenic activities. Remote sensing data of better resolution at different time interval help with analysing the rate of changes as well as the causal factors of driving forces for changes. Hence, it plays a significant role in regional planning at different spatial and temporal scales.

2.1.1 Overview and development

Since the first maps appeared, classification of the countryside has been done for orientation purposes. Land-use mapping started more than 3000 years ago. Of course, geometric forms have been estimated and the only most important classes like street, palace, house, field, forest and water have been taken into account. With the ongoing development in mapping, the details and number of classes have grown continuously. With the first geodetic measurements, the geometry has become better and accuracy has improved. In the Middle Ages, cartography was still a bridge between land-management, orientation tool, and art. The biggest change appeared with mapping science and the production of topographic maps. Terrestrial mapping on tables using rulers, telescopes and theodolites was used until the beginning of the 20th century. Work was slow and extremely time-consuming. The first photographs at the end of the 19th century helped with the image interpretation for the land-use classification. Made from elevated points or balloon, they still had limits in their visibility. The first planes at the beginning of the 20th century made the use of nadir viewing aerial cameras possible and the first roll-films opened the chance to take stereoscopic image series. Still up to today aerial images in very different scales are the main base in medium and big scaled mapping at the cadastral offices, not only for the land cover detection also for the geometric extraction of terrain and main objects. Photogrammetry developed rapidly and digital technology (Camera and Workstation) makes complete workflow in a PC possible. Since the 70ies, first commercial satellite imagery for mapping came to the market. Beside the meteorological and military sensor-data, Landsat TM – Data have been the most frequently used source for land-cover/use classification methods. Remote Sensing as an independent technology and discipline for these data-analyses appeared. The resolution of such satellite scenes limits the final product-scale and its accuracy. Using a ground pixel-resolution of about 30 m, Landsat is suitable for small and medium-scaled mapping. Geocoding is usually done by the use of available ancillary data sources like maps or surveyed control points. Therefore, the work on satellite data was more or less an interpreter’s work done by and for the users, i.g. geographers.

Photogrammetry and Remote Sensing is used for the collection and surveying of objects by means of imagery. Today, the formerly independent subjects "Photogrammetry", with the main focus on geometric questions, and "Remote Sensing", which mainly deals with the interpretation of imagery, are growing together. The main fields of applications of Photogrammetry & Remote Sensing are the collection and the update of topographic data for Geographic Information Systems (GIS), the collection of environmental parameters as well as 3D-measurement of objects in industry, medicine, architecture, archaeology, and other subjects. Today the main focus in research, development and practice lies in DIGITAL Photogrammetry & Remote Sensing: digital imagery is generated with the aid of CCD-Sensors and is processed in the computer in close coupling with GIS. A main aspect is the possibility of AUTOMATION of the various job steps. Besides the vision of the seeing (and understanding) robot there are highly relevant tasks, e.g. the automatic building of digital terrain models or the automatic extraction of topographic objects from aerial and satellite imagery.

As mentioned above, GISs are the key for combining theses different subjects. In the digital world we lose the scale and combine data of different resolution and accuracy for new products. With systems like these, spatial statistics are possible; also temporal data can be easily interpreted.

2.1.2 Comparison of different methods

Several techniques and methods are used for the detection of land-use and it's changes. All of them are important to achieve the desired results. These techniques can be listed as follows

- Photogrammetry
- Remote Sensing
- Terrestrial Geodetic Surveys and mapping

Photogrammetry is frequently used for land-cover/use detection. The aerial camera is usually placed in a wing-based aircraft. Up to now, analogue cameras like the RMK-Top are the most offen used ones. The advantage of selecting flight altitude, overlap and camera focal length makes photogrammetry very suitable, especially in densely urbanized areas. Another advantage of photogrammetry in land-use detection is that information on landscape can be collected and simultaneously the geometric information. According to focal length and flight altitude, a fine geometric resolution can be reached. Principally, aerial images are more accurate, reach a better resolution and provide the possibility of stereoscopic analyses with a brilliant accuracy. Today typical scales of aerial images range between 1:2000 and 1:20k, in digital form the resolution usually ranges from five to 50 cm per pixel and 5 -100 cm in height. One of the biggest advantages of aerial surveying is that the date of the imaging campaign is in local hands. If weather-conditions are favourable, the campaign can start. It is even possible to take images below the clouds at deeper altitudes or other focus length to adjust the time schedule.

Still, analogue cameras are offen used in the aerial surveying companies. After developing the film, scanning on photogrammetric scanners has to be done. This is a time and cost intensive procedure. The images are either coloured or pan-chromatic. On the other hand, many private companies provide aerial surveying and services around aerial imaging (scanning, orthorectification…), which lead to competition and relatively low prices. In some cases, aerial data are cheaper and in better quality than satellite imagery.

New developments in digital aerial cameras enrich photogrammetry, which improves land-use detection and mapping. Different channels, including infrared stored up to 16-bit radiometric resolution, offer completely new possibilities for feature extraction. These new aerial cameras give the chance of full automatic detection of land-use type. These cameras are still very scarce on the market and still have technical problems. Some of them operate as a push-broom scanner and this partly lose benefits of classical aerial cameras.

Another method for land-use detection related to photogrammetry is the orthorectification of the images to orthophotos. Using orthophoto for land-use detection is not only very accurate, but also meaningful for interpretation. The interpretation of aerial images in the non-nadir zone of the overlap renders interpretation of the heights of buildings and their vertical structure even on the orthophotos.

Remote sensing is based on digital sensors placed in satellites surrounding the globe on discrete routes. With the exception of older spy-satellites, most sensors are digital scanners with multi-spectral capabilities. Satellite imageries are usually in scale 1:10k and lower. For large areas, the big coverage is the more effective and cheaper technique for land-use detection. The big distance of the sensor, the small scan angle and typical nadir view make a sufficient orthometric-view of the image possible. Having all the data in digital form is also an advantage of remote sensing. Newly developed sensors are very useful, but depending on request not good enough for sufficient geometric accuracy. Typical resolutions range from 1 m to 50 m. Analysis of terrain or height of objects is a rarity and only possible with special sensors like Ikonos, Spot or radar-sensors. Their accuracy, however, is not sufficient.

A lot of new commercial sensors are surrounding the globe. Beside the new Spot-campaigns, the enhanced Landsat-7 (ETM+) reaches a better quality. The Indian Satellite IRS provides very high-resolution data with 5.8 m, which frequently have been used for urban area observation since the mid 90ies. With the launching of the Ikonos-Satellite 1999, a new generation of extremely high-resolution imagery appeared. With a resolution of 1 m of the pan-chromatic channel, very usable data became available even for monitoring urban areas and its land-coverage. With a resolution of 61 cm, the actual best high-resolution satellite is Quickbird, operating since 2001.

Limits of satellite imagery are also based on the repetition rate and the problem of the weather conditions where satellites are not able to adapt to. Usually satellite scenes have to be paid by a full scene, which makes them expensive. Older images are even available in quarter scenes but the basic price is still relatively high. The recently launched micro-satellites increase the competition between the various data providers.

In the field of multi-spectral sensors, the new strategy with cost-extensive micro-satellites carrying hyper-spectral sensors will surely change the market in the following years. While these mostly concentrate on the environmental sector, the field of urban remote sensing for land-use classification still deals with the high accurate data from IRS, Ikonos, Quickbird or aerial images.

The availability of remote sensing data applicable for global, regional, and local environmental monitoring has enormously increased during the last years. For several years, also old data have been more and more available for smaller budgets. The data of the military spy-satellites (Corona-mission and sputnik) have entered the commercial market. This improves the quality of data-sources for temporal analysis as presented in this study.

Terrestrial geodetic surveys, mapping and topographying

This method is not old-fashioned at all but might be more traditional than others. Geodetic surveys are still done to receive highly accurate geometric data, especially for cadastral work. In the meantime, they are often combined with engineering projects. Topographers usually use geodetic surveys for validation of the coordinate system only, and as a basic point-net. In medium and small-scale applications, survey is reduced to the measurement of control-points as done for aerial survey campaigns. It is the most accurate method and the reference application for all the others. Its accuracy is in the dimension of millimetres. The analogue and electronic instruments like Theodolites and Tachymeters are mostly replaced by Total-Stations. For the last 10 years, geodetic DGPS-Systems (Real-Time-Kinematics) have provided independent measurements using carrier-phase signals and correction data integration. Accuracy can reach even millimetres, depending on the system and DGPS-Services.

While in the past mapping was the typical field of topographers and cartographers, it is today mostly executed using photogrammetry and remote sensing. Geometry is usually achieved by photogrammetric processing. Field-campaigns take place just for additional interpretation. Mapping is more or less the field-sensing of remotely sensed data, but anyway an important task. Some information, however, can only be received by mapping, especially details that are covered for the sensors. Some types of mapping need a more specific education than geodetic or photogrammetric knowledge, i.e. only view information for geology, soil-type-definition, forest and others can be extracted from RS-Data sources. Nowadays, more information can be extracted with the hyper-spectral sensors, i.g. water quality or others: nevertheless, fieldwork will not disappear in the near future.

Another use is the validation of the results reached by other techniques. For that purpose, small test areas are selected and mostly surveyed by GPS or DGPS. Using automated classification tools in RS Software-programs, training-sets have to be defined which usually are received by terrestrial work. Also here, GIS makes work better, faster and more accurate. GIS combined with GPS on a field-PC allow measurements to be done on extracted data or pre-classified results directly in the GIS environment. Mainly the orientation in the field and direct access to the data makes work much more effective than in the past.

By measurement of control-points, which sometimes have to be marked, field-observation starts with geodetic surveying for framing the photogrammetric and RS methods Finally, Field-GIS applications control and validate the extracted results.

Beside local terrestrial work, ground truth-stations provide the service-operators of the satellite sensors with related data to validate the quality of the produced RS-data continuously. Such stations can provide several sensors, which give the opportunity for cross-validation.

Methods for image-based Land-use Detection

In general, methods for land-use detection can be summarized in three groups. These are:

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

Land-use detection applications have two main procedures. One of them is determining the land, its geometric form and size by detecting its borders and neighbours. The second is defining the land-coverage related to its use. Problems can already occur when two neighboured areas with the same land-use class are supposed to belong to each other, but are defined as different geometric objects. They might be separated by a street that has only a line feature and not a coverage due to the generalisation. On the other hand, land-use is not always clearly limited i.g. if we monitor a coastline where the definition of the border between beach and sea is not fixed. Very often, a border-zone can be detected, which makes it difficult to define a clear line.

The main differences between these methods are not only the procedures done by microprocessors or operators and their interference; it is also the limit and scale of the results and their quality. This quality is different to the geometrical accuracy of results. It describes the quality of the spatial database, in which the land-use patterns are saved. It can be said that the term “manual method” refers to applications where both of the two main procedures (geometry and use) are done manually. In semi-automatic methods, one of them is automatically done by microprocessors and in full-automatic methods both of them are done in this way.

Manual methods mean that an operator establishes the definition of size and form. Usually land-use mapping is made in GIS and the patterns are defined as vector-data. Thus, a border as a closed line (polygon) has to be defined first. As a next step the operator defines the land-use according to a legend by visual interpretation of the image and with the help of ancillary data. Usually the area inside the polygon is defined by database-attributes, carrying the land-use information. Operators have to be trained, but there is still a variation between the different operators working on the same objects. This method is not free of individual variation (brain-model), which has to be taken into account. The greatest disadvantage of this method is the manual work, which is time consuming and cost-intensive. However, there are also advantages in the manual method. The accuracy in detecting the geometry is better than in automated methods because context analyses can be done. The detection of the land-use is also done in a context by using ancillary data, local knowledge and field-observations in difficult situations. Areas that are difficult to classify, can be described by additional information stored in the database. Manual methods work better if there are more classes. The operator can work cross wise on data of various resolutions or just with pan-chromatic data – which makes this method the best for the very complex urban land-use detection.

Semi-automated methods e.g. manual segmentation and automated classification or both, need the interaction of an operator. Depending on the automated algorithms and the interactive work of the operator, this method offers the possibility for controlled classification. If the automated procedures work properly, this method usually gives good and reliable results, however, manual work can be time-consuming. If the automated procedures fail, the work for corrections might be considerably larger than direct manual classification. So far, these methods meet limits in high-resolution and detailed classification procedures especially in urban areas. Context-analyses are difficult to realise and the need for equal and multi-spectral data is similar to that of the automated methods.

Automatic methods are the most common ones for land-use detection on multi-spectral data for medium and small-scaled data. Automation has always some advantages in all areas of applications. Saving manpower and objectivity by mathematic algorithms is the advantage of these automated methods. Important for all automatic methods is the definition of the so-called classifiers, which represent specific information on the pixel. There are different strategies in automated procedures, supervised and unsupervised ones.

Unsupervised classification is the identification of natural groups, or structures, within multi-spectral data by the algorithms programmed in the software. The following characteristics apply to an unsupervised classification:

- There is no extensive prior knowledge of the region that is required for unsupervised classification unlike supervised classification that requires detailed knowledge of the area.
- The risk of human error is minimized with unsupervised classification because the operator only specifies the number of categories desired. Many of the detailed decisions required for supervised classification are not needed for unsupervised classification, creating fewer situations for the operator to make mistakes.
- Unsupervised classification allows unique classes to be recognized as distinct units. Supervised classification may allow these unique classes to stay unrecognised and could inadvertently be incorporated into other classes, creating errors throughout the entire classification.

Supervised classification is the process of using samples of known identities to classify pixels of unknown identity. The following characteristics apply to a supervised classification:

- The analyst has control of a set of informational categories tailored to a specific purpose and geographic region.
- Supervised classification is tied to specific areas of known identity, provided by selecting training areas.
- Supervised classification is not faced with the problem of matching spectral categories on the final map with the informational categories of interest.
- The operator may be able to detect serious errors by examining training data to determine whether they have been classified correctly.
- In supervised training it is important to have a set of desired classes estimated in advance, followed by the creation of appropriate signatures from the data. It is a need to have some ways of recognizing pixels that represent the classes to be extracted.

A nonparametric classifier uses a set of nonparametric signatures to assign pixels to a class based on their location, either inside or outside the area in the feature space image. “Parallelepiped” or the “box decision rule classifier” are procedures where two image bands are used to determine the training area of the pixels in each band based on maximum and minimum pixel values. In the parallelepiped decision rule, the data file values of the candidate pixel are compared to upper and lower limits. These limits can either be the minimum and maximum data file values of each band in the signature, the mean of each band, plus and minus a number of standard deviations, or any limits that have to be specified, based on knowledge of the data and signatures. The feature space decision rule determines whether or not a “candidate” pixel lies within the nonparametric signature in the feature space image. Parametric methods of supervised classification take a statistical approach. “Maximum Likelihood” is a classification method, which uses the training data as a means of estimating means and variances of the classes, which are then used to estimate probabilities. Maximum likelihood classification not only considers the mean or average values in assigning classification, but also the variability of brightness values in each class. It is the most powerful of the classification methods as long as accurate training data are provided. The maximum likelihood decision rule is based on the probability that a pixel belongs to a particular class. The basic equation assumes that these probabilities are equal for all classes and that the input bands have normal distributions. The maximum likelihood algorithm assumes that the histograms of the bands of data have normal distributions. Mahalanobis distance classification is similar to minimum distance classification, except that the covariance matrix is used in the equation. The minimum distance decision rule (also called spectral distance) calculates the spectral distance between the measurement vector for the candidate pixel and the mean vector for each signature.

Based on fuzzy logics in combination with neuronal networks, a complete new generation of tools has appeared on the market, which opens completely new methods for automated classification. However, they are only in the scientific status and in the testing-phase. In combination with feature extraction for measuring the geometry in 3D, complete new possibilities for automated processes appeared. Those systems are able to combine different sources e.g. laser-scanned data, to give redundancy in the detection strategies. Nevertheless, such data have to be available. The new algorithms are able to detect what is visible on the images, even in context analyses and in statistical probability – however, such system has to be trained locally.

For automatic land-use detection, the capability of microprocessors is still insufficient. Especially by defining the land-use of urban areas, these systems still are insufficient for data extraction and the results have to be validated intensively by operators. Some applications on land-use detection in urban areas are not sufficient for accessing high quality for land-use database. As an example, for the separation of urban fabric and industrial areas, roofs with tiles and flat roofs are used by their spectral reflectance. In most cases, this approach alone is ineffective and must be validated manually.

In this study, the manual method has been selected according to the great variety offered by the MOLAND legend. The legend of this study contains very complex patterns so that conventional full or semi automatic methods fail. As an example, residential and commercial areas differ from each other in the legend and this difference cannot be determined unless using an operator's interpretation and knowledge. The data sources are only partly multi-spectral; most data are pan-chromatic to reach the resolution required. Especially historical data based on aerial images are not sufficient for semi-automated or automated classification. Moreover, no application can be expected to fulfil the detailed classification into the predefined MOLAND-Legend at all.

2.1.3 Legends: CORINE, MURBANDY and MOLAND

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric 1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units 1.2.2. Road and rail networks 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
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas 1.4.2. Sport and leisure facilities
2. Agricultural areas	2.1.Arable land	2.1.1. Non-irrigated arable land 2.1.2. Permanently irrigated land 2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards 2.2.2. Fruit trees and berry plantations 2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Ann. crops associated with perm. crops 2.4.2. Complex cultivation patterns 2.4.3. Land principally occupied by agriculture 2.4.4. Agro-forestry areas
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest 3.1.2. Coniferous forest 3.1.3. Mixed forest
	3.2. Shrub and/or herbaceous vegetation association	3.2.1. Natural grassland 3.2.2. Moors and heath land 3.2.3. Sclerophyllous vegetation 3.2.4. Transitional woodland shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, and sand plains 3.3.2. Bare rock 3.3.3. Sparsely vegetated areas 3.3.4. Burnt areas 3.3.5. Glaciers and perpetual snow
4. Wetlands	4.1. Inland wetlands	4.1.1. Inland marshes 4.1.2. Peat bogs
	4.2. Coastal wetlands	4.2.1. Salt marshes 4.2.2. Salinas 4.2.3. Intertidal flats
5. Water bodies	5.1 Inland waters	5.1.1 Water courses 5.1.2 Water bodies
	5.2 Marine waters	5.2.1 Coastal lagoons 5.2.2 Estuaries 5.2.3 Sea and ocean

Table 1: *Overview about the CORINE-Level 1-3Legedary defined by the EC*

As already mentioned before, land-use mapping has a long history. Every topographic map carries information about the main land-cover classes. Beside the description of areas like fields, forests, water-bodies and others, particularly objects like the transportation network are usually shown. Topographic maps aim to represent the landscape; land-use mapping was not the main focus. First applications appeared for solving specific thematic problems in land-management, based on aerial images, first in pan-chromatic and later also in colour and CIR.

Despite the high demand for environment and natural resources information, many available maps and digital databases are not specifically developed to meet the various requirements of the user. One of the main causes, though generally underestimated, is the type of classification or legend used to describe basic information such as land cover and land use. Many of the available classifications are generally not comparable with others and very often are single project oriented or made for a sectoral approach. Many classification systems exist throughout the world, there is no standardised internationally accepted land cover or land use classification system.

Land-cover classes can be defined by the combination of a set of independent diagnostic criteria, the so-called classifiers that are arranged hierarchically to assure a high degree of geographical accuracy. Because of the heterogeneity of land cover, the same set of classifiers cannot be used to define all the land cover types. The hierarchical structure of the classifiers may differ from one land cover type to another. This allows the use of the most appropriate classifiers and reduces the total number of impractical combinations. Further definition of the land cover class can be achieved by adding attributes.

The European Commission (EC) introduced the CORINE (Coordination of Information on the Environment) Programme in 1985 in order to gather information relating to the environment for the European Union. In order to determine and assess the effects of the Community's environment policy, it is important to have a proper understanding concerning the different features of the environment like the state and geographical distribution of individual environments and natural areas, the quality and abundance of water resources, land cover and soil state, the amount of toxic discharges and natural hazards (Heymann et.al., 1994).

The basic concept of CORINE land cover classification has to be produced by using satellite images. The mapping scale of this classification is 1:100k and mapping accuracy is at least 100 m. The minimum mapping unit is 25 hectares and minimum width of units is 100 m. Only area elements are classified. The database includes 44 categories in accordance with a standard European nomenclature, organised into five large groups: artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands, water bodies. The classification nomenclature is hierarchical and has been developed in order to map the whole EU territory (see: Büttner et.al., 2002).

Originally, the land cover classification was performed as a visual interpretation of hardcopy printout of LandSat Thematic Mapper satellite images. Digital image processing software was used to prepare the geometric, radiometric, and spectral properties of satellite image so that the good hardcopy printout could be produced. A transparency was overlaid on 1:100k printout of satellite image and areas were delineated and interpreted to the printout with the help of ancillary data like maps and fieldwork. Afterwards the transparencies were digitised. Obviously, the procedure is prone to errors, due to the use of hardcopy products and digitisation (Bossard et.al., 2000).

From 1985 to 1990 the EC has implemented the CORINE Programme. In 1991, it was decided to extend three main CORINE inventories (Biotopes, Corinair and Land Cover) to the Central and Eastern European countries. Since 2000 a new CORINE campaign has been launched to update the data available and to add new associated countries into the European–wide database of land-use patterns.

The European Union belongs to the most urbanized parts of the world and future urban development will be confronted with the finite availability of land. For this reason, the European Commission has initiated a number of studies such as Monitoring Urban Dynamics (MURBANDY) that promote homogeneous and equilibrated development of Europe's landscapes. MURBANDY identifies Earth Observation (EO) as a measurement procedure that can provide a synoptic view on European cities. Spatial analysis and modelling activity are carried out to understand urban cities in their relationship with the environment and the availability of renewable resources. MURBANDY was focused on 15 European cities and launched in 1998. MURBANDY is subdivided into three components, CHANGE, UNDERSTAND

and FORECAST. CHANGE aims at implementing an EO based procedure for monitoring land cover/- use changes in urban and peri-urban areas using very-high resolution satellite imagery. Land use databases covering 40 years and the changes resulting from these have currently been established. The data sets developed are structured within a geographic information system framework that will also include non-EO data. UNDERSTAND aims at computing static and dynamic EO based urban indicators as well as at EO/non-space data environmental indicators to help to understand urban and peri-urban landscapes and their dynamics. FORECAST aims at developing scenarios of urban growth under current and/or future policies and economic systems to assess the sustainability of Europe's landscapes.

Efforts in processing historical data sets in general depend on the nature and the type of data (e.g. aerial photos, orthophotos, maps). Minimum mapping unit is one ha for artificial surfaces and three ha for non-artificial Surfaces. The reference land-use database was produced from photo-interpretation techniques of the IRS-1C imagery, corresponding to a 1: 25,000 scale map The GIS data had to be provided in the topological Arc/Info compatible format.

In contrast to CORINE, a linear feature like transportation (road and rail) and river network has been digitised, too. The land-use pattern was defined by polygon-areas with a related database at the labelled centre-point. To meet the need for urban land-use classes, MURBANDY uses the CORINE Land Cover nomenclature, whereas for artificial surfaces a fourth level was added in order to meet the accuracy.

Level 1	Level 2	Level 3	**Level 4 (new, introduced for MURBANDY)**
1. Artificial surfaces	1.1 Urban fabric	1.1.1 Residential continuous urban fabric	**1.1.1.1 Residential continuous dense urban fabric** **1.1.1.2 Residential continuous medium dense urban fabric**
		1.1.2 Residential discontinuous urban fabric	**1.1.2.1 Residential discontinuous urban fabric** **1.1.2.2 Residential discontinuous sparse urban fabric**
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or 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**
		1.2.2 Road and rail networks	**1.2.2.1 Toll-ways** **1.2.2.2 other roads** **1.2.2.3 Railways**

Table 2: *For MURBANDY added Level 4 classes to the CORINE-Legendary defined by the EC*

While CORINE is interested in the actual land-use coverage, MURBANDY aims to detect the change by down dating the reference year by 3 older dates on which data are available. Historical land use databases are produced through interpretation and comparison with the reference image and reference database. Technical details are the same as for the reference database. Separate linear layers and polygon-layers finally produce 8 datasets, which represent the change and enable spatial analyses.

MOLAND followed the MURBANDY project that led to a few modifications in the legend. This legend was improved by the knowledge of the MURBANDY project, which showed that additional classes sometimes simplify the manual work. Sometimes an aggregation is necessary in order to be comparable to CORINE, MURBANDY or others. Nevertheless, the more detailed information is kept, the more compatibility will be guaranteed.

2.2 MOLAND Legend

In order to conform to EC standards, the nomenclature of the MOLAND project is based on the MURBANDY legend, which on its own is based on CORINE land cover nomenclature. There are two main differences:

1.)The CORINE land cover project represents *a conceptual tool for land cover analysis*, while monitoring land use/cover dynamics (MOLAND) means that both socio-economic functions (land use) and territorial features (land cover) are considered at the same time. This is the biggest content-difference between both, although they are comparable on the lower level of CORINE.

2) The level of detail is different. The scale chosen for the CORINE project is 1:100,000 and the minimum mapping unit are 25 hectares. The scale of MOLAND is 1:25,000, and the minimum mapping unit is 1 hectare. When defining this unit it must always be kept in mind that in reality (in the field) land cover always occurs as a combination of surfaces, which are to a higher or lesser degree homogeneous/heterogeneous, no matter which scale is used. Therefore, the CORINE nomenclature is not always compatible with the purposes of MOLAND. For instance, CORINE states that class 1.1.2 (discontinuous urban fabric) can be distinguished because “buildings, roads and artificially surfaced areas cover between 50% and 80% of the total surface area of the unit”. The same area investigated at the scale of MOLAND would be divided in smaller zones. Consequently, it would most probably show parts where artificially surfaced areas cover more than 80% of the total surface area of the unit, and correspond to continuous urban fabric.

It is therefore of basic importance to keep in mind that a feature having a certain attribute in CORINE, might have a different one in MOLAND, because the mapping unit is smaller and the scale more detailed.

For the same reason a fourth, more detailed level was introduced for “Artificial surfaces” and “Water bodies”. This fourth level was derived taking CLUSTERS into account (the legend produced by EUROSTAT for statistical purposes) and FAO land cover legend.

The transport network (roads, motorways, railways, and river channels) is also produced for each area, at the different dates.

The following is the legend adopted by MOLAND. The third level is in accordance with the CORINE Land Cover, with slight modifications: the changes introduced by MOLAND are mostly in level four. In the fourth level, the new classes introduced by MOLAND can be found.

Table 3*: MOLAND-Classes, which have been used for the Land-use classification for Istanbul*

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 services
			1.2.1.5 Archaeological sites
			1.2.1.6 Places of worship (no cemeteries)
			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	

2. Agri-cultural 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 principal occupied by agriculture , with significant areas of natural vegetation	2.4.3.1 Prevalence of arable land and significant areas of natural vegetation
			2.4.3.2 Prevalence of pastures and significant areas of natural vegetation
		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	

2.2.1 Detailed Description of the MOLAND-Classes

The following description is a SOP /Standard operation procedure) handed out by the JRC (Joint Research Centre in Ispra) of the EC and modified by myself during the project. Such modifications did not change the definition of the class in principle; moreover, non-sharp descriptions have been modified in order to meet the best classification. Nevertheless, if you do the job seriously, you will always meet areas, which are between two or three classes. Anyway, those problems will be discussed by examples later.

Class 1 Artificial Surfaces

Class 1.1 Urban Fabric

Class 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 Database-field Comments or as 1.2.2.2 in the field Alt-legend) will be described in the GIS attributes table.

Class 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" only refers to buildings, roads and concrete areas (thus excluding green spaces such as gardens). More than 50% of the buildings have three or more levels.

Class 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 part of residential structures). Less than 50% of the buildings have three or more levels.

Class 1.1.1.3 Informal settlements

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

Class 1.1.2 Discontinuous urban fabric

Most of the land is covered by artificial structures. Buildings, roads and artificially surfaced areas are associated with vegetated areas and bare soil, which cover discontinuous but significant surfaces. This type of land cover can be distinguished from continuous urban fabric by the presence of permeable 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 GIS attributes table.

Class 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).

Class 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 vegetative areas are predominant, but the land is not dedicated to forestry or agriculture.

Class 1.1.2.3 Residential urban blocks

High-rise apartments buildings with eight or more stories (including “panel houses” for areas located in former European socialist countries)

Class 1.1.2.4 Informal discontinuous residential structures

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

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

Artificially surfaced areas (with concrete, asphalt, 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.

Class 1.2.1.1 Industrial areas

Surfaces occupied by industrial activities, including their related areas.

Class 1.2.1.2 Commercial areas

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

Class 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).

Class 1.2.1.4 Technological infrastructures for public service

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

Class 1.2.1.5 Archaeological sites

Including monuments, fortresses, ancient walls, castles, palaces etc.

Class 1.2.1.6 Places of worship (not cemeteries)

Sanctuaries, convents, monasteries, holy places, mosques

Class 1.2.1.7 Non-vegetative cemeteries

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

Class 1.2.1.8 Hospitals

Class 1.2.1.9 Restricted access services

Military areas, nuclear power plants, etc.

Class 1.2.1.10 Agro-industrial complexes

Buildings like animal sheds, production buildings, and 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 like LPGs in eastern parts of Germany, and 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 MOLAND 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.

Class 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).

Class 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.

Class 1.2.2.1 Fast transit roads and associated land

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

Class 1.2.2.2 other roads and associated land

Normal roads open for public, including roundabouts.

Class 1.2.2.3 Railways and associated land

Including railway stations and directly connected technical areas

Class 1.2.2.4 other rails

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

Class 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 GIS attributes table. The words used in the “Integrative information” column are BRIDGE, VIADUCT, TUNNEL, and FLYOVER. A bridge is defined by a big span between the columns and uses only 1 or a few pairs of them while a viaduct is put on a big number of columns more as an elevated road.

Class 1.2.2.6 Parking sites for private vehicles

Including car parks at supermarkets, ports. etc.

Class 1.2.2.7 Parking sites for public vehicles

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

Class 1.2.3 Port areas

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

Class 1.2.4 Airports

Airport installations: runways, buildings and associated land.

Class 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.

Class 1.3.2 Dump sites

Landfill or mine dump sites, industrial or public.

Class 1.3.3 Construction sites

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

Class 1.3.4 Abandoned land

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

<u>Class 1.3.4.1 Bombed areas</u>

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 GIS attributes 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 GIS attributes table.

Class 1.4.1 Green urban areas

Areas with vegetation within urban fabric. Includes city parks and wider green bands

<u>Class 1.4.1.1 Vegetated cemeteries</u>

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

Class 1.4.2 Sport and leisure facilities

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

Class 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.

<u>Class 2.1.1.1 Arable land without dispersed vegetation</u>

<u>Class 2.1.1.2 Arable land with scattered vegetation</u>

Scattered vegetation occupies less than 15% of the referred area.

<u>Class 2.1.1.3 Greenhouses</u>

<u>Class 2.1.1.4 Drained arable land</u>

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

Class 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.

Class 2.1.3 Rice fields

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

Class 2.2.1 Vineyards

Areas planted with vines.

Class 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.

Class 2.2.3 Olive groves

Areas planted with olive trees.

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

Class 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.

<u>Class 2.3.1.1 Pastures without trees and shrubs</u>

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

<u>Class 2.3.1.2 Pastures with trees and shrubs</u>

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

Class 2.4.1 Annual crops associated with permanent crops

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

Class 2.4.2 Complex cultivation patterns

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

<u>Class 2.4.2.1 Complex cultivation patterns without settlements</u>

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

<u>Class 2.4.2.2 Complex cultivation patterns with scattered settlements</u>

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

Class 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.

<u>Class 2.4.3.1 Prevalence of arable land and SANV</u>

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.

Class 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.

Class 2.4.4 Agro-forestry areas

Annual crops or grazing land under the wooded cover of forestry species including "Dehesa".

Class 3.1.1 Broad-leaved forests

Vegetation formation principally composed 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, has to be pointed out and described in the column "Comments" of the GIS attributes 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).

Class 3.1.1.1 Deciduous forest with continuous canopy

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

Class 3.1.1.1 Deciduous forest with discontinuous canopy

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

Class 3.1.1.2 Evergreen forest with continuous canopy

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

Class 3.1.1.3 Evergreen forest with discontinuous canopy

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

Class 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 is be pointed out and described in the column "Comments" of the GIS attributes 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).

Class 3.1.2.1 Coniferous forest with continuous canopy

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

Class 3.1.2.2 Coniferous forest with discontinuous canopy

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

Class 3.1.3 Mixed forests

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

For any of the following level 4 classes, it has to be pointed out and described in the column "Comments" of the GIS attributes 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).

Class 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 referred area.

Class 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 referred area.

Class 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 referred area.

Class 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 referred area.

Class 3.2.1 Natural grassland

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

Class 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 referred area. Including alpine/subalpine grasslands, steppic grassland. The relevant observations and particularities in the column "Comments" of the Arc-Info attributes table have to be added.

Class 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 Arc-Info attributes table.

Class 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.

Class 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 has to be pointed out and described in the column "Comments" of the GIS attributes 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).

<u>Class 3.2.2.1 Heath land</u>

Mainly dense shrubs and herbaceous plants.

<u>Class 3.2.2.2 Dwarf pine</u>

Class 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, has to be pointed out and described in the column "Comments" of the GIS attributes 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).

Class 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, has to be pointed out and described in the column "Comments" of the GIS attributes 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).

<u>Class 3.2.4.1 Artificial young stands</u>

Planted young stands after logging.

<u>Class 3.2.4.2 Natural young deciduous stands</u>

<u>Class 3.2.4.3 Natural young coniferous stands</u>

<u>Class 3.2.4.4 Wooded fens, bog and wooded transitional bog</u>

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 Arc-Info attributes table is added if known.

Class 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.

Class 3.3.1.1 Dunes

Class 3.3.1.2 Beaches

Class 3.3.1.3 Inland sand

Including other soft sediments, such as riverbanks.

Class 3.3.2 Bare rock

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

Class 3.3.2.1 Littoral/sub-littoral rocks

Class 3.3.2.2 Coastal cliffs

Class 3.3.2.3 Inland cliffs/bare rock/volcanic debris

Class 3.3.3 Sparsely vegetated areas

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

Class 3.3.3.1 Sparse vegetation on sands

Class 3.3.3.2 Sparse vegetation on bare rock

Class 3.3.4 Burnt areas

Areas affected by recent fires.

Class 3.3.5 Glaciers and perpetual snow

Land covered by glaciers and permanent snowfields.

Class 4.1.1 Inland marshes

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

Class 4.1.1.1 Marshes with reeds

Class 4.1.1.2 Marshes without reeds

Class 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.

Class 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.

Class 4.1.2.1 Exploited peat bog with lawn communities

Class 4.1.2.2 Unexploited peat bog with lawn communities

Class 4.1.2.3 Peat bog with pool communities

Class 4.2.1 Salt marshes

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

Class 4.2.1.1 Salt marshes with reeds

Class 4.2.1.2 Salt marshes without reeds

Class 4.2.2 Salinas

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.

Class 4.2.3 Intertidal flats

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

Class 5.1.1 Water courses

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

Class 5.1.1.1 Canals

Class 5.1.1.2 Rivers

Class 5.1.2 Water bodies

Natural or artificial stretches of standing water.

Class 5.1.2.1 Natural standing waters

Class 5.1.2.2 Artificial reservoirs

Class 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.

Class 5.2.2 Estuaries

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

Class 5.2.3 Sea and oceans

Zones seaward of the lowest tide limit.

2.3 Use of geographic information systems GIS

What is a Geographical Information System (GIS)? Some definitions found in literature:

- A powerful set of tools for storing and retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes. *(Burrough, 1986)*
- Automated systems for the capture, storage, retrieval, analysis, and display of spatial data. *(Clarke, 1995)*
- An information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, and a set of operations for working with the data. *(Star and Estes, 1990)*
- GIS is a System of computer software, hardware and data, and personnel to help for manipulate, analyse, and present information that is tied to a spatial location. *(www.gis.com)*
- In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations. Practitioners also regard the total GIS as including operating personnel and the data that go into the system. *(USGS, http://www.usgs.gov/research/gis/title.html)*
- A geographic information system is a special kind of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines, or areas. A geographic information system manipulates data about these points, lines, and areas in order retrieve data for ad hoc queries and analyses. *(Dueker, 1979, p 106)*
- An organized collection of computer hardware, software, data, and personnel designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information. *Understanding GIS, ESRI, Inc.*

GIS has evolved out of a long tradition of map making. Modern GIS dramatically increases the amount of information that can be contained and manipulated in a map. On the other hand, many of the same cartographic conventions and limitations apply to digital maps. Like all models, maps are simplified representations of reality. It is very difficult to draw and interpret multiple information themes on one map sheet that covers a big area. Before computers became widely available, thematic maps on transparent sheets had been put on top of each other, revealing more information about an area than it was possible with any one-sheet paper map. Similar technology was used for the preparation of map printing while different colours had been placed on different sheets. In some cases, 20 of such layers had been produced. Colour, signatures, symbols and small text-information deliver the information to the maps; nevertheless, these layers still are not linked to spatial database structure and like that not able to do an automated querying, filtering or further analysing operation.

GIS technology evolved through multiple parallel but separate applications across numerous disciplines. From the start vector-data in CAD applications and raster methods in military systems operated independently. The early GIS packages were often written for specific applications and required the mainframe computing systems usually found in government or university settings. In the 1970s, private vendors began offering off-the-shelf GIS packages. M&S Computing (later Intergraph) and Environmental Systems Research Institute (ESRI) emerged as the leading vendors of GIS software. In 1981, ESRI released Arc/Info, a standard package which ran on mainframe computers. As computing power increased and hardware prices plummeted in the 1980s, GIS became a viable technology for state and municipal planning. In the 1990s, GIS was slowly being adopted on the sub-municipal level by neighbourhood organizations and community-based agencies. The GIS development for Microsoft Windows OS enabled to spread graphic orientated applications on PC environment – now available for smaller budgets. Since the late 1990ies, GIS has been adapted to Webservers in order to distribute maps and spatial analysis over the Internet. Many of the hardware and licensing expenses of a full software package have been eliminated by this. This has also increased the availability of spatial data to underfunded groups like educational, scientific and many others. Although access to both GIS software and spatial data sets has improved, the adoption of GIS as a planning or research tool still represents a significant commitment by community organization. Terminal Server Technology also reached the GIS and based on Windows CE, GIS is adapted to Palms and Organisers and fits in the pockets of the young generation.

For this project, TopoL-GIS was selected as a good priced and powerful instrument for data processing. The program TopoL for Windows, a product of TopoL-Software s.r.o. in Prague / Czech Republic, allows graphic data creation, maintenance, analysis and presentation on plotter or printer.

TopoL is capable to handle both vector and raster data equally well. Additional descriptive information can be attached to the graphic data and stored in local or external databases. Programmers of the software have taken intensive care on topology and support for topographic structures of vector data. Digitising capabilities of TopoL are easy to use and the system is able to solve topologic relations in real-time while data are being digitised. It means that during the creation of polylines the system calculates their nodes (intersections of polylines) in real time. Thus, only by defining the position of the label point of this area, TopoL creates the area and automatically finds the polylines, which create the boundaries. TopoL can import and export data in many industry-standard formats. TopoL is especially strong in its ability to create composite black-and-white or colour raster-and-vector output - for example, property boundary outlines superimposed on a scanned aerial photograph.

Users can input vector data through manual digitising of existing maps by mouse or special digitising devices. It is also possible to digitise vector data on scanned raster images displayed on the screen. Various methods of snap, adjustable grid and local zoom tools are available during manual digitising of vector data to help users.

Raster data capabilities enable the handling of binary, grey-scale and colour raster images. Very huge files (up to hundreds of MB) can be processed. The system works with TIFF, BMP and TopoL's RAS formats. It is also able to import raster data in various formats including raw binary, HRF, PCX, CIT (CCITT Group 4), GIF, JPG, BMP, and TIFF formats.

Database functionality of TopoL is based on dBase (DBF) format and includes full database facilities and various analysis tools. The system enables users to create and edit local database structures for every feature class (called group) of vector objects separately in each vector layer (called block). In this way TopoL supports definition of class attributes in the object-oriented fashion. Then users can specify descriptive information manually at any moment during or after vector data digitising. The system is also able to import these data into local databases from text files or from external DBF databases. External DBF databases might easily be linked through user-defined database models, which also support 1: N links.

TopoL provides various vector and raster data operations, which enable users to manipulate their data. Full-featured geometric transformations (similarity, affinity, co linearity, polynomial transformation) of vector and of raster data are implemented, including identical points definition and transformation (deviation) table manipulations as well as the possibility to transform vector and raster data in parts. Raster operations allow rotation, resampling, cutting and masking raster data as well as their combination into mosaics. The system is also able to compress and decompress raster data. Statistical information, like histograms, is available. Image processing functions include arithmetic and logic operations; local pre-processing (averaging, median, rotating window, sharpening and post-classification filters); edge operators (Sobel and Previtt operators, manual thresholding, binary thinning, smoothing and boundary detection) and texture processing. Spectral analysis embodies multi-spectral edge detection; neural networks compression, linear combinations and colour composition. Satellite image classifications include non-supervised cluster analysis (k-Means clustering) and supervised methods (k-NN, parallel

pipe, k-Means classifications). Statistical analysis tools also provide correlation matrix, entropy and dependence factors.
Processing of aerial images is possible in PhoTopoL, which is a digital photogrammetric workstation based on TopoL-GIS. PhoTopoL is an advanced system, which permits performing automatic correlation, orthorectification and digitising in a proprietary topologic environment. The vectors are superimposed on the stereoscopic pair and vectors digitised in other format, like DXF or DGN can easily be im - and exported.

For the exterior orientation, tools have been programmed to work with the bundle adjustment *AeroSys,* developed in the U.S.A. The digital terrain model has been created with the Atlas DTM module, developed also in the Czech Republic, by the Atlas Ltd. company. It is a system that permits correcting the altitude of points captured by automatic correlation, thus allowing creation of an automatic contouring ready to print. Moreover, it has other interesting capabilities, like the creation of video file for visualizing the ground, creating sections, analyse the signal propagation or the visibility of areas, hydraulic tools and others. One of the last developments is the tool to create digital models of terrain containing buildings. The operating system is Windows; recommended are Windows 2000 or XP

The basic program for digitising includes the basic photogrammetric functionality, import and export of rasters, interior and exterior automatic orientation, acquisition of data for the bundle adjustment, bundle adjustment AeroSys and full vector operational tools in topologic geographic information system for digitising in 2 and 3D including database and CAD functionality.

Apart from the orthorectification, the Orthophoto-Module allows masking and mosaicing utilities, balance of colours, geometric correction and raster DEM creation with geometric data obtained from digitising or from automatic correlation.

The automatic correlation module includes the epipolar pair creation and automatic image matching for creation of raster digital terrain. The Atlas software is an essential module in the PhoTopoL Atlas bundle. It creates the irregular network of triangles to create the automatic contouring, correction of bad points on-line with TopoL, net refining with correction of altitudes, superimposition of photos on the digital model, creation of virtual reality videos, maps of hypsometry, slopes, and options for sections, visibility, electromagnetic signal propagation, hydraulic tools and many other functions for mining calculations etc.

2.4 Layers, Data-Structure and Data-models of GIS

Spatial data is information, which is linked to a specific location. In many cases, the difficult part of setting up data for a GIS is linking information to a location, a process known as geocoding. Within a particular data set there must be an element that specifies its location. In the best case, this should be a map coordinate, but it could also be a postcode or street address. The element within the data that identifies the location is known as its geocode. A comprehensive understanding of the nature of geographical information is crucial in the data collection process and for the success of GIS as a whole. We have to be aware of the consequences of bringing together datasets collected at different scales, as well as of the accuracy in the locations of features as roads on small scale datasets.

Reality is too complex, even for the most sophisticated GIS software. Thus, in order to represent reality in a spatial database, a simplification of reality has been created. This simplification is known as a data model. In a data model reality is simplified into only four spatial entities or elements, which can be used to represent the real world. These are points, lines, areas and the surface or terrain.

Spatial entities and their attributes are stored using a number of spatial data models by specific GIS software, and it is important to understand the characteristics of each, since the data model used has considerable influence on the functionality of the GIS. The spatial data models are rasters or vectors

The Raster data model is the simpler one of the two and is based on the division of reality into a regular grid of identically shaped cells. Each cell is assigned to a single value that represents the attribute for the area of that cell. The area, represented by each cell, varies from a few metres to kilometres and is known as the resolution of the grid. The higher the resolution of the grid, the more cells are required to represent a given area

Nowadays most GIS Applications store the data in form of vectors, the smaller ones a point, the next a line which combines 2 points, then a polyline which connects several lines and finally a polygon, which is a closed polyline connecting the last with the first point. The most complex structure is an area defined by a border in form of a polygon with a label point inside that itself represents the area. Most CAD Systems (i.e. AutoCAD) just use point and line objects. Those vectors describe a real phenomenon (road, river, pipeline…) and to classify them, the different systems follow two basic ideas. In CAD-Systems, which are the traditional ones, these classes are received by a layer structure. Each class of line is stored in a separate layer. In CAD-Applications layers exist for as many points and lines as classes exist. The well-known DXF-format supports this layer-structure. Symbols and colours as a legend to display or print maps can be connected to the layer.

In GIS the classification using a database linked to the vector is most common. This makes it possible to have different types of points in one layer, which can be identified by attributes in the database. The biggest advantage is the use of databases which can be much more complex than a layer structure could ever be, especially if relational databases or Geo-DBs are used. Apart from the description of the object-type, other information can be added. This depends on the database used. The table structure of dBase is very common and meanwhile even traditional.

Modern GIS-Systems use relational databases or place the database as central operator to display the data in the GIS. Especially big systems, connected with Oracle databases, even store the vectors in the database. Those applications enable huge networks to link several administrations by direct line or via the Internet.

Common to most systems is the fact, that the database is different for each vector-type, as there are points, lines and areas. It is the same with TopoL. Some systems even hold these vector-types in different files, while TopoL is able to handle them in one block. This supports topological structure of the vectors and reduces redundancies to a minimum.

For displaying on screen or printing maps, automated legendary can be built, based on the database. However these features are fine for thematic mapping like the land-use- analyses described here, but still are far away from cartographer's quality in the field of topographic mapping. But even these functions have enormously improved in the last years by the different software developers.

Topological data structure means that special operators can achieve direct relation between points, lines and areas. A point can be a single object but even part of a line or an area. A line can be a single feature, but even a border of an area. This means that a line is able to cut an area into parts. The topological definition of lines and their nod-points is most important. Crossed lines define a new nod-point and become connected single lines. Areas can use one single borderline instead of redundant digitised ones. These are important features in accurate mapping, especially for land-use detection.

2.5 Data-Integration in a GIS-Warehouse

Metadata and GIS-Warehouse are the frame making the data achieved available, not only for the GIS-Operator. As described above, several datasets have been produced in the GIS to describe the line-features and areas of the land-use. They are done based on remotely sensed data and aerial images – so called raster-data. These raster-data, pre-processed and geocoded, form the first information in the warehouse. For the reference year, different imageries have been processed and geocoded. Even though they have different resolution and information, they are free of scale in the digital environment and can be placed next to each other.

Vector-datasets have been achieved for the reference year, one for lines, one for areas and one for 3D-Objects. Each dataset stores the vectors and the database related. Taking into account, that 3 other historical years (vectors and rasters) have to be stored in the system and ancillary data are also added, such amounts of datasets have to be managed in a proper way. This can be done by a hierarchical file and folder system or by Metadata, which are more than data about data. These metadata-files contain information about the data and link to the single data-sources in order to keep overview and to allow immediate access to the information required.

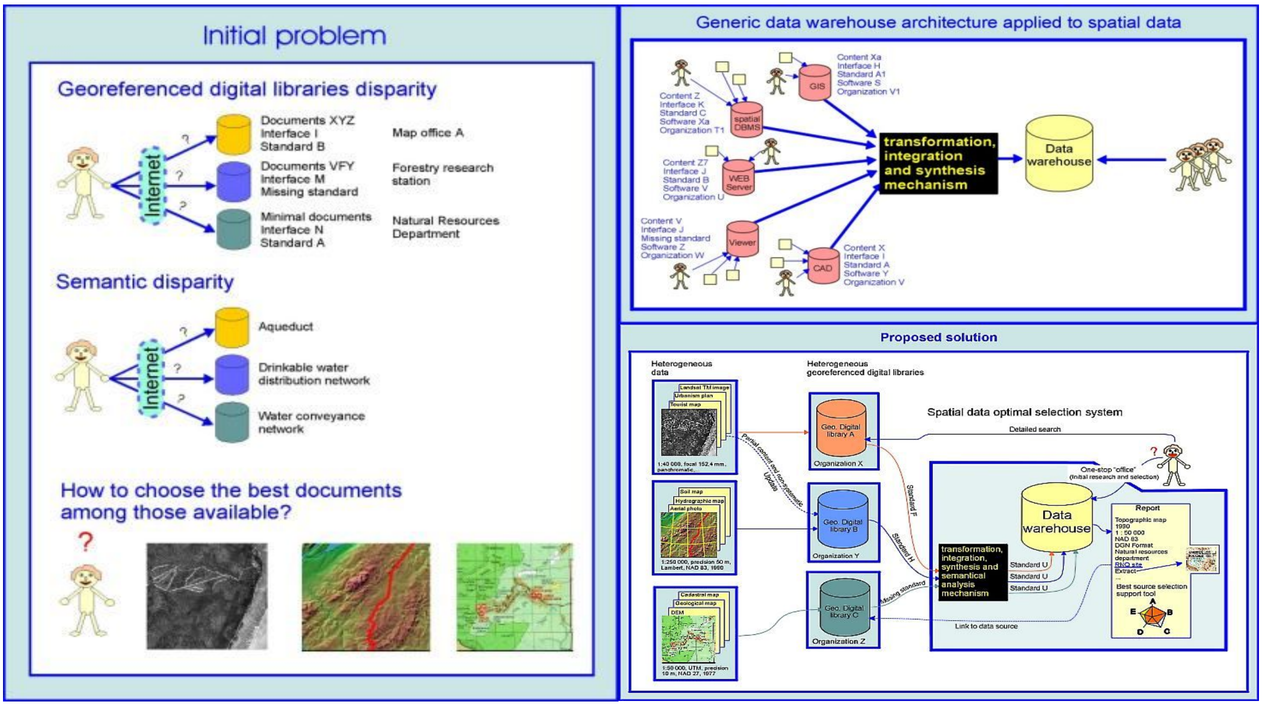


Figure 19: *Structure of a GIS-Warehouse. (www.dlib.org)*

If the access of different users analysing and linking these data to own applications is accepted, a GIS-warehouse has to be implemented. Haderle [1994] describes five elements that are essential for the design of a data warehouse:

The first component of the complete data warehouse system is the one of the operations data stores that may be in any of several operating environments. It means that the managing system of the data-warehouse can be separate to the data-server.

The second element is the access to a distribution network. The suitable network supports the delivery of data from the operations systems to the data warehouse, and consequently, the information from the data warehouse to potential users via net or a complex system of local area networks and wide area networks. The concept of enterprise data requires that any user needing information and having adequate security access is able to retrieve the information easily and quickly.

The third element of the warehouse is data delivery, the ability to move data from the operational sources to the data warehouse. This does not only require the network system described above, but also a process and system to extract and summarize data from operation systems at the correct intervals.

A graphical user interface (GUI) front-end with the ability to locate available data is the fourth element. This is an essential component for using the data warehouse as enterprise data. The warehouse must be accessible to all who need its data. This is a weakness of the stand-alone GIS in so far that the only people who can get access to it are the users of the application. With the help of the warehouse the user can retrieve information directly.

The fifth and final component comprises end-user knowledge tools that provide decision support functionality. I think that the data warehouse is valuable as a repository of information even without additional knowledge tools. As long as the warehouse is designed and indexed adequately with a supportive GUI, users will be able to find and compile the information they need.

2.6 Available data-sources

To give information beforehand, maps in bigger scale than 1:50,000 and aerial photographs and other cadastral information in Turkey are restricted and normally not available. They are produced and protected by the Turkish military. To get access to these data required great efforts, very good contacts, great patience, and a long path through the administrations. Only official organisations are allowed to receive such sources. In the context of the MOLAND project, the Technical University of Istanbul was able to receive these data to undertake this study. The influence on the data, finally delivered, was limited. We are glad so far that we have got them in a suitable although not perfect quality. Furthermore, for the aerial images it took big effort to receive these older data. Since the processing started with the reference year to be extracted from satellite imagery, there was no time pressure.

2.6.1 Topographic maps

As geodetic reference base, we used digital maps in vector and raster format, mainly scanned and geo-referenced topographical maps 1:25,000. For the whole study area 22 maps have been received. Their delivery took about 5 month. The missing maps on the figure had been ordered too late or had been delivered with delay. Because of the enlargement of the project area some had not been ordered because the satellite image had already been georefrenced by a small extrapolation.

As a part of the ancillary data set, city-plans and other maps are pre-processed to facilitate the interpretation. Since all data are geo-referenced into the same co-ordinate-system, we decided to take Hayford-UTM grid of the 30° meridian-strip.

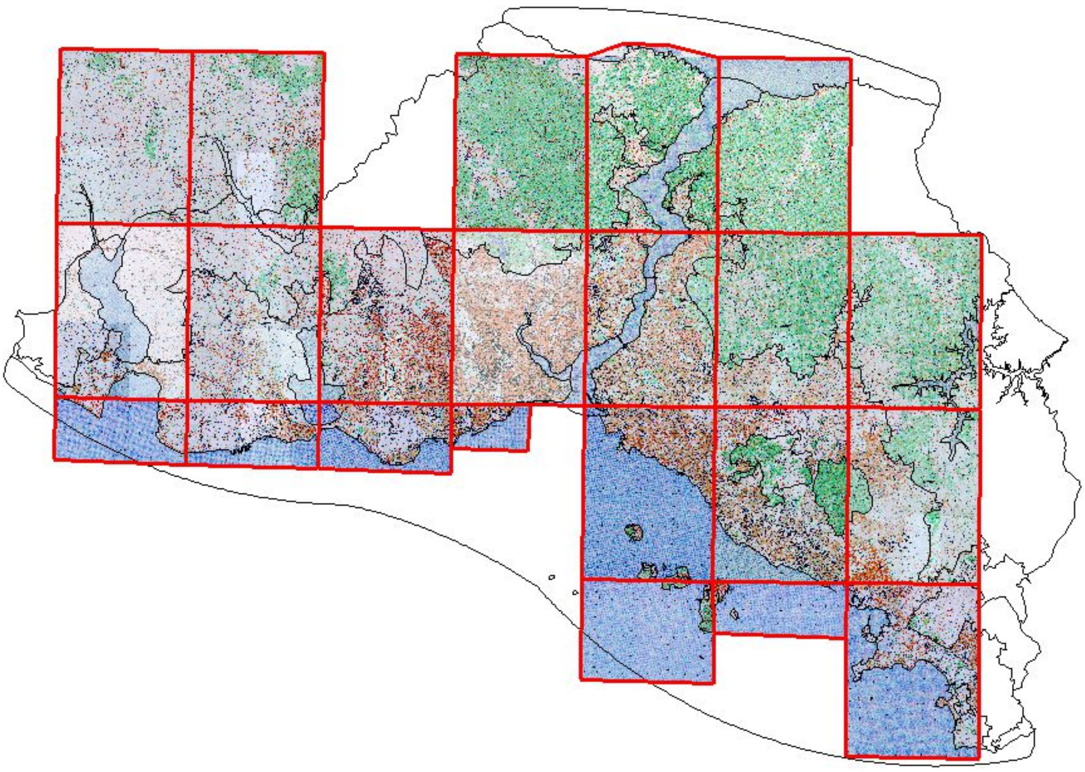


Figure 20*:* *The map sheets of the topographical maps 1:25,000 used in the project*

In some parts of the project we got access to digital maps in scale 1:25,000 and 1: 5,000, but mostly with topographic information only. There are Russian maps too, a set of four sheets of a 1:10,000 city-plan and maps 1:50,000 as topographical maps. We decided against this material its delivery would have taken too long, they were too expensive or its quality could not be prooved. Some maps 1:5,000 as a DXF-data-set are available, but the date of processing cannot be detected accurately. Nevertheless, to complete the data set they can be used for validation and georeferencation. They have DWG or DGN Format.

2.6.2 Remote Sensing Data

The reference land-use database was derived from “reference imagery”. The JRC provided this material for the project. The first reference imagery is an IRS/D with 5.8m resolution in panchromatic and 25m in multi-spectral bands. The image was delivered as an IMG file on CD, which was imported into TopoL-GIS by setting rows and columns. Out of this, merging technologies produced coloured 5m imageries. Big structures are well visible in the scene; the smaller ones can only be interpreted by using additional information from maps, city plans, and field-checks. For the area of the Bosporus, IKONOS imagery with 1m resolution in panchromatic and 4m in multi-spectral bands was available. They have already been delivered as Tiff with a pre-georeferencation in a tfw-file (but it does not fit to the local geodetic system at all). Here merged imageries have also been prepared for interpretation. The quality is excellent and the structures are perfectly visible. Unfortunately, the complete area is not covered, only a strip from north to south coveres the Bosporus.

Figure 21:

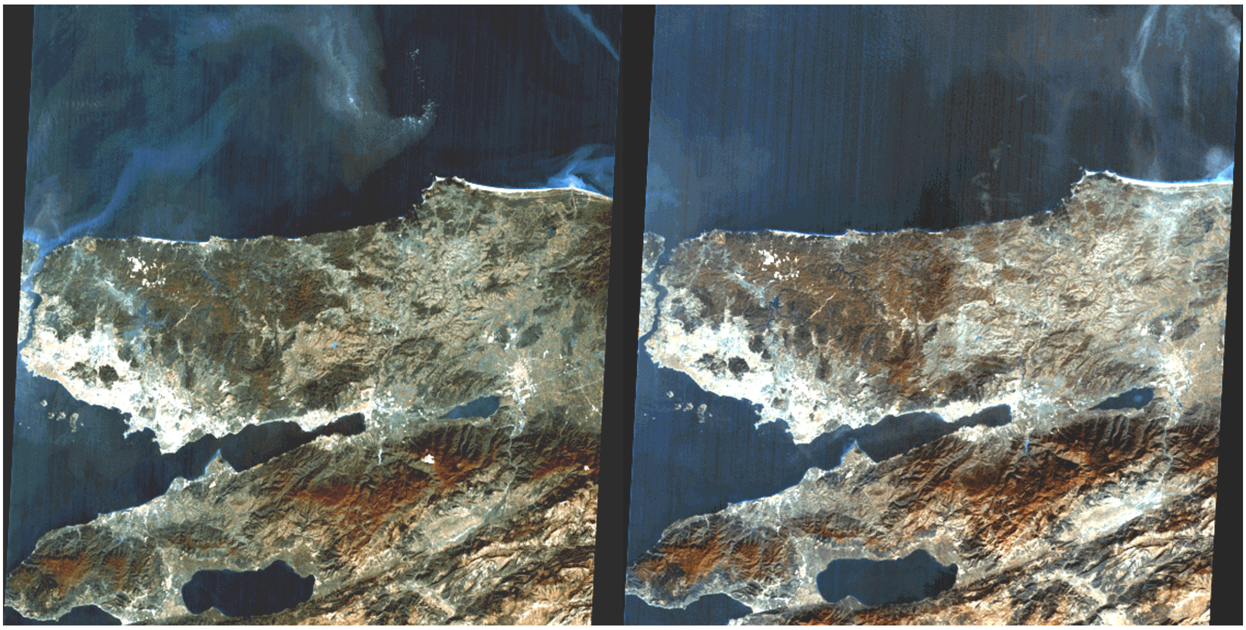
Shown is the same area from different sources. On top the high-resolution Ikonos-Image can be seen with a resolution of 1 m as merged imagery. In the middle the same area can be seen as IRS-C panchromatic imagery with 5 m resolution. Below is the same area on a topographical map of the year around 1985.

2.6.2.1 IRS 1-D (MS, Pan, Merged)

Imageries of the Indian Satellite IRS were delivered via the JRC, 4 scenes in panchromatic and in multispectral mode. The reference imagery IRS-D in panchromatic (5.8 m resolution) and multi-spectral mode (25 m resolution) were imported into TopoL-GIS by IMG import and then changed into Tiff-format.

For the four multispectral Scenes, the channels two (green), three (red) and synblue were combined to an RGB Image as shown below. The ground-resolution is about 25 m. Channel 4 (NIR) is currently not used neither as channel 5 (WIR), which are available for two MS-Scenes. Two scenes cover the entire study area; two belong to the Asian part and the eastern region of Istanbul. Date of capturing is different.

IRS-D MS taken on the 12th May, 2000 *IRS-D MS taken on the 26th July, 2000*

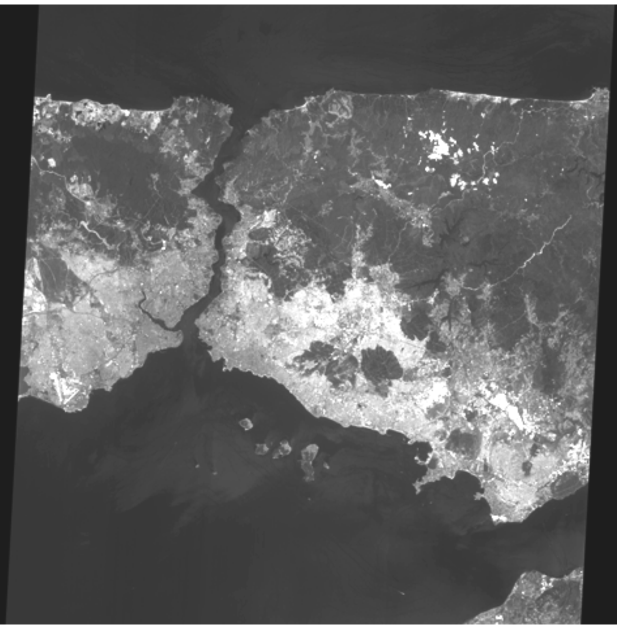


IRS-D MS taken on the 31st October, 2000 *IRS-D MS taken on the 25th November2000*

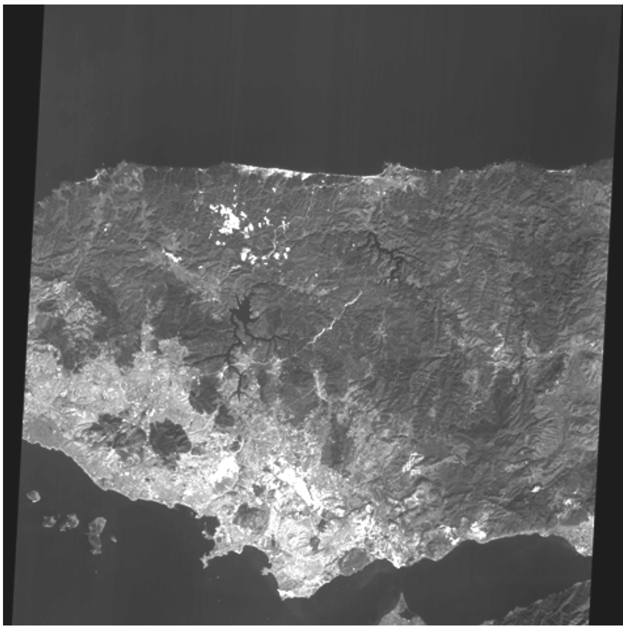
Figure 22: *The four delivered multi-spectral IRS-D Imagery with 25 m resolution already colour- composed*

Four panchromatic IRS-D imagery cover the entire area as a strip from west to east. They were imported as IMG-File into TopoL and then changed into Tiff-format. The ground-resolution is about 5 m (finally between 5 and 6 m per pixel). Three pictures have been selected to cover the project area, the fourth is too far east of Istanbul and not been used in the project.

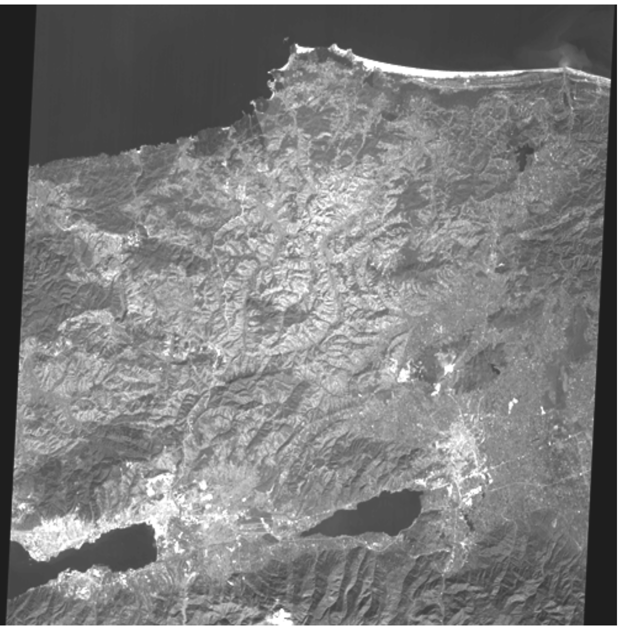
IRS-D pan 4020D taken on the 12th May, 2000



IRS-D pan 4040C taken on the 26th July, 2000



IRS-D pan 4050C taken on the 25th November, 2000



IRS-D pan 4050D taken on the 31st October2000

Figure 23*: The four delivered panchromatic IRS-D Imagery with 5 m resolution*

Two MS IRS Images, already colour-composed, were delivered as pan-sharpened data but they cover only the eastern part of Istanbul and the region far east. They were not been used. After the pre-processing, a new dataset of pan-sharped coloured Satellite-Imagery was prepared. Mosaicing and colour balancing was done in order to produce one single dataset of IRS-Rasters.

2.6.2.2 IKONOS (MS, Pan, Merged)

The IKONOS-Imageries, delivered by the JRC in both, multi-spectral and panchromatic mode, cover the Bosporus area. First the IKONOS-Imageries were not readable, neither the panchromatic nor the multi-spectral in any other programs. There was a possibility to import them as IMG-File, but with a strange raster-structure and poor quality. The description about Geo-Tiff format which should have had an integrated header, lead us to mention the problem here, but finally we detected that it was a normal Tiff with separate TFW-file for the geocode. The mistake was in bad tracks on the CD/DVD and was corrected by a new copy. IKONOS Imageries are typically stored as 11 bit greyscale and to process them they must be changed into 8 bit grey-value. This was done in Adobe-Photoshop, which also supports 16-bit greyscale. The IKONOS imageries have already some georeference-information (tfw-file) which makes it possible to bring the 3 IKONOS-scenes together, but it was impossible to add more,because the co-ordinates do not fit to the local system at all and just have an allocation and not a correct georeference. The images have been delivered as multispectral set (blue, green, red and NIR) with 4 m resolution, and as panchromatic with 1 m resolution. The multi-spectral scenes have been combined to an RGB-File (without NIR) and matched with the 1 m panchromatic imageries. Unfortunately, these three scenes only show the Bosporus and not the historical part of the European Istanbul city with the Golden Horn.

Figure 24: *The three IKONOS-Imageries, which cover the Bosporus-region.*

<table>
<tr><th>Satellite</th><th colspan="2">IRS 1C</th><th colspan="2">IRS 1D</th><th colspan="2">IKONOS</th></tr>
<tr><th>Sensor</th><td>LISS III</td><td>PAN</td><td>LISS III</td><td>PAN</td><td>MS</td><td>PAN</td></tr>
<tr><th rowspan="2">Spatial Resolution</th><td>23.5 m (Visible and near IR region)</td><td rowspan="2">5.8 m.</td><td rowspan="2">23.7 m</td><td rowspan="2">5.2 m</td><td rowspan="2">3.2 m.</td><td rowspan="2">0.8 m.</td></tr>
<tr><td>70.5 m (short-wave IR region)</td></tr>
<tr><th rowspan="2">Swath</th><td>141 km (visible and near IR region)</td><td rowspan="2">70 km</td><td>127 km (Bands 2, 3, 4)</td><td rowspan="2">65 -80 km</td><td rowspan="2">11 km.</td><td rowspan="2">11 km.</td></tr>
<tr><td>148 km (short-wave IR region)</td><td>134 km (Band 5 -MIR)</td></tr>
<tr><th>Temporal Resolution</th><td>24 days</td><td>5 days</td><td>25 days</td><td>3 days</td><td colspan="2">3 days</td></tr>
<tr><th rowspan="4">Spectral Resolution</th><td>0.52 - 0.59 microns (B2)</td><td rowspan="4">0.50 - 0.75 microns</td><td>0.52 - 059 microns (B2)</td><td rowspan="4">0.50 - 0.75 microns</td><td>0.45 - 0.52 microns (B1)</td><td rowspan="4">0.45 - 0.90 microns</td></tr>
<tr><td>0.62 - 0.68 microns (B3)</td><td>0.62 - 0.68 microns (B3)</td><td>0.52 - 0.60 microns (B2)</td></tr>
<tr><td>0.77 - 0.86 microns (B4)</td><td>0.77 - 0.86 microns (B4)</td><td>0.63 - 0.69 microns (B3)</td></tr>
<tr><td>1.55 - 1.70 microns (B5)</td><td>1.55 - 1.70 microns (B5)</td><td>0.76 - 0.90 microns (B4)</td></tr>
<tr><th>Altitude</th><td colspan="2">817 km</td><td colspan="2">780 km</td><td colspan="2">681 km.</td></tr>
<tr><th>Radiometric Resolution</th><td colspan="2">6 bit</td><td colspan="2">6 bit</td><td colspan="2">11 bit</td></tr>
</table>

Table 4: *Comparison of technical specifications for sensors used in the project for the reference year (Sadeghian S. et al. 2001)*

The imageries for the reference-year 2000 are based on different sensors on board of three different satellite carriers. A comparison between the sensors and platforms for the reference imagery is given in Table 4.

2.6.2.3 KFA and KVR-Photographs

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

The historical satellite imageries have been processed out of KVR-1000 photos with 2 m resolution and KFA-1000 photos with 5 m resolution in the year 1988. These data are of Russian origin and belong to the satellite-based spy-campaign of the 80ies. Such systems produced satellite-photographs, not scanned imagery. The data were only available after the development of the film. The process of scanning had to take place before the processing in digital form could be done. The pictures were bought already scanned with high resolution (8 µm) in digital form on CD/DVD. The data processing is partly difficult. Technical specifications on KFA-1000 and KVR-1000 satellite images are given in Table 5.

The KVR-1000 imageries cover the inner part of the centre zone and the Bosporus area. They relate to the Ikonos-Images, but the coverage is about 3 times bigger. These images are panchromatic and taken by the sputnik satellite. The KFA-1000 imageries are also Russian ones and have some special colour. The channels are not separated, but the resolution relates well with 5 m to the IRS/D. These two KFA-Imageries, taken by the cosmos satellite, cover the entire area.

Satellite	KFA-1000	KVR-1000
Spatial Resolution	5 m.	2 m.
Spectral Resolution	Pseudo-colour (partly NIR	Panchromatic (510-760 nm)
Spectral Information	1 panchromatic channel 2 spectral channels	1 panchromatic channel
Scene Size	80 x 80 km	40 x 180 km.
Proposed Maximum Scale	1:15,000	1:5,000
Altitude (km)	270	210-230
Swath Width (km)	80	40

Table 5: *Technical specifications of KFA-1000 and KVR-1000 Satellites, belonging to the Russian high- resolution data of the military spy-campaign during the 80ies*

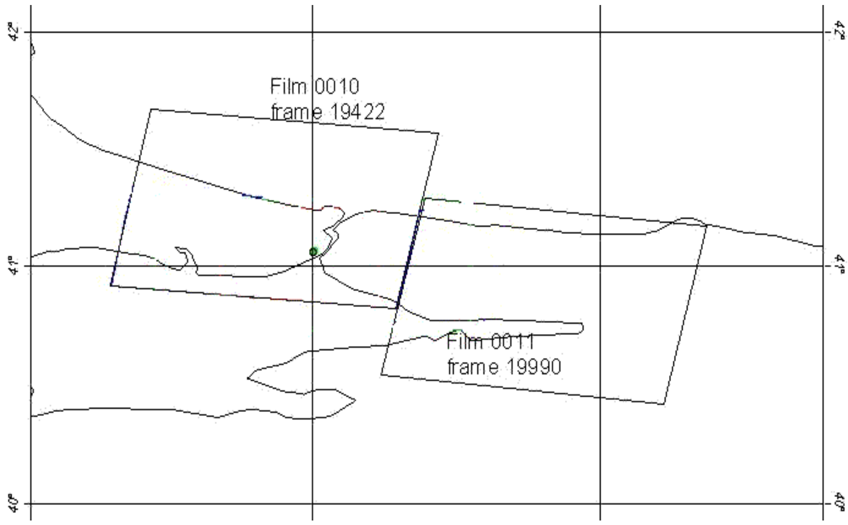


Figure 25*: Overview of the two used KFA Imagery frames*

The colours of this sensor are a bit different from the normal film-material; it is described as pseudo colour, because the red–sensitive film emulsion has a sensitive part in the NIR spectrum. The channels are not separated. The ground resolution is between 4 and 6 m but in detail you can realise the structure of the film's grain. The imageries have been processed globally, this also means with extrapolation to cover the entire area. The quality is rather good and can be compared to the IRS-Imagery of the reference year. However, the contrast is smaller and the city-structure in detail is not as clear as in IRS-images. For the purpose of our work and to support areas outside the maps we used global transformation algorithm to be able to extrapolate the computed parameters. This means that the entire image was georeferenced.

Figure 26: *A detailed Screenshot in 5 m resolution and in pseudo-colour to show the quality of KFA-1000 scanned satellite photograph.*

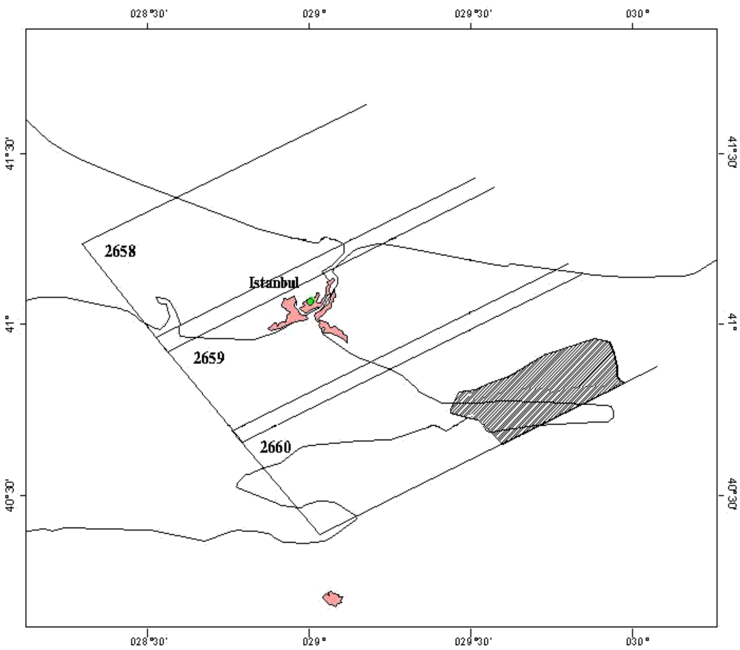


Figure 27: *Overview of the imaging route and the frames of the KVR-1000 photographs*

Four photographs of the high-resolution satellite camera KVR-1000 cover the central part of the study area. The sputnik satellite carries an extreme high-resolution panoramic camera with a very long focus-length. A special film-carrier. uses a mirrored hole leading the light to the film in order to cover a wide area as used in some panoramic cameras. This is very different from aerial cameras or the KFA-1000 system. This material has got a strong nonlinear distortion that makes the processing to orthophotos extremely difficult.

Figure 28: *The coverage of the panchromatic KVR-1000 scenes with a resolution between 1-3 m*

Four scans were necessary to cover the central part. The Shooting route 7/422-2 was done on 3rd August 1987. The frames S0726281, S0726582, S0726592 and S726591 were received in 8µm resolution. The ground-resolution ranges from 1 and 3 m. The processing of the imagery was very difficult. Only the special transformation algorithm rendered good results. In small areas, the result was acceptable. Bigger parts of the images were not combined to a mosaic. The big distortion did not allow that. The photos were bought at the company GISSAT in Prague / Czech Republic, which provides business-relation to the Russian owners of the data. Scanning was made in Russia on photogrammetric scanners and delivered through GISSAT on CDs.

Figure 29: *Example of a KVR-1000 image detail to visualise the quality*

2.6.2.4 Airborne photographs of the year 1968 and the 1940ies

The historical imageries for the years 1968 and the 1940ies were created out of aerial photographs. The acquisition was not very easy because such old flight campaigns are not very well documented in Turkey. The photos had an overlap of about 80%, so far only every second photo has been acquired. The photos were often rotated, shifted, and tilted which made the processing rather difficult.

The photos were delivered from the “General Command of Mapping” of the “Turkish Military Cartographic Institute” in Ankara as contact copies. The camera calibration was delivered only partly other information was taken from literature or measured on the copies of the images. Other information required, especially on the fiducial mark coordinates and the radial distortions of the lens were not delivered.

There was no unique flight campaign in 1968; different dates resulted in different blocks of images. Finally, there are three blocks with numbers 1968, 1907, and 1914. The same camera with focus length 99.40 mm took them all in 1: 40-42,000 scales. All the photos, 94 in total, have 18x18 cm size. Flying altitude was calculated from focus length and scale.

Year	ID of Block	Number of Photos	Approximated Scale	Approximated Flying Altitude	Focus length
1968	1968	9	1: 40,500	4,050 m	99.40 mm
1968	1907	50	1: 42,000	4,200 m	99.40 mm
1968	1914	35	1: 40,800	4,100 m	99.40 mm
Sum	-	94	-	-	-

Table 6: *The used aerial photographs for 1968*

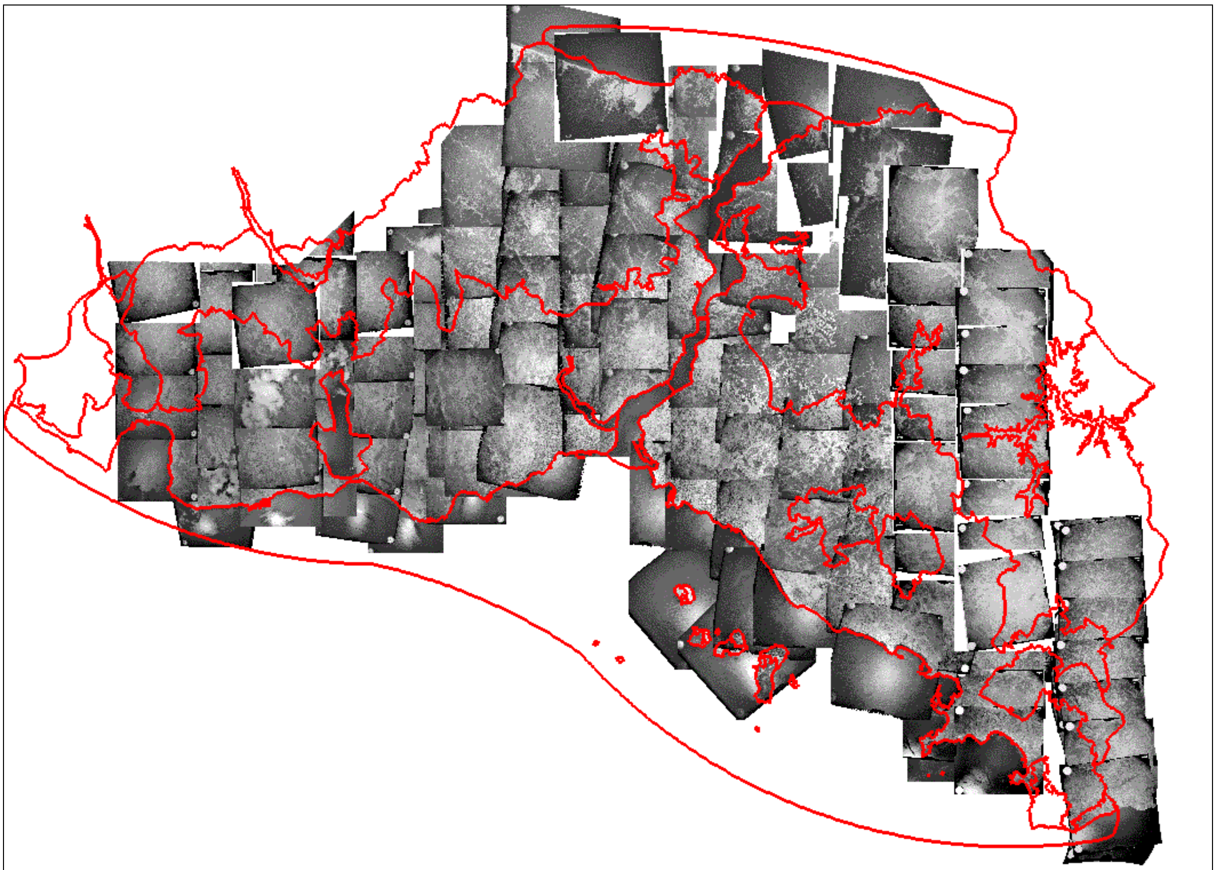


Figure 30: *The computed Orthophotos for the year 1945.*

Historical photos of the 40ies were taken in different years. It was possible to get data only from different years, but also here the exact date was not known. It were approximately the years 1940, 1942, and 1949. We defined the year 1945 as an average one. The differences between the land-use information on the photos of different years are rather small; this, however, made the correct dating of the photos difficult, but enabled us to use them for one homogenous period.

The photos were delivered from the “General Command of Mapping” of the “Turkish Military Cartographic Institute” in Ankara as contact copies. The camera calibration did not exist; all information had to be searched in literature or measured out of the sets of the images. Other information required especially about the fiducial marks coordinates and the radial distortions of the lens were not supplied.

Different cameras were taken the photos; it is immediately visible in different shapes of fiducial marks. However, the size is the same – 18x18 cm. Each detected year had different image (blocks) with different cameras and sometimes also different flight-altitudes (scale). For some photos-blocks the focus-length was not clear. In the case that there are two possible values for the focus-length documented in literature, I tried to estimate from overlapped images, in order to find out, which could be the correct one. Focus length is one of the most important values in photogrammetric processing, so far mathematical analyses on the overlapped zones have been done to receive usable results. Residual deviations can be corrected by digital photogrammetric methods as a kind of “on-site- calibration”.

Since a DTM was missing near to the border of the study area, photos were processed using georeferencing tools. 3D GCP were not available either, they had to be taken out of maps with bad accuracy of heights. Due to this fact, such photos were geocoded using triangulated partial georeferencation and transformation algorithms. All airborne photos were scanned with 600 dpi on a good but non-photogrammetric scanner to prepare them for processing in TopoL and the digital photogrammetric workstation PhoTopoL.

Year	**ID of Block**	**Number of Photos**	**Approximated Scale**	**Approximated Flying Altitude**	**Focus length**
~1940	48-b	33	1: 36,000	3,600 m	99.48 mm
~1942	55	36	1: 33,500	3,350 m	99.50 mm
~1949	518	45	1: 43,000	4,300 m	99.68 mm
Sum	-	114	-	-	-

Table 7: *The aerial photograph used for the 40ies*

2.6.3 Ancillary data

The data types are not only satellite or airborne images, also some additional data useful to detect land cover changes and to support the final interpretation have become part of the data source. They can be grouped in 4 sections.

Spatial data -

Like: topographical maps, city plans, geological maps, digital terrain model, additional orthophotos, historical maps, other maps.

Those data are available either as prints or in digital form as vector or mostly as raster. They are based on a reliable geodetic basement and can either be geocoded or transformed into the selected coordinate system. These data can easily be integrated into the GIS-data-warehouse

Plans -

Like: thematic maps, public transport maps, master-plans, environmental maps and non-finalised and controlled field-maps

These data have a spatial information or spatial relation but are not always exact in space and distance compared to the spatial data. Such sources can be geocoded but even the accuracy in geometry is difficult to extract reliable results. They usually have to be remapped by an exact base.

Numeric data –

Like: statistical data, census-data, and environmental measurements

Those sources are valuable but even difficult to connect with other spatial information. Some statistics are related to a region, but not very much differentiated. On the other hand, they usually provide temporal analyses and help a lot with the interpretation of the spatial data.

Qualitative data -

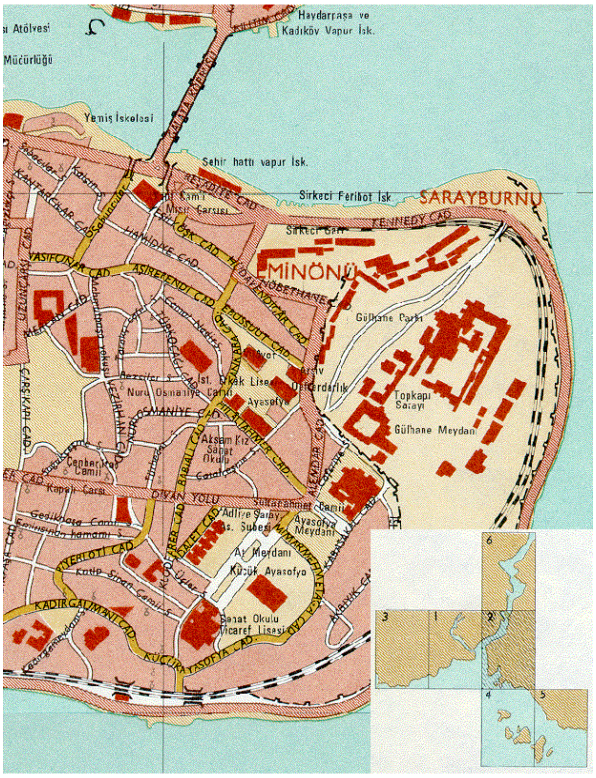
Like: photos, reports, publications, historical views, and many more

These data support well in the interpretation and documentation, but do not for the quantitative analyses. They can provide background to understand some phenomena. They have rich information, but mostly with little objectivity. It is always difficult to use such sources.

2.6.3.1 Topographic maps and City-plan

As mentioned above in 2.6.1, the topographical maps in scale 1:25,000 were bought to establish the main reference system. The last revision of these maps was done in the late 80ies and early 90ies. Therefore the actuality is not given, but the quality is fine. In combination with the satellite imagery, they provide a good information-basis of the city. They have been used beside the geo-basis as a help for the interpretation. A lot of information about the use of official buildings (schools, hospitals…) is also documented. Unfortunately, the data are restricted and had to stay at the Technical University of Istanbul. They exist in paper as well as in digital form georeferenced in the projects-co-ordinate system (Hayford UTM 30°). Four older maps of this set exist in digital and in paper format. They date from the 70ies.

Figure 31*:* *Find left an example of the topographic maps 1:25,000.*



In addition to the topographic maps 1:25,000, 6 topographic city-plans in scale 1:10,000 were acquired. They were printed in 1978. These city-plans only cover the central part of the project area, mainly the historical city and some parts of the Bosporus. They have also been scanned but not geocoded to the projects co-ordinate system. Since they belonged to late 70ies, they did not contain any information related to the terrain. In relation to the maps 1:25,000, they are strongly generalised and were used mainly for the interpretation of old satellite and airborne photography. There are maps in scale 1:50,000 of the Turkish army and also of the Russian military. Furthermore, there exist a 1:10,000 City-plan of Istanbul of Russian origin. In cases there was no example to prove the quality, they were not been ordered. These Russian data are very expensive because they usually have to be bought via US-companies – however, they have the access to this kind of data.

Figure 32: *Snapshot of the topographical map 1:10,000 with the overview-sketch*

A small set of CAD-maps has been received in digital form as DGN-Files, which relate to scale 1:5,000 and 1:10,000. These vector-data mostly contain contour lines with heights. So far they can be used as DTM basis as well. They have been converted by using AutoCad-2000 from DGN to DXF, which was readable in Atlas-DMT and TopoL-GIS. Some other achieved data contain artificial structures like parcels, roads and buildings. In the case where there is no complete set for the study area, they have been used for the validation of accuracy in geometry of the satellite images and for the geometry and content of the extracted land-use data.

2.6.3.2 Digital Terrain Model

A digital terrain model is a most important base for the orthorectification of the aerial photos – due to this fact a DTM had to be created. Digital topographic map-layers in scale 1:25,000 contain contour lines in vector-format. They are in DGN-format and were converted to DXF (3d) via AutoCAD. They were pre-processed in Atlas-DMT and also in TopoL-GIS. The contour lines were completed in some parts, especially on the European Side of the Black Sea Coast north of Istanbul by manual digitisation on the scanned topographic maps. In case that data are vectors, the quality is good and the resolution of contour lines is about 5 m. For the DTM computation, the vertex-heights of the contour lines were used as points and the contour line as break-line inside of Atlas-DMT-Software. A new triangulated network was built with 1.1 Mio. points, 2.2 Mio. edges and 3.3 Mio. triangles. In some parts, 3D data from the other digital maps were integrated to complete this data set. The procedure of computation, generalisation and others will be described later.

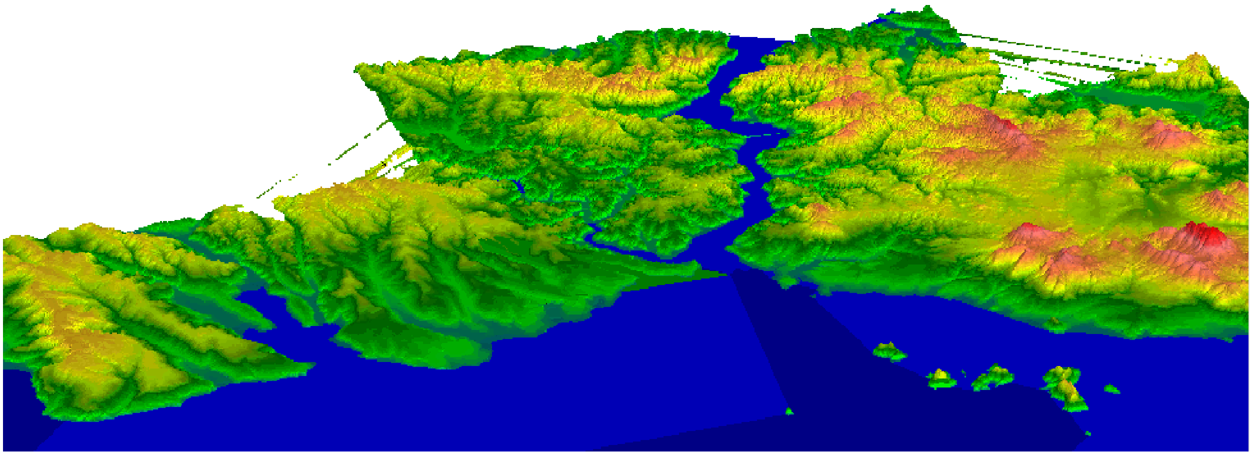


Figure 33: *3D-view of the terrain-model computed for the Istanbul study area*

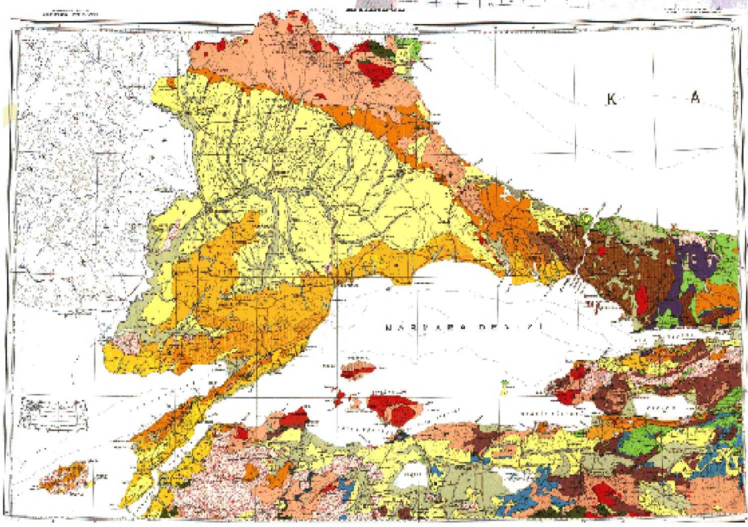
2.6.3.3 Orthophotos

The orthophotos of the year 1968 and the 40ies, which were prepared in this project, are restricted and remain at the Technical University of Istanbul. Like the topographical maps, they have to remain in Turkey. Other data sources with aerial images are scarce. There is a printed book with aerial Photos of the entire Istanbul-area of the year 1993 in the library of the ITÜ; however, this book was not published officially and printed only for administrative organisations. Nevertheless, it is a good source, helping in the interpretation of the land-use. The scale is big and compensates the bad quality of the print. However, in some parts the geometry is extremely bad, probably due to mistakes in the orthophoto-production.

Figure 34: *example of the aerial image Atlas of Istanbul, produced for public management only*

2.6.3.4 Geological maps

Figure 35: *2 examples of geological maps, down a generalised map of the entire area, up the detailed manuscript map of the Bosporus area (Ketin, 1990)*



Different sets of geological maps in different scale, quality and covering of the area were found. One map, which properly covers the central part and the Bosporus, has not been published up to now because it is not prepared in the design yet. It was received from the geological department of the University in Istanbul. This map in scale 1:50,000 cover the Bosporus and was scanned, properly georeferenced and digitised in vector-form with an area-database of the geological formations. This map contains quite more detailed information about the situation around the Bosporus area than other maps acquired for this study. It contains detailed information about the stratigraphic situation. Some other geological or geo-tectonic maps were acquired in raster format, but they bear a rather coarse resolution. Some of them carry information about tectonically ruptures and a core zonation of the earthquake risk. For the final interpretation, geological data can be useful in order to gain knowledge about the soil-base for rural or urban activities and information about risks for landslides.

2.6.3.5 Thematic maps and others

A large number of various maps, mainly e.g. city-plans for tourist affairs does exist. These types of maps are strongly generalised and the quality cannot be proved. Nevertheless these types of data give specific information, for example, on hotels, archaeological sites, and many more. This kind of maps does not cover the entire project area; the coverage is limited to the historical centre of Istanbul mainly. However, there are also thematic maps, which give sub-quantitative information to the land-use change. They are often produced as visualisation in reports or scientific studies. An example can be seen in the figure 36 about the land-use of Istanbul at the end of the 1970ies. Many more of such maps exist and some of them were been geocoded and digitised to a spatial database.

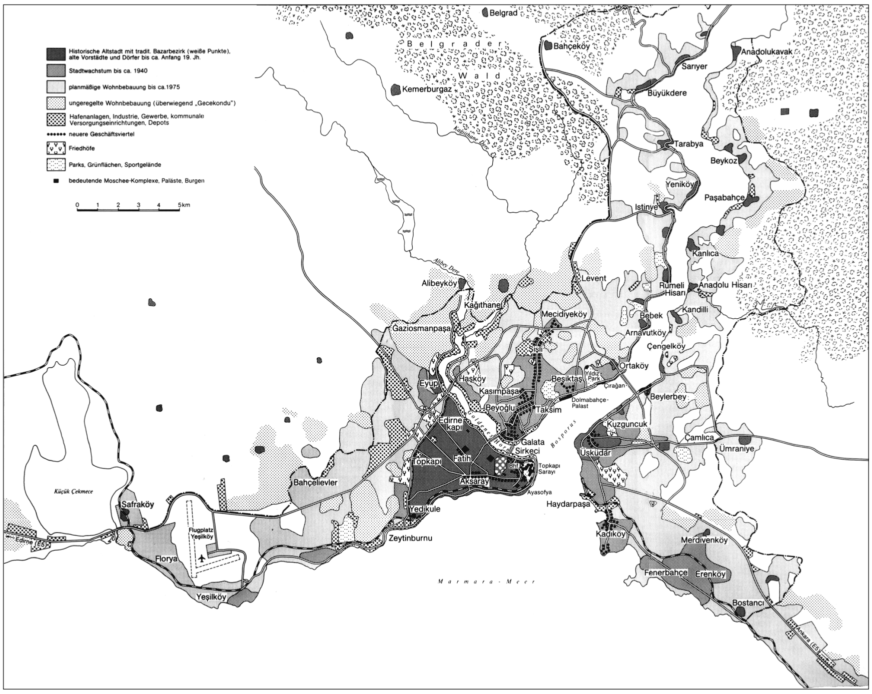


Figure 36: *Land-use Change of Istanbul 1940-1982 (W.-D. Hütteroth 1982)*

2.6.3.6 Public Transport Data

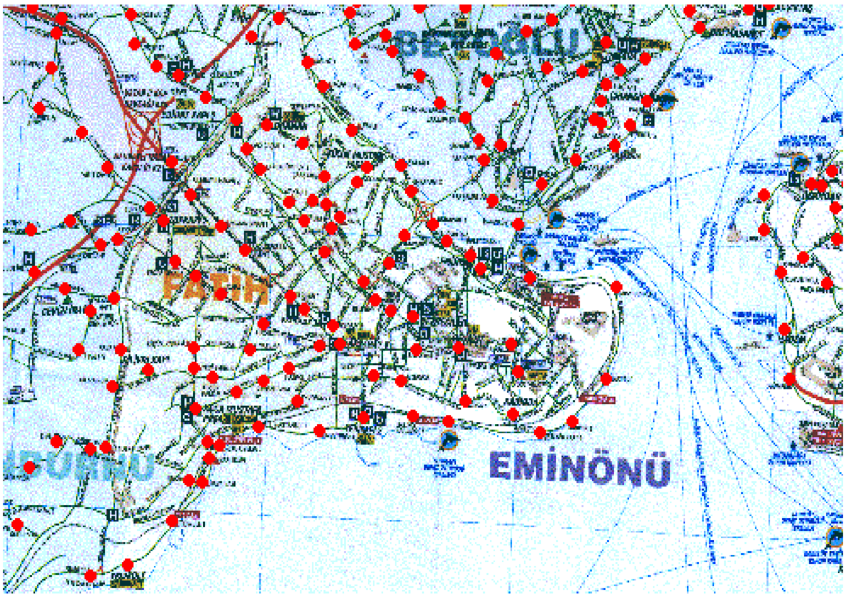


Figure 37: *map of public transport with digitised bus stops*

A map of public transport-structures in scale 1:38,000 was received and already scanned and georeferenced to the project's co-ordinate system. The map is strongly generalised but all bus-stations are marked there. The publishing date of this map is 2001; so far it is relatively up to date.

On this map, the bus-lines with the bus-stations, the ferries on the Bosporus and the 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 are stored. The information on the map is quite good, however, the georeference is poor.

Private companies, however, manage most buses as so called "Dolmusch" - a peculiarity of Turkey. They are not mapped anywhere. These small busses are more like taxi-service, but they are cheap and run on discrete tracks. To get statistic data and a road-map is impossible.

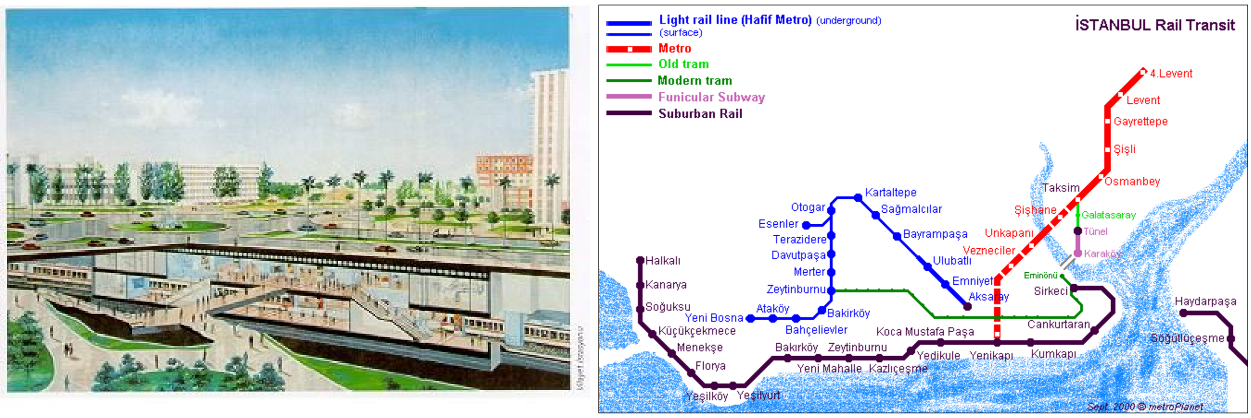


Figure 39: *Schematic plan of the new Underground-Station Levent (left) and a plan of Metro-and Tram-lines (right) (www.state.gov.tr)*

The same applies to small ferries, which connect the Asian side with the European one. Pedestrians use them. The railway is of little importance and statistic data are rarely available. On the two subways, some statistic data are available. First of all, the historic "Tünnel" rail is to be mentioned, a historic and only short connection, which is one of the oldest but shortest subways in Europe. It is connected to the historic tram leading to Taksim-Square. For public transport, it is not really important. The new metro, however, is starting slowly, but is already ameliorating public transport. Since last year, a modern subway has been running, but its extention is limited by the financial situation in Turkey.

2.6.3.7 Statistics

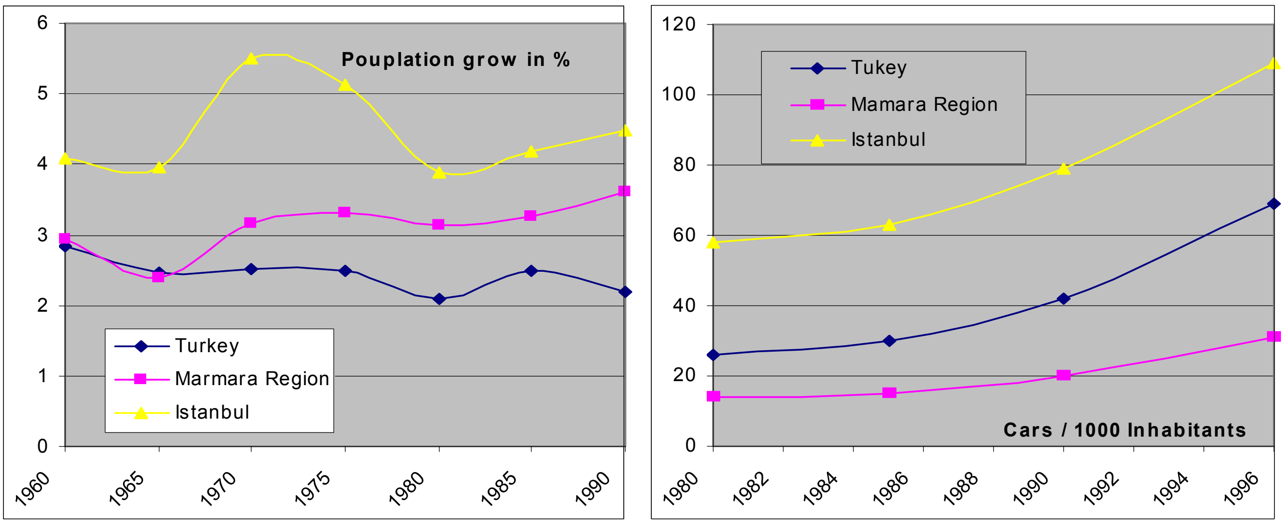


Figure 40: *Statistic about the population growth and the private traffic (Data from State Institute 1998)*

Large amounts of statistical data were received in form of printed material. Some of them are temporal ones others are thematic. Only few of them have a spatial objective, most of them are related to wider regions. However, the variation of these data is amazing. There are statistics of migrations, mortality of babies, cultural statistics, demographic data, data about power management and many others. A higher number of statistical data were found in digital form or prepared as a Word-Table or an Excel-sheet. Only a few examples will be given in the interpretation part of this thesis. In this context the districts of Istanbul have been digitised into a polygon database. Some demographic data have spatial resolution on base of the administrative districts, however, these districts have changed in size and administrative importance during the years. It is difficult to convert the statistic data back to the district areas.

2.6.3.8 Environmental data

Environmental data are scarce in Istanbul. There are only some brief statistics without spatial resolution. Natural and urban areas were mapped in this project, other data have not been found. Some printed material of the water-management Institute has been received; it contains additional information about the water-reservoirs and the wastewater management.

As far as city warming effects are concerned, the NIR and WIR Channels already described were used. These data are available and may point out the cities hotspots.

In this context it should be mentioned, that the water-management companies undertake demographic studies and trend-analyses to estimate the needs for technical development.

Year	Asian Side		European Side		Total Population (1000)	Growth Rate (%p.a)
	Population (x1000)	% of Total Population	Population (x1000)	% of Total Population		
1990	2,699	36.11	4,776	63.89	7,475	4.56
2000	4,075	40.31	6,035	59.69	10,110	3.07

Table 8: *Estimated population growth for the planning of the water-management (ISKI 1990)*

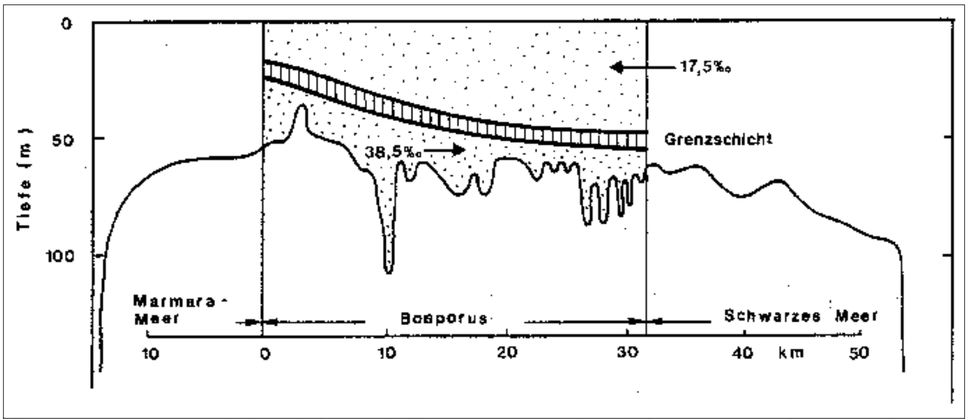


Figure 41: *Profile of Bosporus salinity (Thewalt 1996)*

Some actual ecological data on the heavy metal pollution in the black sea have been found at the Geological Institute of the University of Heidelberg. However, the paper is already several years old and of temporary resolution. Anoxic conditions have been discovered in the deeper Black Sea, which fixes the heavy metal.

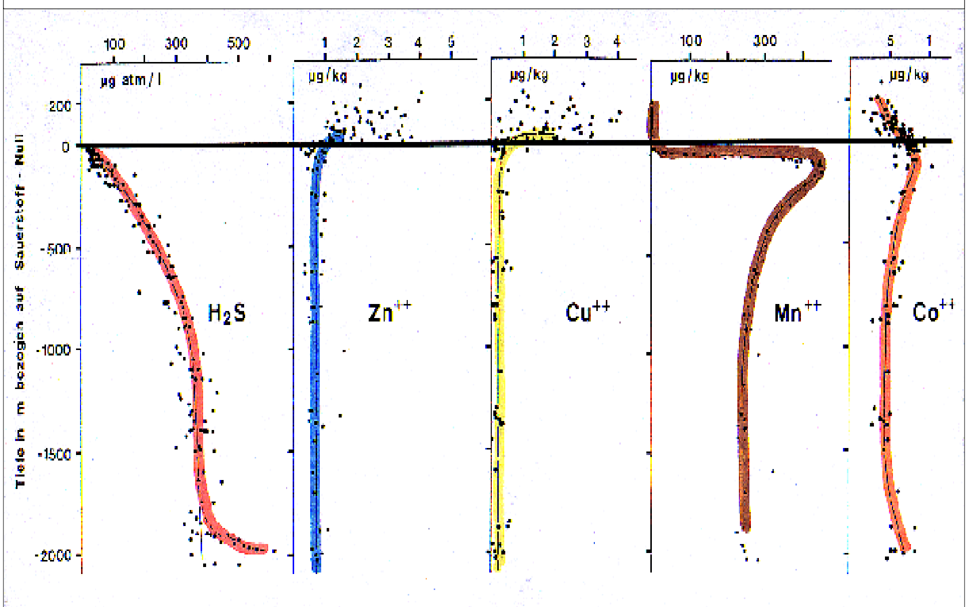


Figure 42: *Relation of Sulphur bi-hydrogen to heavy metals. (Thewalt 1996)*

2.6.3.9 Master-Plans

It is very difficult to receive any plans from Istanbul municipality especially, those, which cover the entire study area. Some overviews on the water management area and the planned wastewater treatment have been received as a book with plans. Two examples of those data are given below.

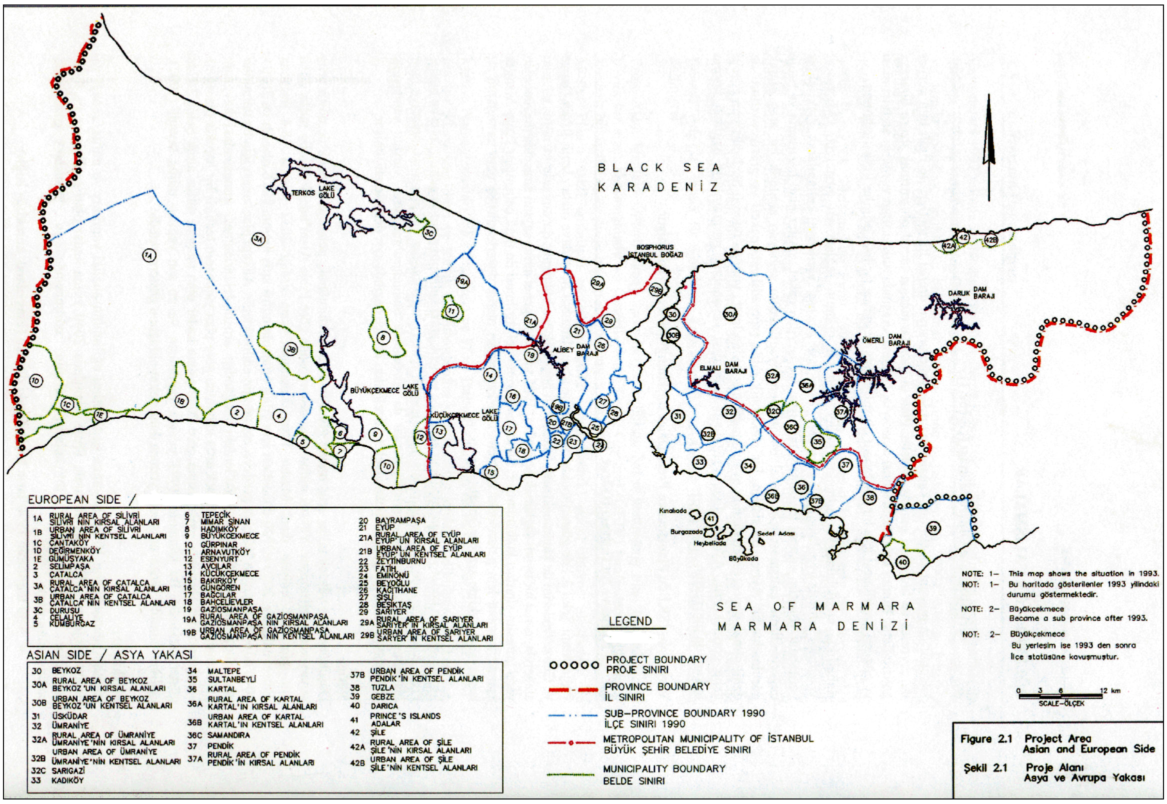


Figure 43*: Overview of the master-plan districts. (ISKI 1999)*

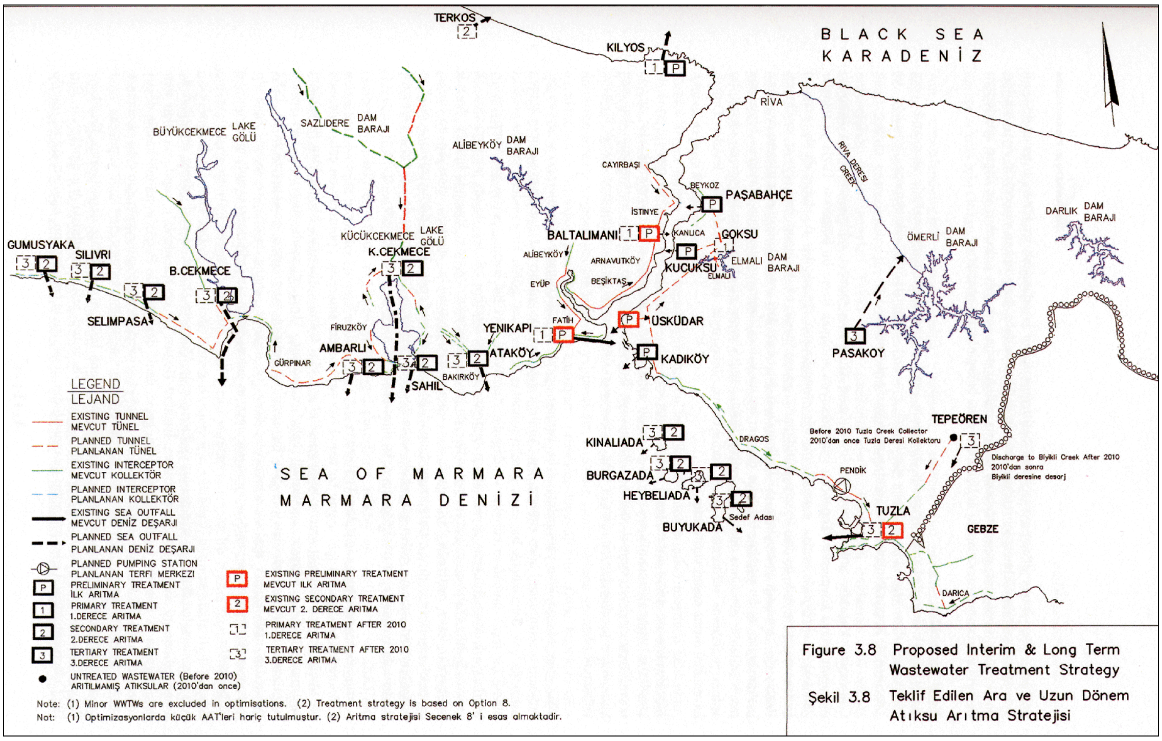


Figure 44: *Overview of the wastewater treatment planning (ISKI 1999)*

2.6.3.10 Historical Maps and Views

Some maps of the inner city, showing the historical structure of the last centuries, were detected in history books. A larger number of them have been scanned. Very useful seems to be the publications of Wolfgang Wiener-Müller (1977): Bildlexikon zur Topographie Istanbuls). There are also a number of historical photos and many maps related to the historical development of Istanbul.

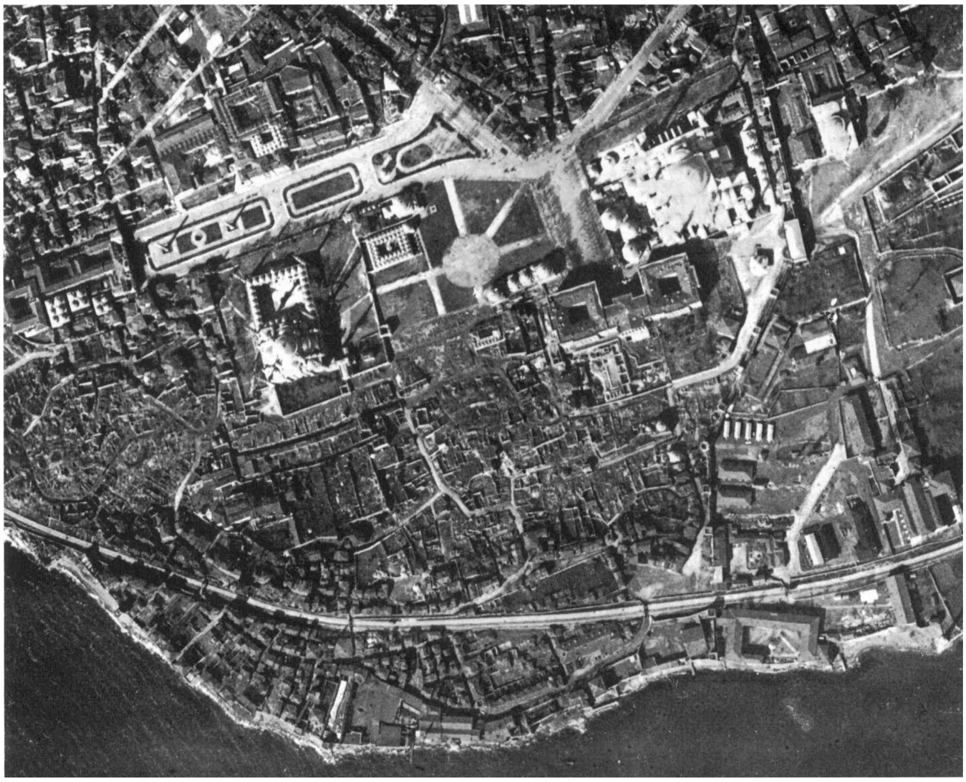


Figure 45: *Aerial Image from 1918 of the inner city; (Wiener-Müller, W. 1977)*

This Photo was taken in 1918 and shows the area of the Topkapi Palace (right), the Hagia Sophia mosque (middle right up) and the Sultan Ahmet Mosque (left). In the Year 1912, a fire disaster burned the residential areas south of these mosques, which can be seen from the damaged buildings.

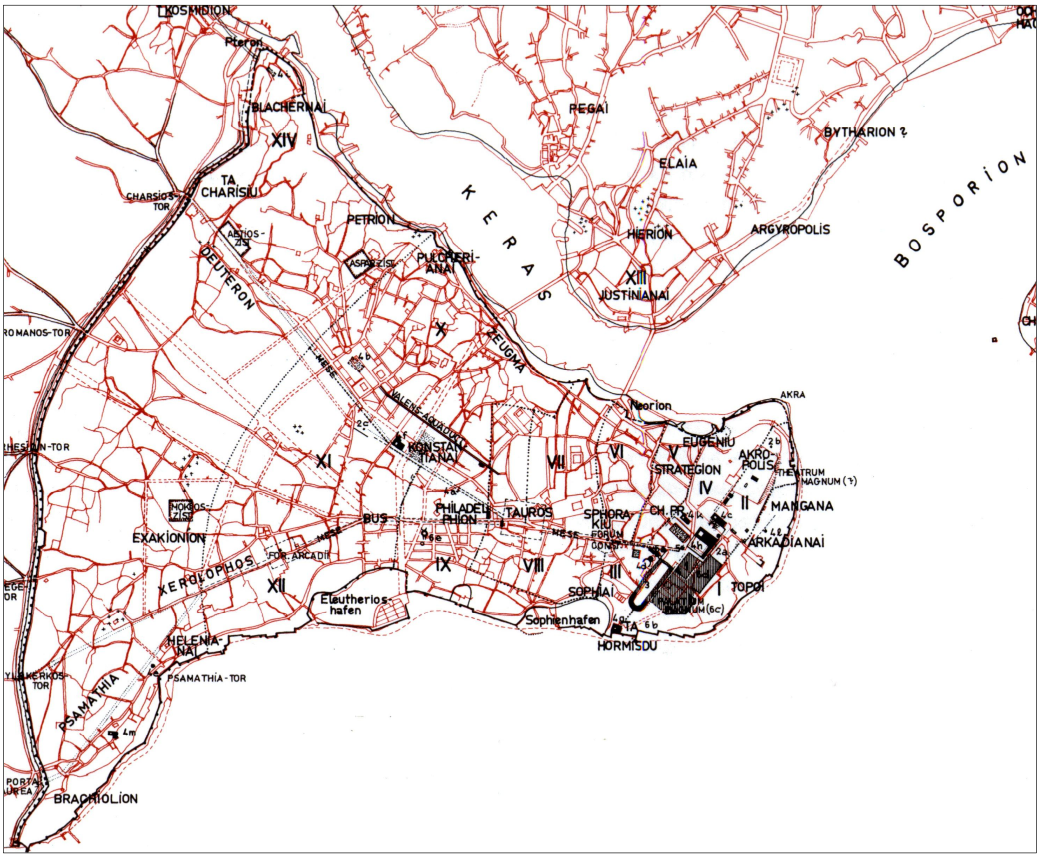


Figure 46: *Plan 1:50k of Constantinople in the years 400-700 (Wiener-Müller, W.1977)*

2.7 Map projection and geocoding

For the region of Istanbul, different types of maps with different accuracy and scaling are used.. However, all used geocoded data sources in the project are based on the Hayford ellipsoid. So far there was no need to compute translation, rotation and scaling parameters for a 7 parameter based local ellipsoid transformation. Older maps, however, still have a Gauss-Krüger projection based on Bessel ellipsoid. Newer maps already use an UTM-projection based on the Hayford ellipsoid. Overviews of the ellipsoids are shown in the table below:

Ellipsoid	Bessel (1841)	Hayford (1909)	Krassowsky (1940)	WGS84 (1984)
A [m]	6,377,397.155	6,378,388.000	6,378,135.000	6,378,137.000
B [m]	6,356,078.963	6,356,911.946	6,356,753.388	6,356,752.314
F	1 / 299.1528128	1 / 297.000	1 / 298.3000	1 / 298.257223563

Table 9: *Overview about the different used Ellipsoids in different map-projections (Baumann, E. 1994)*

The Russian maps available use Krassowsky ellipsoid with Gauss-Krüger-Projection in 6° strip-width, the so-called System S42. The system will be used in future will be compatible to the EU, one which is under construction. It will be based on a localised WGS84 (ETRF89) with a 6° UTM projection.

A brief set of transformation parameters can be given in form of three translations for Hayford and Krassovsky from WGS84 to the named ellipsoids:

WGS84-Hayford:	dX = -87m	dY = -97m	dZ = -121m
WGS84 – Krassowsky	dX = +28m	dY = -121m	dZ = -77m

The big scaled maps, like 1: 10,000 or bigger, use an UTM-Grid with 3° strip width, based on the Hayford ellipsoid and running from 27° and 30° as the middle-meridian. Most of the available data are in the 30° strip, which means between 28.5° and 31.5° (+- 1.5° of the middle-meridian). So we found it appropriate to use this strip. The Bosporus near the Marmara Sea is situated on the 29° Meridian. On small-scaled maps like 1:25,000, the projection is different. They are also based on Hayford ellipsoid and on UTM grid, but they use a strip width of 6° with the values 27° and 33°. So far we had to transform them all into the 30° strip. This was done by the discrete back conversion from UTM-Grid coordinates into geographical coordinates on the Hayford ellipsoid, and then into the defined strip of the UTM-grid. We prepared an Excel-sheet for this. The working-steps are described in the next chapter.

Since the dimensions of a map from a scale of 1:25,000 were about 55.5x42.5 cm, they could not be scanned in conventional scanners. Therefore, first of all, the 1:25,000 maps had to be partially scanned in DIN A4 flatbed scanner and then each parts were georeferenced individually. Georeferencing these partial maps, the original grids on the maps were used. The whole map was created by merging of these georeferenced parts. Details of the georeferencing process for maps in scale of 1:25,000 are as follows:

All maps were scanned with 600x600 dpi geometric and 24-bit radiometric resolution. The coordinate system is selected as UTM 3° with middle meridian 30° east as described above.

Georeferencation was done in TopoL-GIS software, coordinate transformations by an Excel calculation. With the method of partial transformation, we were able to achieve most accurate georeferenced maps. We defined standardised operating procedures by three steps: first, a normal Affine-Transformation to place the scanned maps to the position of the maps' origin coordinate system to reach a good orientation and to detect the displacement in the next step more easily. That was only the first and approximate transformation and done by using the map corners. Afterwards, all the maps were transformed exactly to the corresponding coordinate system using all the grid points printed on them. With this partial transformation, the maps are not only georeferenced; the errors are reduced. Like that we have achieved perfect neighbourhoods and a mistake minimisation of scanning and paper sheets (and sometimes also of the print) effects. Then a third Affine-Transformation, in order to move the image to the final coordinate-system (from one to another strip or ellipsoid), followed. The correct coordinates were calculated by the map-corner coordinates or by the grid on the map-sheets. A standardised operation procedure was developed in order to guarantee most accurate transformation with minimal displacement. By this method we could be sure to achieve the best result possible.

Standardised operating procedure (SOP) for Map-Transformation

- Create from the co-ordinates of the map's-corners a txt-file, where in the first column is the number; second the value in meters for y and third the value for x in meters. Be aware that the decimal-limiter is a dot and not a comma.
- Import this file into a vector-layer (TopoL-Block) by import-reading points. Now there should be a raster of the map's-corners-points.
- Create lines between the corners using snap mode. The vertexes of the lines have to fit perfectly to the points.
- Pick up the map corners on the TopoL-Block and the corners of the map and transform them using Affine-Transformation algorithm. Check before the residuals, which should be smaller than 5 m.
- The new raster will be loaded automatically
- It is very useful to enable displaying of a grid, which you should set to the value of the co-ordinate-crosses, for the maps of Istanbul it is 1000 m * 1000 m
- Start special transformation and chose the pre-georeferenced file. Fit this raster map to the window.
- <u>Georeferencation of the corners.</u> Set snapping mode to a distance of 0.3 m and only snap to points. First TopoL wants to have the correct place, so you can either put it manually or click to the point with snap. Second, TopoL wants to have the source that you have to click on the corner of the raster map. The correct corner is the most inner part of the frame line; you might say the borderline between the map and the frame. There should be a more or less clear difference in colours by the pixel. Set the cross just in edge of the black pixels of the corner.
- <u>Georeferencing the frame-co-ordinates</u>. Leave snapping-mode at a distance of 0.3 m and only snap to line-bodies. First TopoL wants to have the correct place again, so you click to the point where the vector line crosses perpendicular the rastered-line of the whole-valued co-ordinate. Second, TopoL wants to have the source again so that you have to click on the raster map. The correct position is the most inner part of the frame line; you might say the borderline between the map and the frame. There should be a more or less clear difference in colours by the pixel. Set the cross just at the beginning of the black pixels of the frame and in the middle of the co-ordinate-line, which usually goes into the map or also crosses the map.
- <u>Georeferencing the co-ordinate-crosses</u>. Set the snapping-mode at a distance of 0.5 m and only snap to Grid-points. First TopoL wants to have the correct place again, so you click to the grid-point. Second TopoL wants to have the source again so that you have to click on the cross and then to the centre.
- Correcting co-ordinates: You have to check and also to manipulate the co-ordinates. The first 4 co-ordinates are the frames. These should be ok. The next perhaps 32 points are the frame-co-ordinates, where each should have whole co-ordinate-value. Correct this to an integer amounts, usually in steps of 1000 m. The co-ordinates of the crosses should also be correct and both co-ordinates have whole value.
- Set Affine-Transformations and control the distortion, which should be less than 10 m for a 25,000 map. If there are some strange mistakes, check the points. Otherwise, run partial transformation. The system will chose the TIN automatically and try to set the minimum and maximum co-ordinates like this, so 1 m resolution (Pixel size) will also be in new raster.

By these standardised methods a best possible geodetic basis was achieved, nevertheless, we have to be aware there may be mistakes in the mapping, either unknown or occurred due to military protection. We found the map fitting very well to the real situation, but in few places, there big differences of several 10th of meters. This might be an effect of changes in the urban structure since the last updating of the map, by mistakes during aerial photo-interpretation during map creation, or intentional changes because of military or political background.

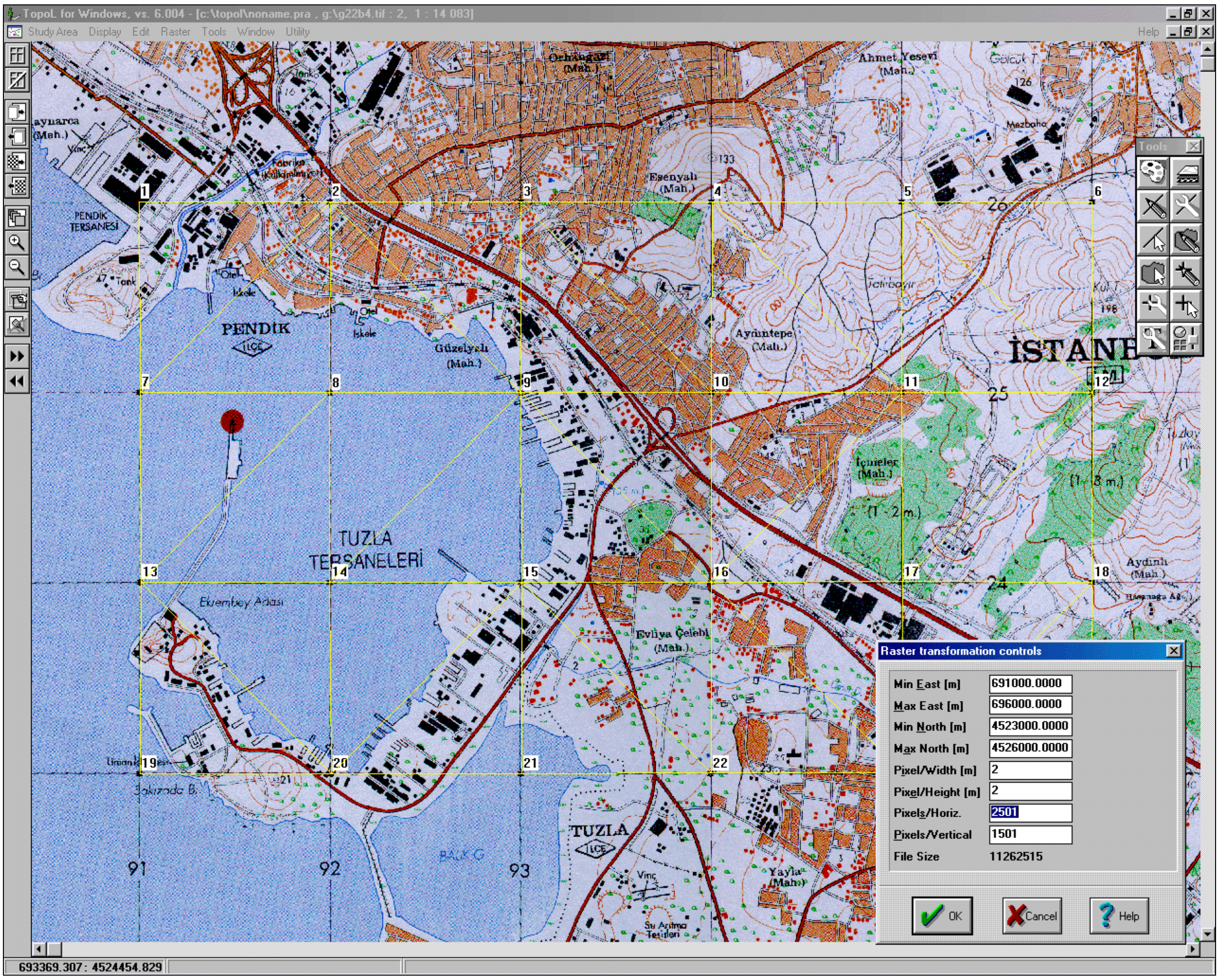


Figure 47: *Screenshot during the partial transformation of the topographical maps 1:25,000*

The spatial resolution of the map is related to the scanning about 1 m, related to the usual quality of prints less than 2 m. The geometric accuracy, however, depends on the accuracy of the geodetic basement, the drawing, and the generalisation of the maps. The generalisation however is relatively small, only roads are in some cases wider.

In average we estimate the geometric accuracy between 4 and 10 m – mainly effected due to generalisation and drawing.

2.8 Methods for transformations of satellite data

Satellite imageries are produced via different optical systems connected to multi-spectral scanners or CCD arrays. The forward movement of the platform and the optical systems effect a principal geometric distortion of the data. The terrain can effect 2 other displacements, in the case of big scenes by the curvature of the globe and by the effect of the terrain at high-resolution scanners. Other effects occur, if the sensor is shifted to a forward, backward or sideward view instead of the typical nadir orientation. This cause big problems in the image-orientation and transformation.

Georeferencation of all satellite-data was done by using different transformation algorithms, either globally or by a triangle-network computation. All these processes were done by TopoL-GIS. The different satellite imageries effect different methods and algorithms for their most fine georeferencation. Principally all georeferencation steps were performed by using picking up ground-control points on the map. An exception was during processing the historical years. Here the IRS-Image was used as an additional reference source.

Beside this, we made analyses of the geometric accuracy on these transformations. Even if it is possible to achieve sub-pixel accuracy in small areas, it is not a reliable value for bigger scenes especially if we consider the interpretation-limits.

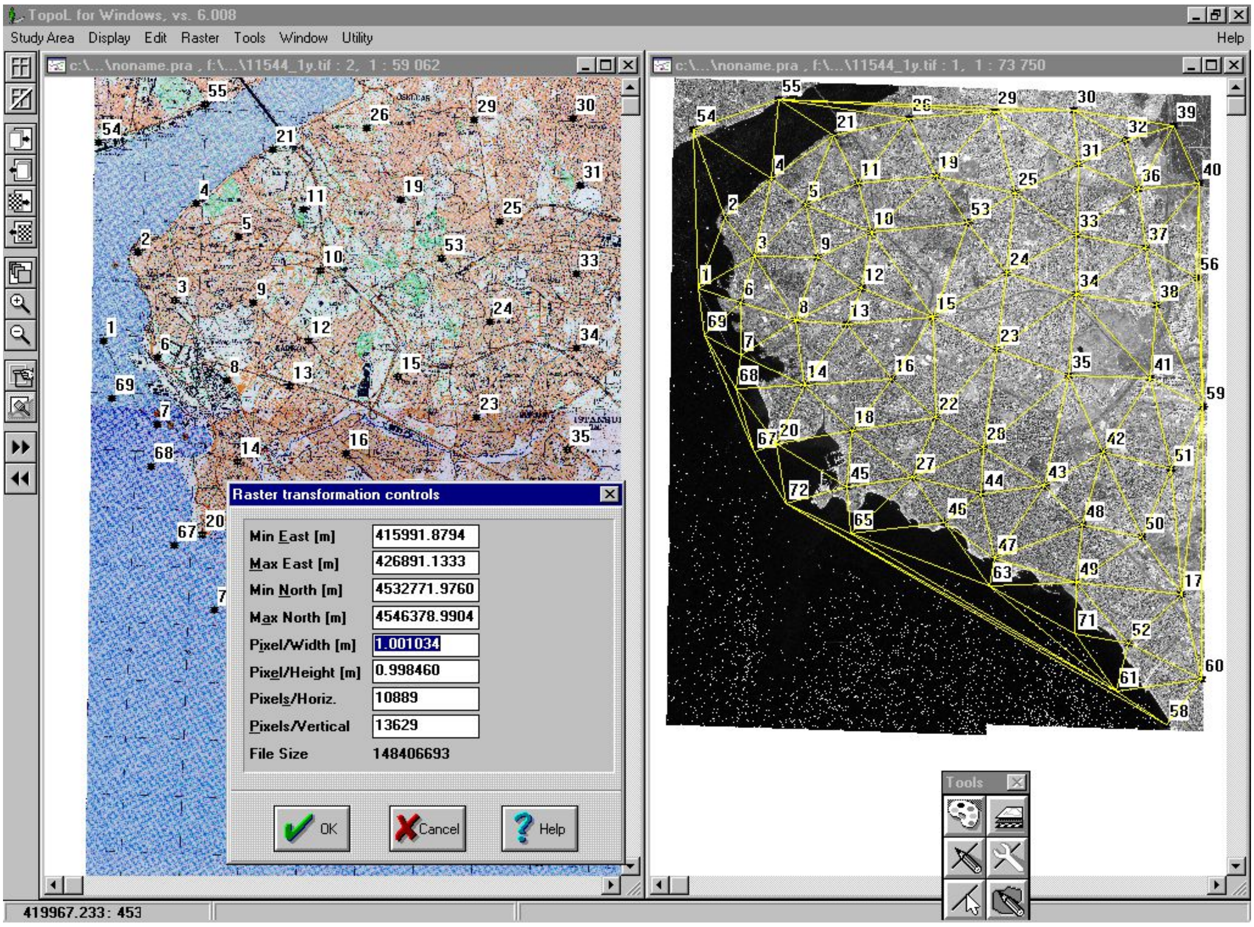


Figure 48: *Special (exact) transformation method on a Satellite Image*

2.8.1 IRS-1D Scenes in Pan and MS

Easier, however, was the geocoding of the IRS Imagery. For the purpose of our work and also to support areas outside the maps, we used global transformation methods to be enabled to extrapolate the computed parameters. This means that the entire image was georeferenced. The multispectral IRS-D Image from 26.07.2000 was geocoded by Affine-Transformation based on 15 points. This was accurate enough according to the pixel-size of 25 m. The transformation table was used for all channels, *Synthetic Blue* (computes out of the spectral band differences), *Green, Red, NIR* (near infrared) and *WIR* (wide infrared).

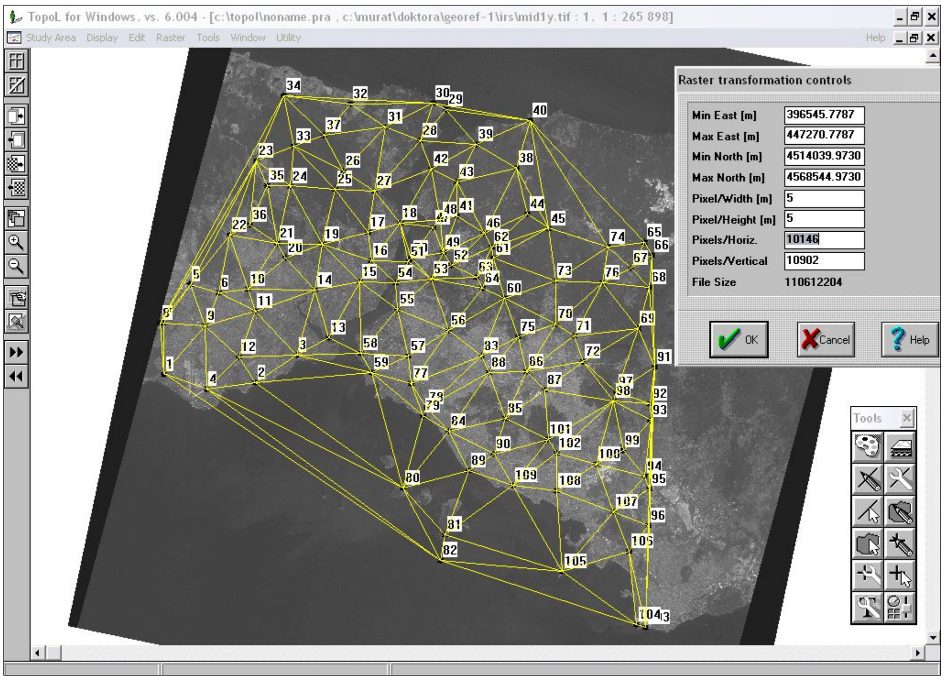


Figure 49: *Distribution of ground control points on the IRS-1D image during the special transformation method (east)*

The accuracy, given by the transformation table, is in the range of the pixel-size. Transformation was used as Affinity -Transformation algorithm at about 15 points

The PAN-chromatic images *IRS-D pan 4020D* taken at the 12.5.2000 and *IRS-D pan 4040C* taken at the 26.7.2000 were processed more accurate. After a first Affine-Transformation by 6 points for each image, which brought the image into a good position, a refinement was done with about 30 control-points for each. The transformation table was tested by different methods and Collinear- Transformation brought the best results with residuals less than 10 m. Control-points can be dis- or enabled, that is the way how insufficient points can be skipped. Both pan-chromatic IRS images, which cover the entire area, were processed like this. These new rasters were compared with the map and the result validated as fine.

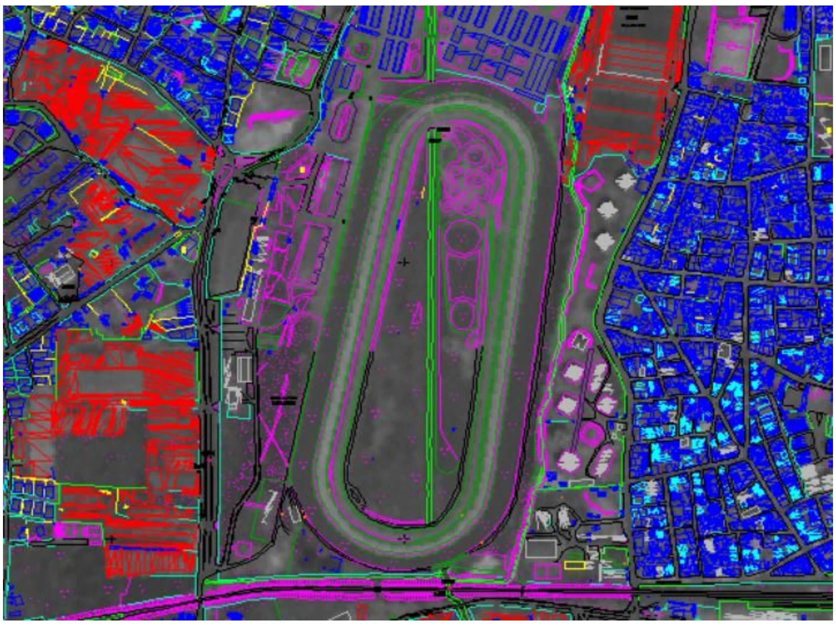


Figure 50: *Comparison of a geroreferenced IRS-Imagery with already existing digital vector data*

[m]	Co-ordinates		Deviations			Co-ordinates		Deviations	
Point	Easting	Northing	East	North	Point	Easting	Northing	East	North
1	442209.4	4520458.6	-3.0	-6.8	13	438914.5	4553928.2	0.6	7.7
4	446288.7	4513995.5	7.0	-2.0	16	435974.2	4564886.3	3.0	-16.7
5	446869.6	4515164.7	-1.5	1.3	18	426962.7	4544421.2	-7.0	-3.0
7	446758.4	4524953.6	-2.0	0.0	19	423154.5	4558098.1	-0.8	11.6
8	446714.7	4524174.6	-7.2	5.0	21	422194.5	4528164.3	0.9	3.4
10	446817.5	4533133.2	-2.1	5.1	22	401056.2	4536555.5	4.4	-5.3
11	446864.9	4541045.7	11.0	-3.8	23	419048.7	4568781.5	-3.3	3.5

Table 10*: Coordinates and deviations of some GCPs, used by georeferencing of IRS-D pan image*

After this first transformation test, the IRS-pan were transformed again by using 71 GCPs for the western one and 109 GCPs for the eastern image. Accuracy ranges at the pixel-size, a specific orientation of the displacement-vectors cannot be detected. This might be the effect of the geo-basement of the maps. Average accuracy is better, CEP can be found at 4 m

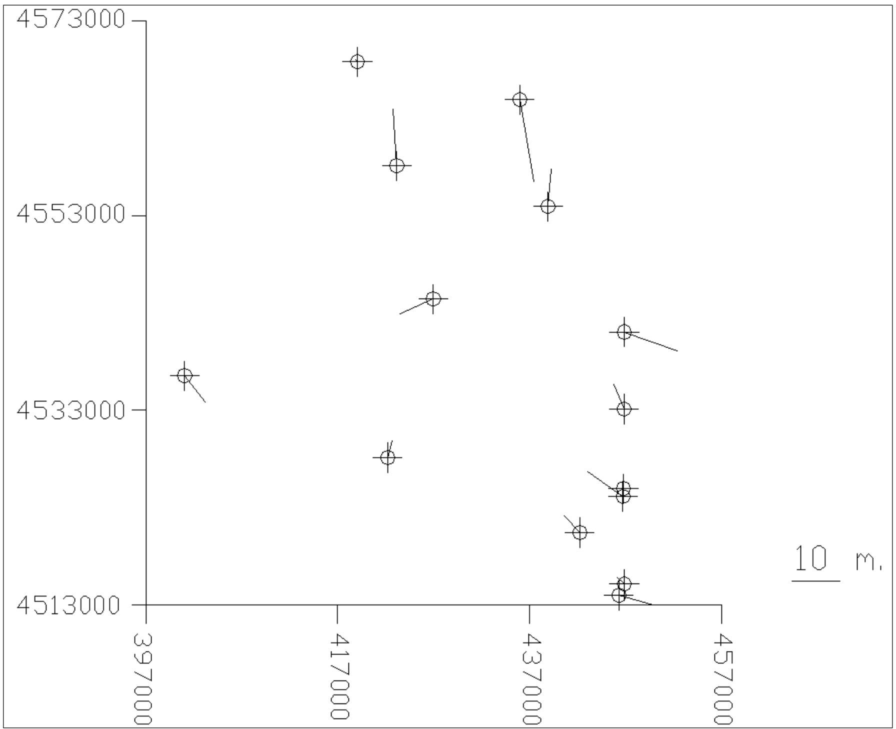


Figure 51*: Displacement-analyses of a geocoded IRS-Imagery*

2.8.2 IKONOS Scenes in Pan and MS

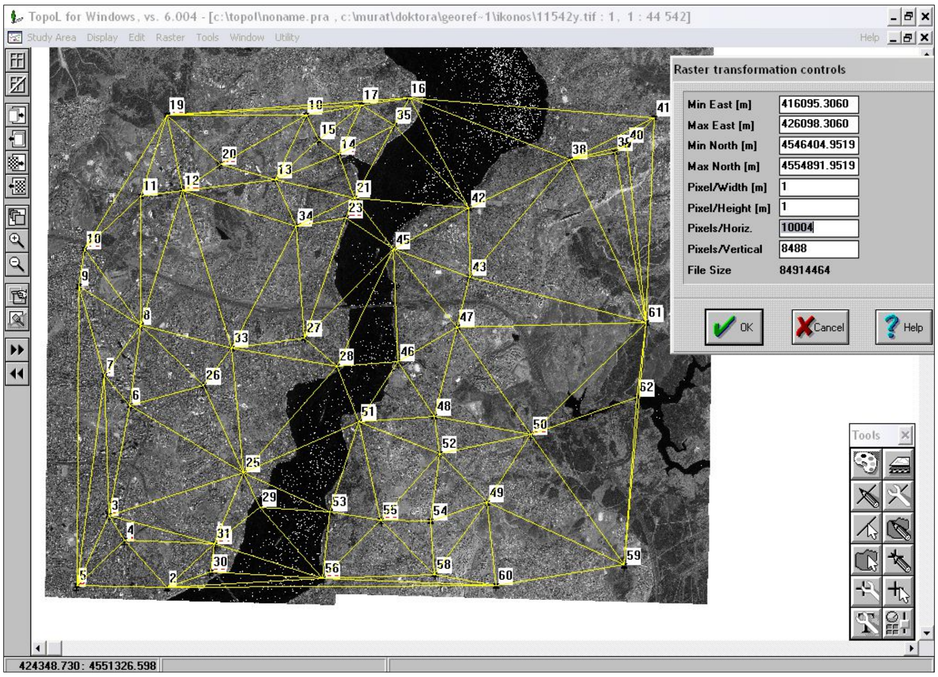


Figure 52: *Distribution of ground control points on IKONOS image (middle)*

The georeferencation of the Ikonos-Imagery was much more difficult. Due to the higher resolution based on a deeper flight-altitude and a non nadir aspect of the scanner combined with the hilly terrain especially near the Bosporus caused various problems. They were using the method of a partial transformation, which enabled us to get most accurate georeferenced satellite-imagery in similar quality like orthorectified ones. We defined standardised operating procedures in two steps: first, a normal affine-transformation to place the image near to the real position to make a good orientation possible and to detect the displacement more easily in the next step. Then we ran the partial transformation. The control points were taken from the already geocoded maps by searching a big number of identical points with x and y coordinates. The identical points were picked up on the map and the image. The software calculates a transformation table a global set with deviations for every point then. The method of transformation can be changed (to Helmert, Affine, Collinear and Polynomial) in order to test the the equation method. Control-points can be dis- or enabled, so far bad points can be skipped. Finally, the system builds a triangulated network and computes every triangle by Affine-Transformation to a new triangle. The new triangles fit to each other and finally they are mosaiced automatically

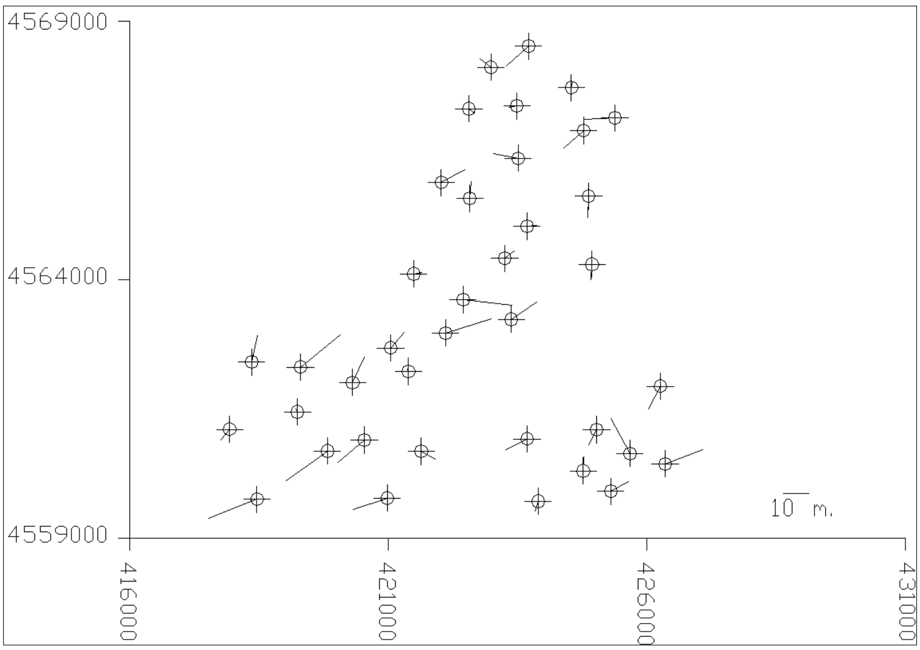


Figure 53*:* *Displacement-analyses on an IKONOS-Imagery*

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The finally received new Raster is georeferenced most perfectly. The quality only depends on the accuracy of the control-points and their density. We estimate that the average result is better than 3 m; however, we are not able to prove the quality of the maps and the compatibility with the real situation as seen on the images. The score quality of the map worsens the final accuracy.

[m]	Co-ordinates		Deviations			Co-ordinates		Deviations	
Point	Easting	Northing	East	North	Point	Easting	Northing	East	North
1	420971.7	4559774.0	-13.1	-4.4	24	425666.8	4560636.6	-7.3	13.4
3	420530.4	4560896.5	-10.2	-8.6	25	426256.4	4561938.2	-4.5	-8.9
4	419236.7	4561441.4	-0.6	1.1	26	421482.6	4564112.0	3.2	0.4
6	421039.4	4562678.4	5.4	6.0	27	426351.7	4560435.8	14.5	5.6
7	418454.8	4559751.9	-18.7	-7.2	28	424934.6	4564298.3	-0.3	-5.8
8	417927.5	4561104.1	-3.5	-4.1	29	423676.5	4565033.9	3.9	0.4
9	419296.3	4562308.4	15.3	12.4	30	423249.0	4564412.3	3.7	2.9
10	422440.3	4563614.2	18.9	-2.2	31	422571.5	4565572.8	0.7	6.4
11	423374.2	4563231.9	9.8	6.7	32	423502.5	4566347.8	-9.3	1.9
12	422100.8	4562968.0	17.8	5.4	33	422554.4	4567306.2	2.0	-1.8
13	421385.1	4562225.5	-0.4	1.0	34	424868.5	4565613.9	-0.5	-8.3
14	420303.2	4562010.2	4.4	9.8	35	425377.8	4567127.5	-11.6	-0.6
15	423891.8	4559713.5	-1.0	-3.8	36	424768.4	4566884.9	-7.5	-6.9
16	421631.3	4560680.0	5.4	-3.1	37	423481.6	4567362.6	-3.0	-0.6
17	423678.8	4560919.2	-8.4	-4.0	38	424534.9	4567714.5	0.4	2.2
18	419817.8	4560685.2	-15.9	-11.5	39	422978.7	4568109.3	-4.2	3.3
19	425021.8	4561097.6	-3.2	-5.8	40	422020.1	4565880.6	9.2	5.0
22	424766.0	4560298.5	0.1	5.6	41	423706.8	4568517.0	-8.6	-7.7
23	425298.8	4559905.9	6.7	3.6	42	418349.7	4562407.7	10.2	2.2

Table 11: *Coordinates and deviations of ground control points, used by georeferencing of IKONOS image*

The examples shown visualise that a big number of ground-control-points fit fine, others reveal a big deviation. If the deviation is different in neighbour points, there is either a mistake in the capturing of the points or a mistake of the basis. Sometimes also structures (buildings, roads etc.) have changed during the years. If the deviation in the neighbour points is similar, there might be a bigger effect of terrain or a principally error in the maps.

2.9 Digital methods with Satellite Imagery

Some procedures will assist to make the data more efficient for the interpretation procedures. Some of them are stretching, colour-balancing and mosaicing procedures as well as colour-composition and pan-sharping methods. They are briefly described below.

2.9.1 Colour composition

In both cases, for the IRS and Ikonos data, the cannels of the MS-Data are in separate files as greyscale, in case of Ikonos as 11-bit grey-value stored in 16-bit Tiff grey-format. To process such data in TopoL, the 11-bit grey value had to be converted into an 8-bit standard Tiff format using Adobe Photoshop software, including automated stretching operation. The Channels *Blue, Green,* and *Red* were matched to an RGB coloured Image via the TopoL Process for colour-composition. In case of the IRS Imagery, the blue channel was already delivered as a separate file computed out of the differences between all the other data to a so-called Synblue-channel.

2.9.2 Stretching, colour balancing and mosaicing

The panchromatic data were stretched in order to receive a most detailed visible image. This was done in Topol-Software using histogram balanced stretching algorithm. To receive also information in dark parts too, the contrast was chosen a bit lower than the automatic optimisation procedure would recommend.

After this step, all single panchromatic images were automatically balanced in the overlapped zone. To make these procedures possible, all black frames had to be masked via the related raster operations in TopoL. A powerful tool in TopoL helps to achieve in this overlapped zone minimal differences in the greyscale. After masking the single images, they were mosaiced into a new entire raster. This procedure was done for the IRS and for the Ikonos Imagery.

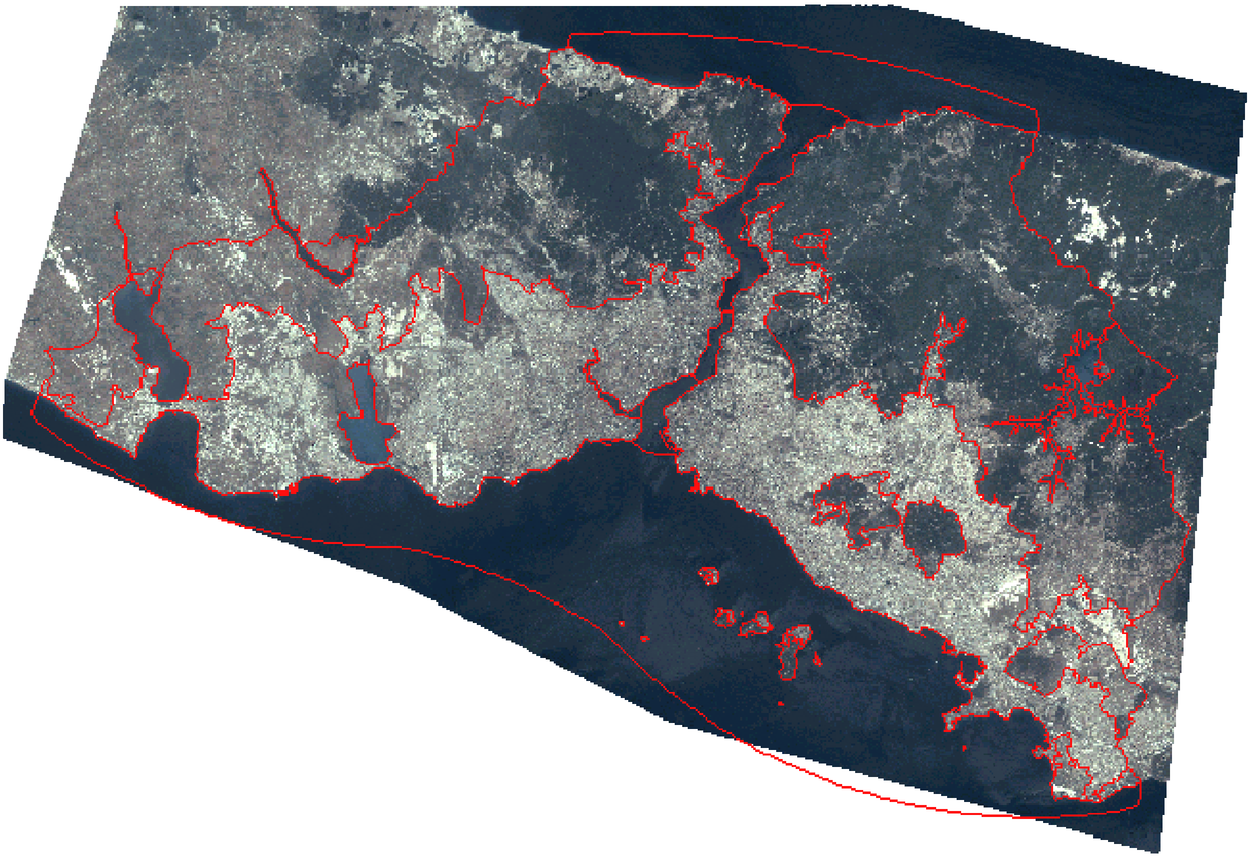


Figure 64: *The mosaiced IRS-Panchromatic imagery merged with the multi-spectral IRS-RGB channels*

2.9.3 Pan-sharping

The RGB Images produced like this, were overlapped by the panchromatic mosaiced data. Due to the setting of the overlayed panchromatic Image as transparent with a level of 50%, the data were pan sharpened on the screen. This way, low resolute MS-Data become structural information of the pan-data – or in other terms, the more detailed pan-data receive colour-information from the MS data. A special tool in TopoL, which makes to save the actual setting of the screen into a new raster by using full original resolution and geocoding possible, managed the storage into a new raster-file for the later use.

This was done for the IRS data and the result was a coloured 5m resolute Image. For the Ikonos, a coloured 1 m sample was produced.

2.9.4 CIR, TIR and NDVI-computation

Additional combination of multi-spectral bands can assist in data-analysis. The different bands allow the production of new images, especially in the combination with the NIR (near infrared) I and the WIR (wide infrared) channel available in some of the IRS-MS data. Even if the spatial resolution is just 30 m, these data show as overview the distribution of vegetated areas and localities with high thermal radiation. A first example shows the colour-composition of a Coloured Infrared image (CIR). The setting of the NIR to red, the red to green, and the green to blue give the typical colours like known by CIR aerial photographs. An example is shown below where urban green areas can be seen better than on RGB-Images only. The use of the NIR channel allows the semi-quantitative measurement of chlorophyll activities, which itself gives information on the vegetation activity. It somehow shows the distribution of the vegetation-types. On the example below the region of Büyükcekmece and the airport can be seen. We used the channels 2, 3 and 4 of the IRS-MS data from the 26th of July 2000. The urban sprawl into the agricultural area can be detected very easily.

Figure 65: *CIR computed image out of MS IRS data from 26.7.2000*

The disadvantage of this procedure is the low resolution of 30 m only. Pan-sharping is not suitable for such data since in combinations like that grey colours are used already for non-active areas. Overlapping with the panchromatic data would cause redundancy and limit the usability of the newly produced dataset.

A more advanced method for the detection of vegetated areas is the computation of the Normalised Differential Vegetation index (NDVI). The figure below is also computed using data of 26 July 2000 while the rural areas are still well vegetated and green. The dry period is just about to start. For this computation, the Software Idrisi was used in order to receive coloured 8-bit data correctly labelled by the Index, ranging between –1 and +1.

The computation of the NDVI is based on the equation: NDVI = NIR-RED/NIR+RED

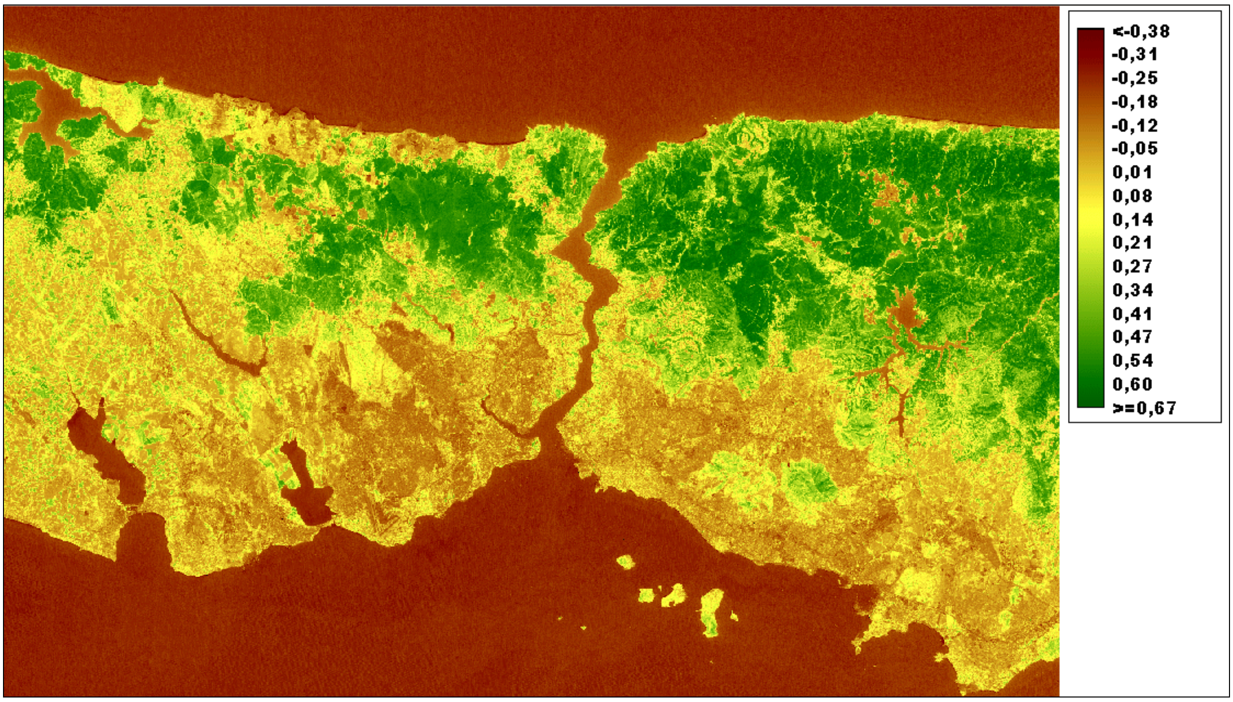


Figure 66: *NDVI computed data out of MS IRS data of 26 July, 2000*

In another step the use of the wide infrared channel (WIR) was tested in combination with the NIR and the red channel in order to receive data that show the urban heat effect during a sunny day. The WIR data, however, does not represent a thermal channel; so far the data do not really represent what can be called an urban heat effect. The result received did not really provide new aspects for the interpretation; only in some cases, the differentiation between NIR and WIR pixel was easier. The data in this WIR had several mistakes in pixels and did not appeare very sharp. So, these data were not used in the later interpretation procedures.

Figure 67: *WIR, NIR, Red composed image out of MS IRS data from 26.7.2000,*

2.10 Methods for transformations of satellite photographs

As mentioned above, the satellite photographs derived from the Russian spy campaign and taken by photographic technologies. Especially the KFA camera has got the ability of photogrammetric processing, however, the calibration data were not available and we even did not have complete scenes in order to get access to the fiducial marks. Finally, data like that must be treated as a snapshot of a camera with a photo-centre. In contrast, the KVR Imagery are much more difficult because they are taken by a panoramic camera which needs for a single image several seconds to capture while the satellite is moving. This results in a stretching along the flight-track. Furthermore, this panoramic camera has no calibration for standard photogrammetric processing.

To solve all these problems we decided to use planar transformation algorithms in order to receive reliable results. This is described in the following chapters.

2.10.1 KFA-1000 Satellite photos

For the purpose of our work and also to support areas outside the maps, we used global transformation to be able to extrapolate the computed parameters. This means that the entire image was georeferenced. Both KFA-1000 photos were processed similarly to the IRS-D satellite imageries.

After a first Affine-Transformation by 5 points for every image, which brought the image in a good position, a refinement was undertaken with about 40 points. The transformation table was tested by different methods and a polynomial transformation of degree 3 showed the best results with residuals less than 15 m. This raster was compared with the map and the IRS-Imagery and the result was in the accuracy expected.

In order to receive the most accurate result, a partial transformation of triangulated GCPs was tested shown below. More than 60 GCPs were selected and the average result was similar to the previous polynomial 2D transformation. In cases where the partial transformation had cut the image outside the GCPs, we stepped back to the previous method.

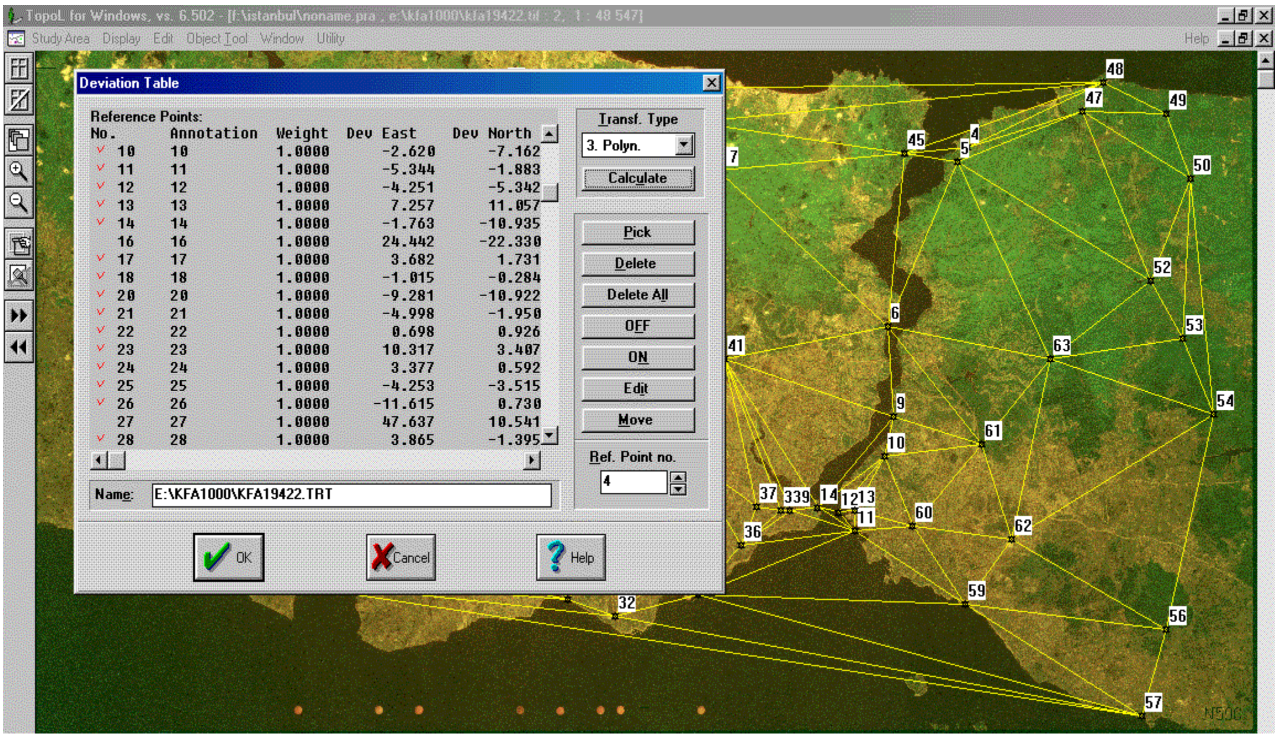


Figure 68: *partial transformation on the western KFA-1000 Satellite Imagery*

[m]	Coordinates		Deviations			Coordinates		Deviations	
Point	Easting	Northing	East	North	Point	Easting	Northing	East	North
4	427887.6	4563751.5	-1.1	-7.0	35	406437.2	4546901.4	3.6	-2.2
5	427110.8	4562929.9	8.0	7.2	36	409144.0	4541020.8	1.6	-5.7
6	421030.1	4553317.2	-3.9	-7.3	37	410571.1	4543279.6	3.1	-2.0
9	420594.3	4547726.5	-3.6	-9.0	38	412130.9	4542849.4	-6.9	0.4
10	419660.9	4545371.0	-2.6	-7.2	39	412812.7	4542801.0	7.0	3.1
11	416991.3	4540988.2	-5.3	-1.9	41	409655.1	4552728.9	3.7	3.5
12	416072.2	4542262.9	-4.3	-5.3	42	406681.3	4557641.6	-8.7	1.5
13	417200.0	4542285.9	7.3	11.1	43	399340.9	4559803.8	9.2	6.8
14	414705.4	4542723.5	-1.8	-10.9	44	394021.4	4560490.2	3.4	3.9
17	410804.5	4564596.1	3.7	1.7	45	423640.3	4563909.8	4.6	10.5
18	409467.3	4567800.9	-1.0	-0.3	47	435840.0	4564969.0	2.0	0.3
20	403372.4	4567210.2	-9.3	-10.9	48	437507.5	4566554.6	-4.7	-0.2
21	396738.7	4571528.2	-5.0	-2.0	49	441348.8	4564031.7	5.2	-2.1
22	392145.1	4566574.2	0.7	0.9	50	442400.7	4559898.1	-0.4	4.4
23	381118.4	4563462.4	10.3	3.4	52	438909.4	4553926.2	-13.2	-7.5
24	374935.4	4562051.9	3.4	0.6	53	440524.7	4550209.7	-3.1	-7.5
25	376895.4	4558942.4	-4.3	-3.5	54	441941.5	4545323.0	1.8	2.5
26	377019.4	4554056.2	-11.6	0.7	56	436902.0	4532611.2	12.1	6.2
28	371750.9	4543911.6	3.9	-1.4	57	434577.7	4527542.4	-7.6	-7.3
29	379221.4	4544627.1	-1.9	-0.6	59	423788.1	4535620.7	-5.7	4.0
30	392364.1	4546985.2	-2.8	-2.8	60	420969.4	4540837.2	-5.0	0.9
31	396769.3	4539046.7	-0.9	6.0	61	426303.6	4545322.2	-1.5	7.1
32	399855.0	4537662.5	6.2	6.4	62	427473.8	4539269.2	7.3	7.8
33	405733.3	4538301.1	-0.1	-4.2	63	431648.7	4549987.9	8.2	8.1

Table 12*:* *Coordinates and deviations of ground control points, used by georeferencing of KFA-1000 image with a planar polynomial transformation procedure*

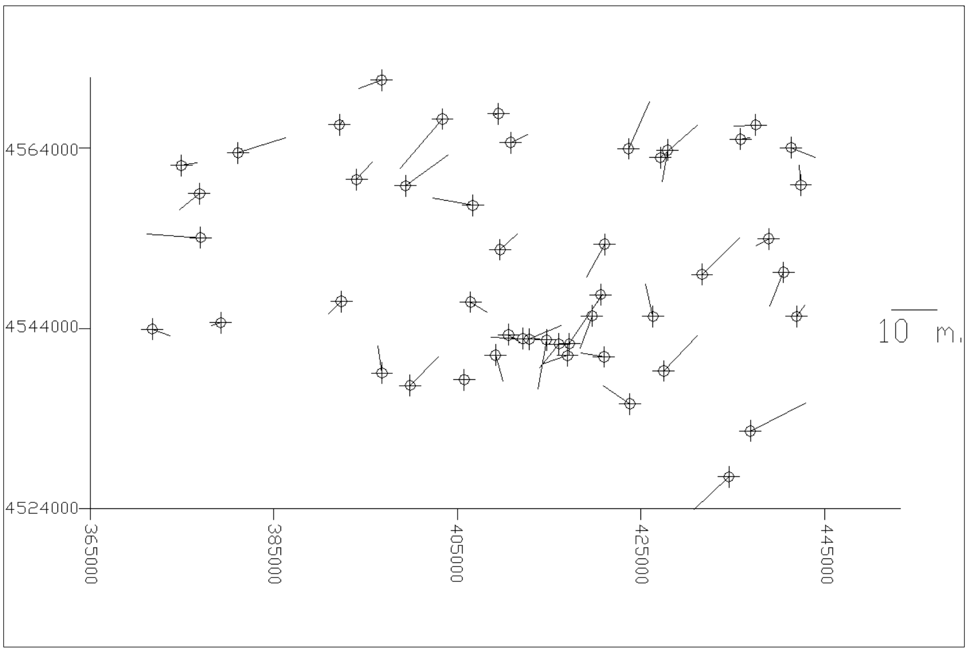


Figure 69: *Displacement-analyses of a KFA-1000 Imagery*

After this step, the single raster was automatically balanced by RGB-Colours in the overlapped zone, framed and mosaiced to a new entire Raster. The colours however were very different; so far the colour balancing did not work without problems.

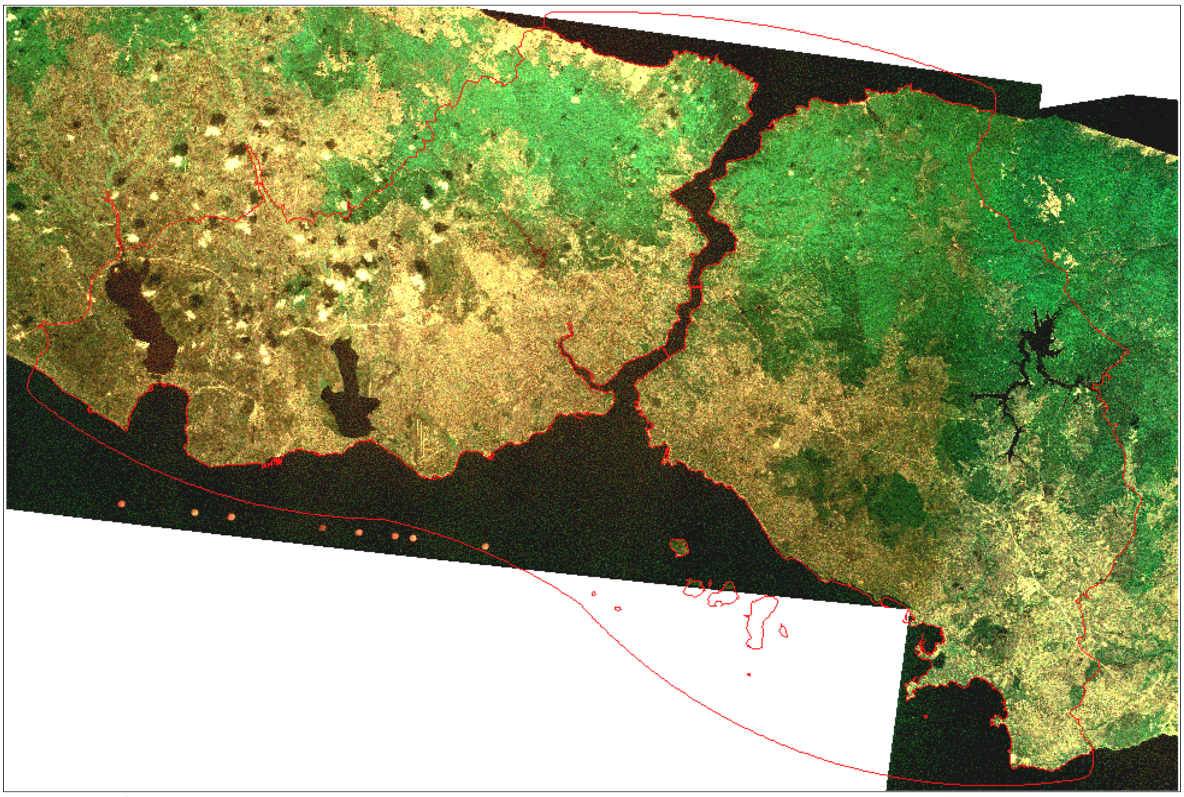


Figure 70: *Mosaiced and more or less well colour balanced KFA-1000 Image set*

2.10.2 KVR-1000 Satellitephotos

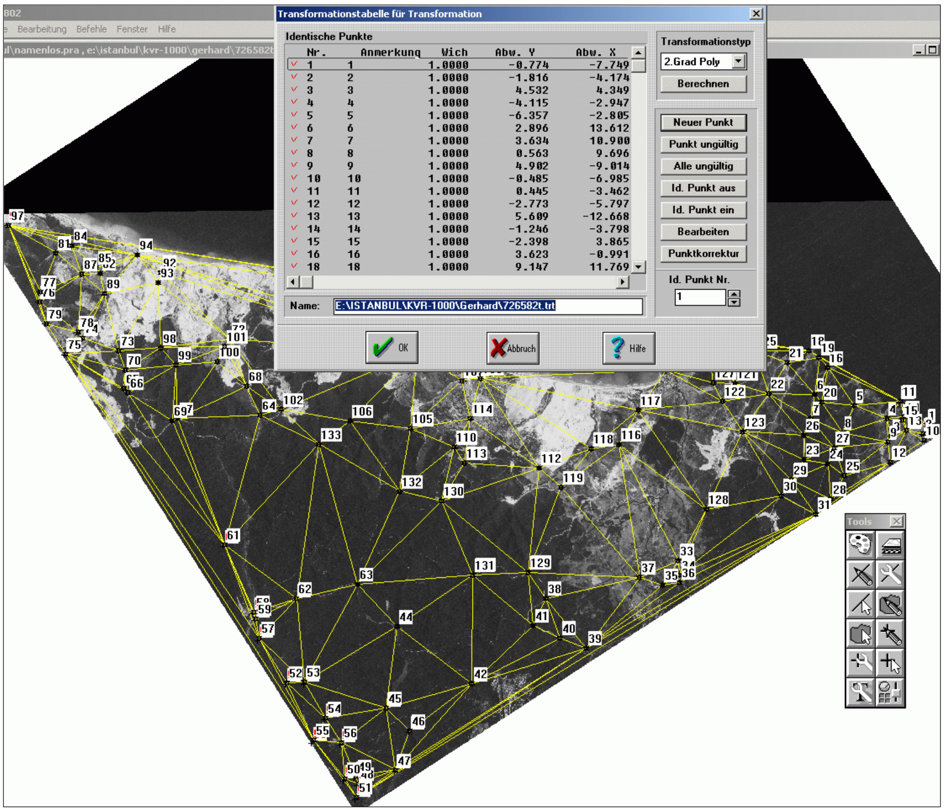


Figure 71: *Polynomial transformation of KVR-1000 image S0726582*

The four KVR-frames were received scanned in 7µm resolution. The ground spacing was about 2 m. Because of the strong radial distortion of the KVR-camera, the processing of the imagery was very difficult. Trans-formation was done in two steps with planar transformation pro-cedures. For the smallest image, the S0726582, an affinity transformation was computed using 20 GCPs. Their detection was rather difficult since the landscape had changed dramatically in these parts. The maximum distortion was up to 40 m, but acceptable as a first step, in order to receive better correspondence via correlation of the GCPs in the ongoing procedure. Then, using visual correlation to maps, IRS and IKONOS Images, more than 140 GCPs distributed all over the image with special respect to the frame, were collected. Using a polynomial transformation of degree 3, the result achieved was better than 20 m for all points. The average displacement, depending on the computation, ranges between 5-9 m.

The deep flight altitude causes displacement problems related to the terrain. The detection of suitable GCPs, however, even adds unsorted directions of deviations. The change of roads and unprepared paths are just one aspect of many others. The georeferencing of these images took rather long and mainly smaller parts of the entire image were transformed correctly with acceptable deviations. Nevertheless, they are useful in combination with the KFA-1000 data for the manual down dating of the land-use data. Nevertheless, even all the other parts of these KVR-1000 data were mainly used for the land use interpretation. Corrections of the geometry were done most carefully and only if the change was significantly higher than 25 m.

[m]	Co-ordinates		Deviations		[m]	Co-ordinates		Deviations	
Point	Easting	Northing	East	North	Point	Easting	Northing	East	North
1	4254747.8	45675336.1	-0.8	-7.7	64	4094664.6	45678023.4	8.3	5.5
2	4253808.6	45673409.2	-1.8	-4.2	65	4061437.4	45684458.9	2.3	13.0
3	4246401.5	45673037.6	4.5	4.3	66	4062485.5	45683578.5	0.2	9.9
4	4245243.4	45677133.1	-4.1	-2.9	67	4074564.0	45677208.6	10.4	14.3
5	4237439.5	45680215.5	-6.4	-2.8	68	4091330.3	45685060.7	9.1	-0.7
6	4228091.8	45683059.6	2.9	13.6	69	4073289.5	45676721.6	16.1	15.2
7	4227050.5	45677347.6	3.6	10.9	70	4061896.8	45688999.6	4.2	9.5
8	4234745.6	45673833.1	0.6	9.7	72	4087407.8	45696500.0	8.1	7.6
9	4245557.4	45671443.8	4.9	-9.0	73	4060249.3	45693549.4	-1.8	2.3
10	4254041.4	45671849.8	-0.5	-7.0	74	4051466.9	45696506.9	-10.0	-4.1
11	4248420.7	45681214.3	0.4	-3.5	75	4047308.6	45692657.3	-10.9	-5.7
12	4246100.5	45666583.5	-2.8	-5.8	76	4040973.3	45705450.8	-1.6	1.9
13	4249939.6	45674075.3	5.6	-12.7	77	4041203.1	45707854.7	-1.3	-2.0
14	4249316.8	45677439.4	-1.2	-3.8	78	4050265.7	45698019.8	-11.8	-5.5
15	4248834.4	45676773.4	-2.4	3.9	79	4042687.8	45700122.4	-6.2	1.4
16	4231231.2	45689353.7	3.6	-1.0	81	4045211.1	45717343.5	5.5	3.1
18	4226698.1	45693481.0	9.1	11.8	82	4055964.1	45712328.5	0.5	-2.0
19	4229171.5	45691773.3	-2.4	9.6	84	4049043.4	45718986.1	8.9	0.2
20	4229707.3	45681114.7	1.4	-2.6	85	4054995.8	45713777.2	3.1	-0.6
21	4221535.5	45690583.3	3.1	5.6	87	4051400.3	45711968.1	0.6	-6.7
22	4217151.5	45683263.7	7.6	4.1	89	4056947.4	45707291.9	3.6	-14.4
23	4225398.8	45667252.5	-1.0	-2.0	92	4070503.2	45712568.7	-18.7	7.7
24	4231108.7	45666279.0	-4.0	-5.9	93	4070030.3	45709993.9	5.3	-1.6
25	4235040.8	45663397.5	-7.1	-3.9	94	4064896.4	45716794.6	-5.7	5.1
26	4225409.8	45673107.4	0.1	-4.1	97	4033581.1	45723715.1	-7.0	-12.7
27	4232629.2	45670046.0	-5.1	-1.5	98	4070511.5	45694406.8	4.9	8.8
28	4231777.9	45657908.8	-5.6	-6.5	99	4074191.6	45690308.9	6.9	12.4
29	4222586.6	45662611.8	14.6	5.1	100	4084251.7	45691060.8	10.2	0.3
30	4220008.7	45658844.9	3.8	5.9	101	4086076.4	45694622.2	10.3	2.8
31	4228340.6	45654418.1	4.9	8.3	102	4099500.6	45679216.4	-5.3	-11.3
33	4195322.9	45643178.7	5.1	-2.4	103	4132600.5	45693007.5	-8.7	-14.3
34	4195549.0	45640033.5	-0.2	19.1	105	4130917.4	45674683.4	4.1	-4.4
35	4191265.5	45637195.6	-21.4	-4.1	106	4116421.3	45676658.3	11.1	0.8
36	4195620.5	45637853.6	9.0	-5.8	107	4143442.3	45686404.5	-1.6	-4.1
37	4185945.0	45639012.1	-1.5	-4.9	108	4147740.2	45687005.9	-1.3	-3.5

Table 13: *Coordinates and deviations of ground control points, used by georeferencing of KVR-1000 image with a planar 3-degree polynomial transformation procedure*

2.11 Photogrammetric Methods for the Orthophoto-Generation

For the processing of the aerial images of the 1940ies and 1968, digital photogrammetric procedures were used in order to produce orthophotos in a suitable quality as source for down-dating of the land-use data. All the data were processed in PhoTopoL-Atlas, a digital photogrammetric workstation, based on Windows PC.

PhoTopoL is an affordable photogrammetry softcopy system. Developed by TopoL Software s.r.o in the Czech Republic, PhoTopoL is an advanced system that permits performing the automatic correlation, the orthophoto-creation, and digitising in a proprietary topologic environment. For the exterior orientation, there are tools to work with the bundle adjustment *AeroSys,* developed in US. The digital terrain model can be created with the Atlas module, also developed in the Czech Republic, by the company Atlas Ltd. It is a system that permits correcting the altitude of points captured by automatic correlation, thus allowing to create contour lines automatically ready to print. It has also other capabilities, like the creation of video file to visualize the ground, to create sections, to analyse signal propagation or to show the visibility of areas, to integrate hydraulic tools and others. One of the latest developments is a tool to create digital models of terrain containing buildings. In this project, the tools for project-management, orientation, and aero-triangulation were used at the beginning, followed by the module for the photo rectification to orthophotos, with masking and mosaicing utilities and the balance of colours.

2.11.1 Scanning and interior Orientation

All the contact copies of the aerial photos (positive slides) were scanned with 600x600 dpi geometric and 8 bit radiometric resolution by using a transparent illumination on an HP office-scanner. A camera-protocol was developed for each camera by using focus-length and measured co-ordinates of the fiducial marks. The use of a relatively cheap scanner instead of a very expensive photogrammetric one was sufficient because even the geometric accuracy of the contact-copes could not be proved. The distortion produced by contact copying and scanning was taken into account in the processing of the photos.

The camera calibration was not delivered for all the photos; partly they were extracted from literature or measured out of some sets of contact copies. The detection of the exact type of camera was the most difficult job. Information required especially about the fiducial marks coordinates and the radial distortion of the lens had to be detected.

Data of the fiducial mark coordinates and the focus-length were stored in the camera-file, while the radial distortion was unknown and set to zero as well as the unknown principle offset or the auto collimation point (PPT).

Figure 72: *Fiducal mark on a photo of the year 1968*

For each series of photo-blocks an own project was created with respect to different cameras, scales, flight-altitudes, focus-lengths and block-layouts. The internal orientation consists of two steps, which define the transformation of pixel coordinates. When performing the related command, a window is opened to select the photo and the rotation of the photo (position of instruments). The fiducial marks are displayed in the same order. They were defined when specifying the camera. The marks were digitised, using auto-panning, correlation, and local zoom. On some photos, the fiducial marks were not visible correctly. In those cases, the internal orientation was first computed with a Helmert-Transformation, then with an Affine-Transformation. The residuals were rather big - compared to the mentioned unknown distortion of the camera, the quality of the contact-copies and the low scanning quality, not surprising. Usually the average displacement was around two pixels. In some cases, only three marks could be used, rarely only two were detected in the images.

2.11.2 External Orientation and Aerotriangulation

The exterior orientation, relating the photo coordinate system to the exterior, is relative, if only relative points are observed, or absolute, if control points are used. The minimum control required to perform an absolute orientation, is two complete points, plus one in Z.
PhoTopoL supports different methods of external orientation,

- *Single image,* if the orientation is to be performed for only one photo; in this case, it is necessary to know at least four complete control points to perform a bundle adjustment.
- *Stereoscopic pair,* which is the normal case, uses the indicated left and right photo in relative and absolute way.
- *For photo-strips,* where 6 or 10 Gruber points are observed first and oriented with a set of Gruber points and at least 4 complete control points in order to perform the aero triangulation computation.
- *For photo-blocks,* where several strips can be combined and be computed in a bundle block adjustment within the aero triangulation computation.

As the overlap between the photos was too small or inhomogeneous (somehow rotated or shifted), in most cases the orientation for single images was used. The most severe problem, however, was the detection of ground control points in position and height. There are no measured and no geodetic points for this period. There is no marked signalisation for these campaigns and in each case the data are no more available for these periods.

PhoTopoL has full GIS and CAD capabilities; therefore, it performs the use of raster and vector data also in the orientation procedure. This possibility allowed to use the already geocoded topographic maps for the measurement of GCPs interactively besides the photograph to be orientated.

Figure 73: *Photo of the year 1945 with high contrast (hot-spot) and very dark corners*

Those points were observed on the topographical maps as identical points on the photo and the raster. The planar position was picked up and transferred to the photo. To receive the Z co-ordinate of the point, heights written on the maps contour lines were edited into the dialogue box. In the ongoing procedure, we also used the contour lines from the DTM, which were imported as 3D vector data. PhoTopoL is able to snap (either position, height or both) to vector data and to receive the coordinates exactly. This combined function, taking position from the raster-map and heights from snapped vectors, made the orientation procedure a bit easier. Relative-points, height-points, position-points, and full-points were mixed in the bundle-adjustment method, depending on the methods described before. The accuracy was set to 1 m in spacing and 2 m in heights in order to be reliable to the accuracy of the scanned photos (~1m/pixel) and the accuracy of maps and vectors. However, the strong land-use-change made the identification of identical points, especially outside the urban centre, very difficult. In the case where already 2 points had been picked up, the system helped using estimated position panning into the expected next position. Nevertheless, to find enough suitable points was a kind of detective work. On some images, it took more than 2 hours to detect good points. Another big problem were in the extremely dark corners of the photos where the photos had almost been black; the centre was usually too bright. Even different pre-processing steps with different programs (Photoshop and others) where not able to solve this problem. Especially the areas near the corners are very suitable to place tie- or control points for geometric adjustment. In addition to this, some cameras already have a frame vignetting the corner or have placed additional information instead of a separate control panel. On some photos there had also been clouds. These effects finally interrupted the process of an aero-triangulation, because in the overlapped zone the tie-points (Gruber or relative points) had to be placed in the final 10% of the three images zone, close to the corner. The use of AeroSys-Software for the strip- or block bundle adjustment failed due to big relative residual.

2.11.3 Orthorektification, Masking and Mosaicing

The creation of a DTM is an important part of this workflow, and was derived from CAD-Data. The process and details will be described later. A triangulated irregular network (TIN) terrain model was prepared with Atlas-DTM Software. For the process of Orthophoto-calculation, DDE connection between both softwares, PhoTopoL and Atlas-DMT, was used to support this TIN-based DEM directly for the calculation. That way, the most accurate computation can be expected.

As long as the photographs are orientated, this process can be started as a batch-process for every defined project without any operator's intervention. The orthophotos were resampled to a resolution of 1 m, which is better than the expected accuracy. Not all of the calculated Orthophotos however were fine. This might be due to the problematic selection of control-points, but moreover we believe that there is a big radial-distortion in the camera and indeed the DTM is not faultless. But for the purpose of the project the quality was fine.

Figure 74*: Example of an orthorectified aerial photo of the year 1949*

2.12 Automatic classification

Based on the experience of the JRC and many other partners in similar projects, automated classification methods are will fail in order to fit to the MOLAND classification legendary.

It is a commonly known fact that urban areas give limits to the automated interpretation of satellite data. Structures are too complex. By spectral-radiometric measures only, pattern cannot be divided easily. The structure of the urban fabric consists mainly of neighbourhood of linear elements and areas. Structured areas like that define the kind of pattern, but not the actual use inside. Even during manual visible interpretation, ancillary data have to be used in order to define the corresponding land-use seriously. Only the local knowledge, the context, and the association between different areas lead to a reliable interpretation of the land-use pattern. In the past, many scientific researches tried to divide urban regions at least into a few classes, typically with big efforts but very limited success. Even the use of fuzzy logic based neuronal networks did not solve this task.

The recommended accuracy forced the use of the panchromatic data to detect the geometry and correctly e.g. the width of streets. However, automated classification procedures on remotely sensed data of urban structures need, in order to reach a good segmentation, multi-spectral data in the resolution required. Such data can be achieved for this project from the IKONOS imagery; however, this information is limited to the Bosporus area only.

There is another problem given by the necessity to create topologic vector data. Most of the tools for automated classification create a new set of raster-data. It was decided to create topological vector data as lines and areas combined with a database. In any case, this would mean a correction of automated created vectors to suitable topological structure. From the various software tools, which are able to process clustering and classification, only a few are able to create vector data.

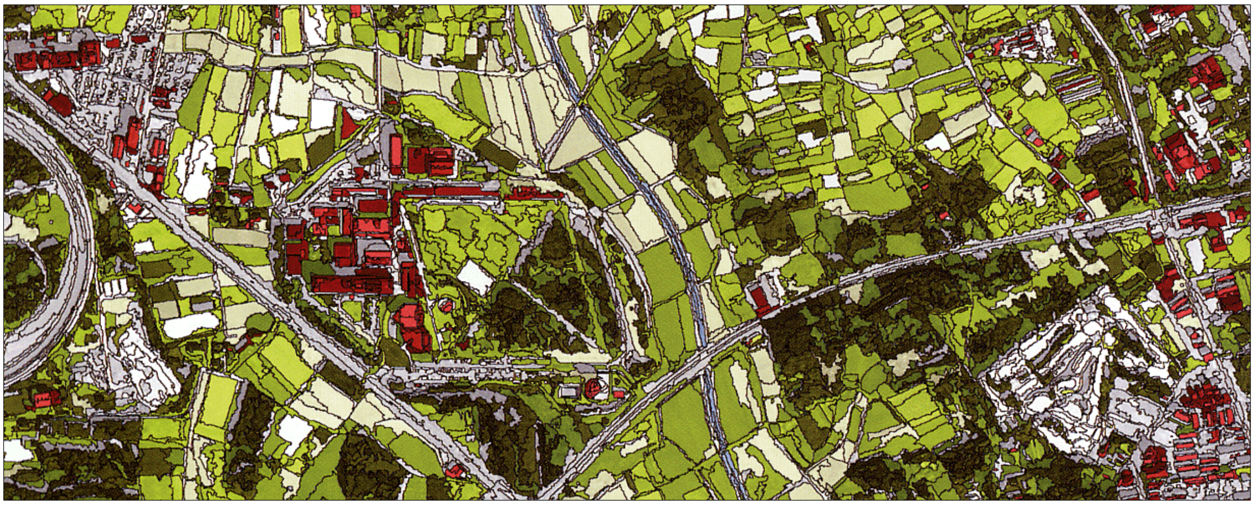


Figure 75: *Example of a classified satellite image done by ECOGNITION software, which already creates vector data*

As shown in the figure above, single buildings have been extracted, but not areas of similar structure. The vectors extracted are inhomogeneous and non-topologic. They have a strongly curved outline.

Nevertheless, it had to be tested, if any clustering or classification method could help in order to give a kind of predefinition of the land-use classes. A predefinition could help to speed up the process of the digitalisation as far as the result has practical use and gives reliable information.

This typical Remote Sensing procedure can be divided into the following sections:

- Image pre-processing
- Image enhancement
- Information extraction

Image pre-processing like import, stretching and georeferencing has already been described. The radiometric correction objective is to adjust the image record values to reach their best corresponding with the real or radiant object characteristics. A measuring device calibration is usually done automatically, e.g. by periodical sensing reference areas (ground truth) with known qualities. The information on sensor calibrations and correction coefficients is saved most often in headers of image records.

Most of the digital image records include random inaccuracies like a missing line. Those errors can be removed by an average calculation from neighbouring line values. Suitable algorithms to remove all radiometric inaccuracies having a direction of lines, columns, or diagonals are so-called Fourier's filtrations. Especially absorption and diffusion cause image record values that do not correspond with the reality. For example, haze and turbidity occurs in case of the visible and near infrared radiation. They can be eliminated, e.g., by a method of the darkest pixel, where water areas should appear as black ones. Differences from black colour of water areas are caused by atmospheric impacts and they are subtracted from all image elements. Another method can be the regress analysis of data measured by the distance methods and by terrain measurement. The third possibility is modelling the atmospheric influences. All these methods have a certain reliability, advantages and disadvantages. The aim of all atmospheric corrections is to obtain so-called absolute values of object reflection and radiation from originally measured data.

Image enhancement serves for image look modifications and for a facilitation of their visual interpretation. There is no particular way, leading to the results guaranteed. Image pre-processing, especially radiometric, and atmospheric corrections should precede image enhancement. There are three groups of image enhancement – point (radiometric), spatial and spectral enhancements.

Radiometric enhancements work with image histograms (a graphic depiction of pixel numbers related to individual grey tints or colours) and Look-Up-Table (LUT). Several types of enhancement exist, e.g.:

- threshold – divides pixel values into two categories – under and over the chosen thresh, e.g. for the distinction between land and water
- density sections – divides pixel values into more classes (sections) than threshold, the differences inside the classes are suppressed and the differences between classes are enhanced
- contrast enhancement – the stretching of all or only chosen original image values to the entire capability of displaying device, is used e.g. in case of little sunlit polar areas

Spatial enhancements determine a new element value dependent on values of some neighbouring elements. The image record contains so-called high- and low-frequency information. High frequencies describe big differences in neighbouring pixel values (line elements – watercourses, roads, nature borders). Low frequencies delineate successive changes in the pixel values (water bodies, large fields, and forests). The filter function is to transmit only some information type to the result image, which means that high-frequency filters transmit lines and edges, low-frequency ones smooth information. First, the filtration window is defined, which is represented by the square matrix with odd line and column number. Every pixel of the window has a coefficient – weight. The window moves pixel by pixel on image and the pixel values are multiplied by their relevant weight. The result is assigned to the central pixel of filtered image.

There are various filtration methods, differentiated by different window definition ways, weights in the window and methods of central pixel calculations:

- low-frequency – reduce the range of the grey tint output values (e.g. averaging, median filter, centre weighted filter, rotating window filter etc.)
- high-frequency – enhance the pixel value changes (sharpening, Sobel's filter, Prewitt's filter and so on)
- texture enhancement
- Fourier's transformation – transfers the image by means of *sin* a *cos* functions to a frequency co-ordinate system, many useful information can be derived from frequencies, e.g. edge orientation

Contrary to the previous operation, **spectral enhancement** works with several bands. These procedures can also serve as an input to the next processing apart from the facilitating the visual interpretation.

- Principal Component Analysis (PCA) – the bands are flagged by a considerable correlation, a result of correlation field is an ellipse, whose main axis is the principal component carrying information on main image topographic features, other components contain other information
- Colour image transformation – subtractive colour composition CMYK
- Decorrelation enhancement – modify the principal component contrast and transform them back to the RGB system
- arithmetic operation with two or more bands – are used for the enhancement or suppressing some phenomenon (the image division – for vegetation index calculations, the image difference – for Change determination between two time horizons, the image add – e.g. for edge enhancement, the image multiplication – for an image area masking)

Image classification is a procedure, in which the same meaning is attributed to individual image elements. It aims at substituting the values of original image radiometric characteristics, which expresses spectral object properties and displayed phenomenon, by the values of the so-called information class. Desired information classes are defined at the beginning of the classification process as a nomenclature of a result map.

Image classification is based on the use of some adjudicating rules (so-called classificator), and each element can be placed into some class. The classificators are distinguished according to different image and phenomenon characteristics (classificators of spatial, time or spectral behaviour).

Unsupervised classification does not use training sets for an image element sorting, but it investigates unknown pixels on the base of their spectral behaviour and connects them into groups (clusters). First results are spectral classes but not information classes. The basic steps of the unsupervised classification are the following:

- a definition of an approximate result cluster number – e.g. minimal and maximal number
- a generation of an initial centroid position for every cluster
- a successive assignment of all pixels to the proximate cluster
- new centroid calculation for every cluster on the base of assigned pixels
- repeating the third and fourth steps until the cluster positions or allocated pixel numbers are not changed distinctly
- an assignment of the concrete meaning to every stable cluster
- information class creation by a connection of spectral classes

Commonly used algorithms of the unsupervised classification are „K-means“ and „ISODATA“. The modified method of the nearest neighbour, where a distance between the individual cluster centroids is evaluated by different distance measures, is used as an adjudicating rule.

This method was also used in this study in order to test, if clustering is able to separate land-use pattern by the multi-spectral radiometric information. By the use of the already pre-processed IKONOS channels blue, green red and infrared, the following result was achieved:

Figure 76: *Example of a classified IKONOS MS-satellite image, using 4 bands, with the overlaid manually digitised land-use pattern*

In this figure, the classified MOLAND-borders, which have been digitised and interpreted manually, are overlaid as black lines to the 20 different clusters achieved by the automated process. Typically of urban areas, this method is not able to group several buildings into a common group. The interpretation of shadow, roof, and terrain in-between leads to a small mixture of single pixels instead of homogeny-structured areas. The colour of the roof differs more than the use – like this, such a classification is suitable only for a very limited use. For this reason, no additional efforts were put into a supervised classification because no better result could be expected. Nevertheless, one fact which can influence the MOLAND-Legendary was highlighted; this is the urban green between the houses and bigger areas like playgrounds, sport facilities and parks.

2.13 Topological Digitising Technology

Vector-data are hierarchical mathematical objects, which on lowest level represent **POINT**S as the simplest ones. Points are represented by planar or 3D coordinates (Y, X, Z) of the point-position related to the origin (0,0,0) of the 0-vector. On the next higher level, we can use **LINE**S, which are the connection vectors between 2 points. These points are defined as "begin and end" and represent the orientation of the line. These 2 points are fixed to each other, they are no single points. When combining several lines, we create the next level, the **POLYLINE**. These polylines are represented by a sequence of point (vertex) coordinates. These points are always part of the polyline, starting with the begin-point, followed by numbered vertexes up to the last point, the end-point. The vertexes are sequentially numbered which defines the orientation of the polyline. Closing such a polyline means to create a connecting line between the end-point and the begin-point and like that to create a **POLYGON**. The simplest polygon is a triangle. A polygon can have an unlimited number of vertexes to solve complex structures. A polygon builts the border of areas; inside and/or outside. The highest level of the vector-hierarchy is an **AREA**, which more or less is a combination of a polygon and a label point to represent the area inside or outside. This means that an area needs both, polygon and label-point.

The definitions are sometimes different from the mathematical, geodetic and GIS-professions, especially the term polygon. Geodetic engineers create a polygon track during surveys while measuring a line forward and backward. In mathematical terms, this is only a polyline since it is not closed. The GIS Producer ESRI however uses Polygon as synonym for already created areas. The mathematic definition is the clearest and most reliable one and therefore used for the following descriptions.

What is **TOPOLOGY**?
The most simple definition is: "Topology stores the relationships of one spatial element with respect to another". Anyway, there are many different opinions what topology means. In our definition, topology can already be created on the base of vectors, even without added databases because it is a geometric type of model. Points as the lowest level on vectors have a topology, respecting relation to others, only by their distance or their participation in a line-object, a polygon, or an area. This means that lower level objects can become part of the higher level vector. More interesting is the relation on the same level, especially when observing lines. Two lines, which cross each other, have one relative point where they cut each other. In case of 2d-lines it is a nod-point, which splits the lines into single lines connected by this nod-point. That way, two lines become four lines. In case of 3D lines, the nod point can be split into two points, placed by the position where the lines would cut each other in the zero plain. Finally, these nod-points have the same position but different heights. There are different strategies of snapping and solving this problem, either by a priority line, which defines the height, or by an average, where the nod point represents the average, or as mentioned above, as two points on the same position with different height. This fact can be used for lines and polylines and of course, influences the polygons as well. However, it is also possible, that one line ends on another line. In that case the new line stays as a single line and the old line, which is touched by the end-point, will be separated into two.

Topology is of great importance for the creation of areas. As already mentioned, an area is defined by a bordering polygon and a label-point. If using a topological system, the vectors should create automatic polygons via the nod-points; this means that no redundant lines are necessary to build the boundary for an area. In fact, in topological systems we only need to digitise the additional polyline to build a new area. Moreover, we are also able to split one area automatically, by just one cutting line, which separates the old single area into two.

The description of the type of vector can either be managed by symbols and colours, by internal attributes, so called object-codes like in CAD-Layers, or by an added database linked to this vector-object as in most GI-systems.

Besides geodetic survey onscreen digitising is the most accurate and effective method for the production of vector data. CAD-functionality combined with topological data structure makes a relatively fast capturing of the needed structures possible.

The data processing was done in TopoL-GIS, which is capable of handling both vector and raster data equally well. The above mentioned additional descriptive information can be attached to the graphic data and stored in local or external databases. The tools for digitising are focused on topology and supports topographic structures in vector data. Digitising capabilities of TopoL are easy to use and the system is able to solve topologic relations in real-time, while data are digitised. During the creation of polylines and polygons, the system calculates the nodes (intersections) on-the-fly. Thus, you can create the area only by defining the position of the label point of this area and the system automatically finds the polygon which creates the boundaries.

Users can input vector data through manual digitising by mouse or special digitising devices as GPS, tablet or others. It is also possible to digitise vector data on scanned raster images, displayed on the screen. Various methods of snap, adjustable grid and local zoom tools are available during manual digitising of data. TopoL uses different types of external devices for graphic input. The system can use external devices (Tablet, GPS receiver) to collect data.

Database functionality of TopoL is based on DBase (DBF) format and includes full database facilities and various analysis tools. The system enables users to create and edit local database structures for every feature class (so called group) of vector objects separately in each vector layer. That way TopoL supports definition of class attributes in the object-oriented fashion. Thus users can specify descriptive information manually at any moment during or after vector data digitising. The system is also able to import these data into local databases from text files or from external DBF databases. External DBF databases might be easily linked through user-defined database models which also support 1: N links.

Vector data are stored in so-called **BLOCKS**. A block is a basic data unit. In blocks, you can edit your vector data and description data attached to them.

A block is like a transparency layer with graphic information. Usually one block contains data of the same sort, for example, the block of roads, the block of buildings, and so forth. If you stack these entire transparencies one onto the other, you will see the complete graphic information. A block can also contain the information of one part (square) of a map, the other parts (squares) being empty. The dissection of graphic data into single blocks depends on the amount of the data processed and on the purpose of their use. The content of each block should correspond with one information level. TopoL is able to process different types of vectors and areas, as well as attributed ones, even as different groups in just one block.

The important characteristic of each object is its group. It describes what the object represents in the real world, i.e. roads, contour lines, borders of a building plot, of a forest, and so forth. Sometimes it is also called feature class. The information of the object group is stored in TopoL in the numeric form the so called group code or object code. At the same time, this is a layer in CAD-Systems and makes a data-exchange via DXF-file format possible.

For each object group (at least one) one database file of the type dBASE 3.0 can be defined. It can store additional information on graphic objects, i.e. the number of a building plot, its owner, conceivable other data on him (or, more efficiently, because one owner can own more plots, another database -so called external database - can be linked with this one to store data about owners - address, date of birth, ….).

A single object of the specified group has a single record in the corresponding internal database. The object is associated with the database file by means of an attribute called “NUMBER” into which an unambiguous identification number specifying the given object is automatically written. The attribute “NUMBER” is created by TopoL, the user can define other attributes to describe features of the object.

If a database associated to areas has the attribute "AREA", its size in hectares or square meters is automatically counted from its graphic representation and stored as attribute-value into the database. The same applies for polylines and their LENGTHs, the co-ordinates X and Y of points and many other automated information.

The main products to be derived from the frame of the project are one "reference" and three "historical" land use data sets. Visual image interpretation techniques have been defined as obligatory method to derive the reference land-use data set from a "reference" image(s) for the year 2000. For each time period a "vector-area" (i.e. land cover/use) data set and a "vector-polyline" (i.e. transport and water networks) and additional a "3D vector-area" (i.e. bridges, viaducts…) data set has been produced. The vector-area data set includes the land use classes of the extended MOLAND land cover legend in a database. All of the data sets had to be provided in Arc-Info (.e00) export format, which is a topological one. It has got features usually shown on a 1:25,000 scale map. The minimum mapping unit for urban areas was predefined by one ha and reduced to three ha for the non-urban classes.

The following digitising rules should be adopted for the development of the vector-datasets by the recommendation of the JRC.

Selection of relevant information includes the elimination of details for land cover units smaller than 1 hectare for artificial areas and smaller than 3 hectares for non-artificial areas.

Amalgamation and aggregation. If a unit does not respond to the MURBANDY criteria of the minimum mapping unit (1 hectare or 3 hectares) and minimum width of 25 meters:

- If only 1 unit surrounds the small one, this is aggregated to the larger one
- If two or more units surround the small one, this is aggregated or subdivided proportionally to the neighbouring units. This aggregation will depend on the type of land cover, which surrounds the area, because some aggregations are more logical than others.

Simplification. It is related to the amount of detail that is maintained in tracing the border between 2 adjacent land covers units:

- Straight lines, if they exist, should be maintained as often as possible
- Characteristic land cover features, such as extension of built-up areas along roads, cut-off meanders, should be maintained as precise as possible at the scale of 1:25,000
- The position of generalised borderline should be fit as much as possible with visible structures on the satellite panchromatic image.

Smoothing. All visible details on the border between two different land cover classes up to 25 metres detail should be represented and taken into consideration during generalisation. Smaller details should be generalised.

Exaggeration. The linear features should maintain their continuity as much as possible, without causing an interruption in the zone. An exaggeration over 25 meters should be envisaged if useful to maintain a representative structure, especially for roads and railways and for discontinuous build-up areas along roads.

Merging. Gaps between units with identical land cover class should be merged to emphasize the structure of the landscape:

- If the distance between 2 units is less than 25 meters, the units should be merged
- If the units belong to the same land cover class, the border between both units is dissolved
- If the land cover classes are different, the corridor will be deleted and the 2 units will become adjacent

Harmonisation. In the land-use database, only polygons exist. For the harmonisation with other data sets that will be used for intersection with the land cover data, a number of rules should be respected:

- The limit water/land should be respected and maintained during the generalisation process
- The position of shoreline, large rivers, lakes, canals, etc. should be maintained with precision
- Existing linear structure in the landscape and the land cover features should be maintained. Roads, rivers, limit of parcels, etc. are useful to position a limit between two different land cover classes
- Within heterogeneous agricultural areas, the aggregated units should maintain the macro morphological structure of the landscape. Aggregation of units that are clearly separated by a natural corridor should be avoided.

Figure 77: *digitising of linear objects, Red = 1.2.2.1, Lila = 1.2.2.2*

Line-Layer: First the linear elements (lines and polylines), such as transportation (road and rail) and river/sea-canal network, were mapped according the legendary on-screen by using an optical mouse. Topological data-structure was required. Limits were given by the visibility in the satellite-imageries. Wider linear features were digitised by a middle line and as far as they had a bigger width than 25 m, they were mapped in the area-layer as well. During digitisation, each line-feature was mapped first as a solo line until the operator confirmed. After the line-object was drawn, the dialogue-box for capturing the attributes of the related database was opened automatically. When this step was done, the line was connected to 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. Therefore, they were copied to the file with the area-database of the processed year.

Area-Layer: The lines and polylines of the line-layer were used as a base for the area-layer (polygon with label-point), only the middle line of linear-objects with a larger width than 25 m were 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 one ha. Smaller areas were digitised as long as they were important. In addition, topological mapping was required to reduce the work and the risk, which might occur with redundant lines. Also the snap-mode was set to lines and vertex points in a suitable radius to fill the entire project area without macro rest polygons. The database was filled while defining the label-point inside these boundaries. All lines, which were digitised after the creation of areas, cut their areas and divided them according to the topological structure.

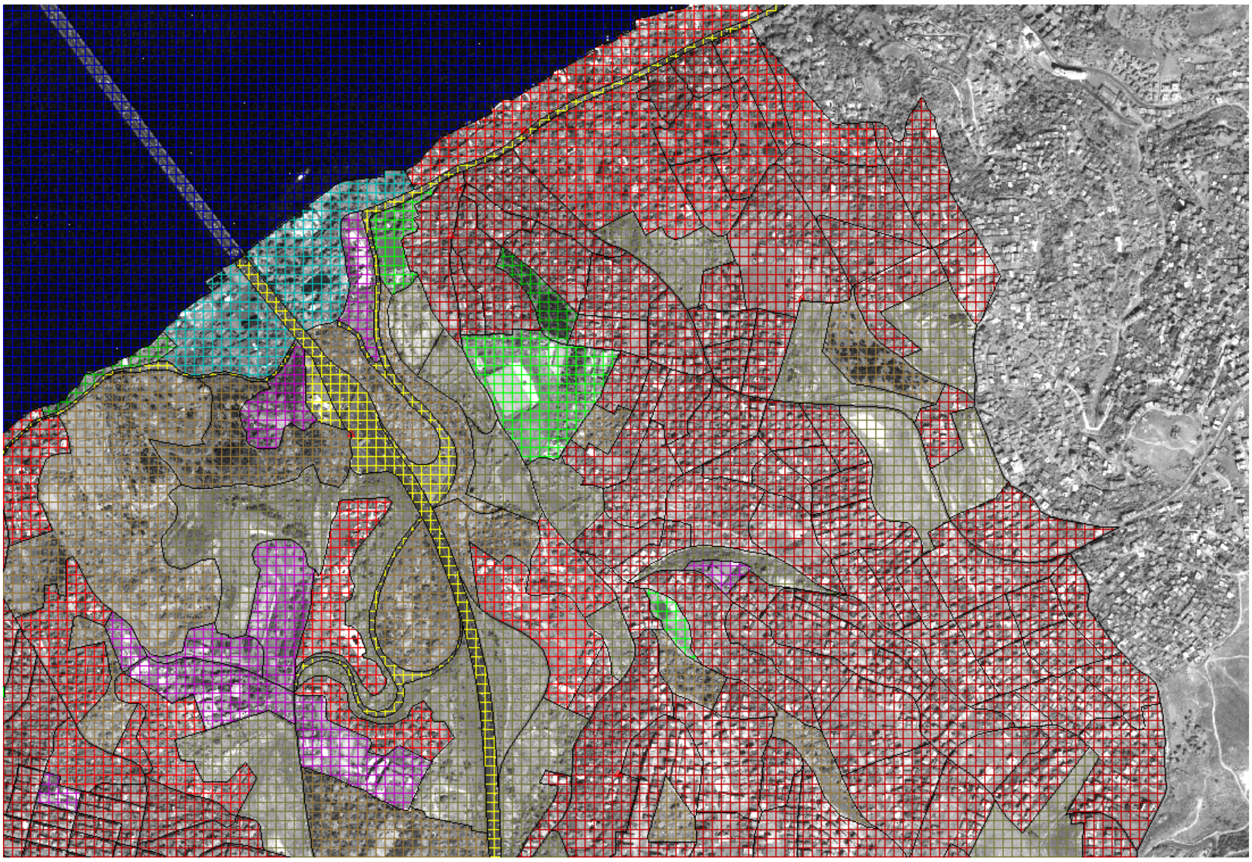


Figure 78: *digitising of polygons with created areas. In relation to the figure above, you can see that often roads build the border of the area, Red = Class 1.1.*.*, Lila = Class 1.2.1.*, Green = class 1.4.*, yellow = 1.2.2.1*

3D Area-Layer: An additional area-layer was added to this project in order to take area objects into account, which would cover other area objects. These are big bridges (like the Bosporus-bridges) and highway tunnels. These elements are connected correctly by the middle-line in the line layer and by a direct neighbourhood to a related object in the area layer. In case that only few objects were digitised into this layer, the snap mode was activated in order to snap to other, non-active layers to guarantee at least a semi-topological data structure.

2.14 Interpretation and Object definition

Interpretation of the object type or land-use pattern digitised on the imagery was done by visible interpretation with the use of local knowledge and additional data. A procedure like this is surely not free of a the operators subjective opinion, but especially here the detailed legendary of MOLAND helps a lot with proper and comprehensible interpretation.

The classification of linear objects was relatively easy since only minor difficulties occurred here. The database was built as a dBase-3 table structure as shown below. Additional fields in it enabled the storage of enhanced information i.e. about difficulties in the interpretation or links to images and alternative classes. The topological vector-structure of TopoL allows the separation of lines by automatically inserted new nod-points or by copying already connected attributes to the new single lines. Thus, no information was lost and the lines were separated without any additional work.

NUMBER	CODE	LEGEND	INFO	COMMENTS	ALT-LEGEND	Y	X	LENGTH	PICTURE	TEXT	COMMENT
18	1.2.2.2	other road and associated lines		build-up road for electricity		429196	4555612	358	1a		
19	1.2.2.2	other road and associated lines				430067	4529333	14	2d		
20	1.2.2.2	other road and associated lines				431357	4528755	9	124		
21	1.2.2.2	other road and associated lines				420530	4547923	322	112		
22	1.2.2.2	other road and associated lines				420666	4547876	117	221		

Table 14: *example of the attribute-database for linear objects stored in TopoL as dBase-3 format*

Interpretation of areas, however, was much more difficult and sometimes lasting longer than the digitalisation itself. No classification meets the real land-use type in all cases. Complex knowledge and the use of ancillary data like maps, city-plans, photographs or other information had to support the interpretation. In many cases, a mixed use was detected in areas where buildings or blocks are used as residences, as shops and offices. Nevertheless, it makes no sense to define mixed use; otherwise, Istanbul would be mapped in 50% as a mixed used city. The biggest problem was the definition of the major use of an area. We are sure, that we did not always find the best solution, but a more detailed study was not the goal of this study. In each case, the buildings and blocks are two dimensional and not separated by floors in the final database. Same problems always occur in similar studies.

NUMBER	CODE	AREA	LEGEND	INFO	COMMENTS	ALT-LEGEND	Y	X	PICTURE	TEXT	COMMENT
3900	1.2.1.9	33,33	restricted access service		Access Controlled Traffic Area for Driving Schools	1.2.1.10	405498	4548642	345.jpg	Des1	
7252	3.2.4	18,11	transitional woodland/ shrub		after mineral extraction		394723	4557183	122.jpg		
5882	5.1.2.2	249,97	artificial reservoir		Alibey Dam		408376	4555176			
1727	1.2.4	773,81	airport		Atatürk International Airport		400436	4539406			
2181	5.1.2.1	2493,7	natural standing water		Büyük Cekmece Lake	5.1.2.2	378515	4551649			
389	1.1.1.1	4,23	residential continuous dense urban fabric		Buildings aren't high enough for Urban blocks	1.1.1.3	418163	4547932			
796	1.2.1.2	5,23	commercial area		controlled, OK	1.2.1.1	415751	4547296			

Table 15: example of the attribute-database for area objects stored in TopoL as dBase-3 format

2.15 Examples of frequently used classes

In this chapter commonly used classes according to MOLAND Legend are presented. The examples shown are based on the reference year. Some classes were used very often through all years; others were valid in some years only. These examples show the chosen classes quite clearly, in the next chapter some difficult examples will be shown.

1.1.1.1 Residential continuous dense urban fabric

In this class you will find especially urban fabrics where buildings are close together and have several floors. One cannot say that this kind of structure can only be found in the centre of the city. It is well known that that Istanbul has not only one centre according to its topography and urban density. This class is mainly used in the centre zone of the project. However, there are some exceptions in the buffer zone. The main use is residential, but usually there are also small shops in the ground floor and 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 the attribute table. We tried to detect the main use. The images show an example of the European part of Istanbul.

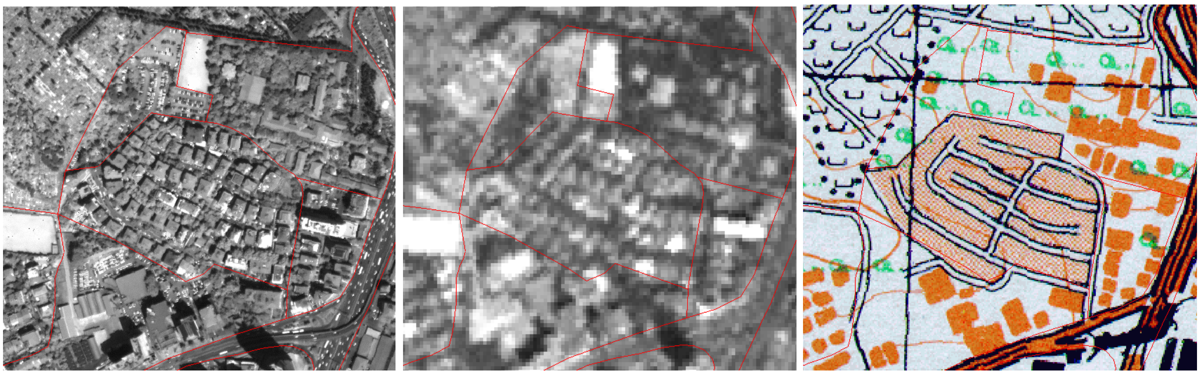


Figure 79: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is residential surface with class 1.1.1.1*

1.1.1.2 Residential continuous medium dense urban fabric

This class consists of buildings as described in class 1.1.1.1. But buildings in this class have either less stories than 1.1.1.1 or they are not so dense as 1.1.1.1. This class is mainly used in the centre zone. But as in class 1.1.1.1, there are some exceptions: sometimes small gardens belong to such buildings but do not influence the density so much, as to put them in class 1.1.2.1.

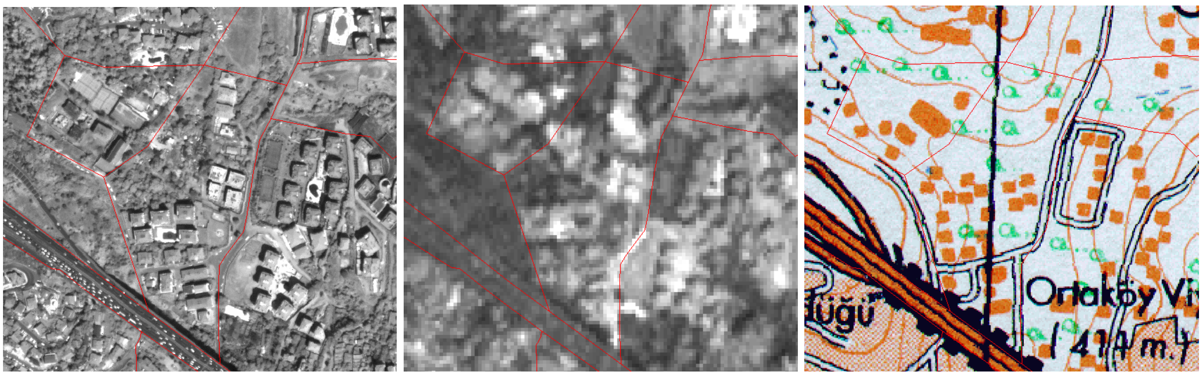


Figure 80*:* *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is residential surface with class 1.1.1.2*

1.1.2.1 Residential discontinuous urban fabric

This class contains mainly suburban buildings. But there are some parts in the centre of the city, where buildings are stored here. Mainly rich people live in these parts. That kind of class was mostly detected along the Bosporus and some suburban zones. These houses are not built in a continuous style; there is a space between, mostly used for garden, green areas or others.

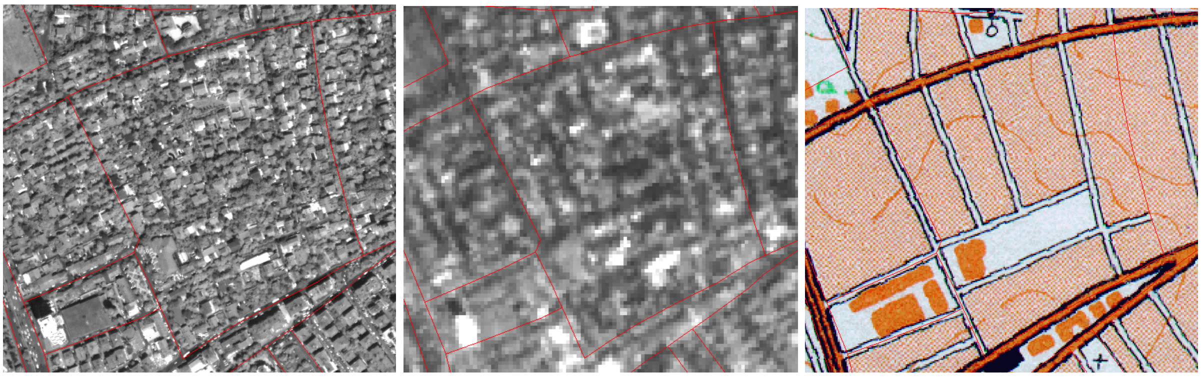


Figure 81: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is residential surface with class 1.1.2.1*

1.2.1.1 Industrial areas

Being the biggest metropolis and the economic centre of Turkey, Istanbul has many and large industrial areas. Today, the recent industrial areas are mainly in the buffer zone. Nevertheless, some of them are remaining in the centre zone, e.g. those not polluting the environment strongly or those which cannot be moved easily due to technical difficulties. Most industrial areas have been transferred already to the suburban areas to keep the inner city (a bit more) free from air pollution.

Figure 82: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is industrial surface with class 1.2.1.1*

1.2.1.2 Commercial areas

One of the most common classes besides the industrial ones are commercial areas. There are not only shops, which you can usually find everywhere, there are also many skyscrapers, which are used commercially as well e.g. for offices, banks etc.. Modern commercial sites are mainly located in the new developing districts or at important trade places like the historical Peninsula, which is mainly covered by this kind of land use. Areas, where those commercial areas with modern high buildings are grouped can frequently be found on the European side of Istanbul.

Figure 83: *left = IKONIS pan, middle = IRS-D pan, right = Map 1:25k : shown is commercial use 1.2.1.2 with new skyscrapers*

1.2.1.3 Public and private services not related to transport system

With 10 Million citizens, there is a need for a big amount of public and private services in Istanbul. This is not only found in the centre zone, but also in the new developing areas in the suburbs. Schools, universities, public building etc. belong to this group.

Figure 84: *left = IKONIS pan, middle = IRS-D pan, right = Map 1:25k : shown is class 1.2.1.3*

1.2.1.4 Technological infrastructures for public use

In this class there are radio and TV towers (If they are together and clearly visible), electric infrastructures etc.

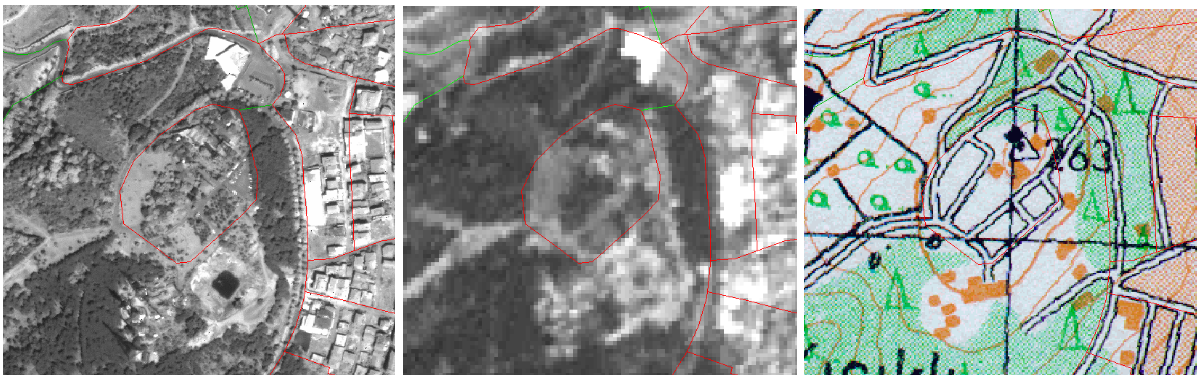


Figure 85: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is a radio-transmitter station of class 1.2.1.4*

1.2.2.1 Fast transit roads and associated land

In this class main bypass roads and motorways are stored. Into the line layer, bridges crossing the Bosporus are saved. The main difference of this class and the class “other ways” is that the roads of this class cannot be reached by pedestrians and they have minimum 4 lanes. In case of bridges, a road-tax has to be paid. Highways in Turkey do not need vignette or tax; so far the official MOLAND argument “toll way” does not fit here.

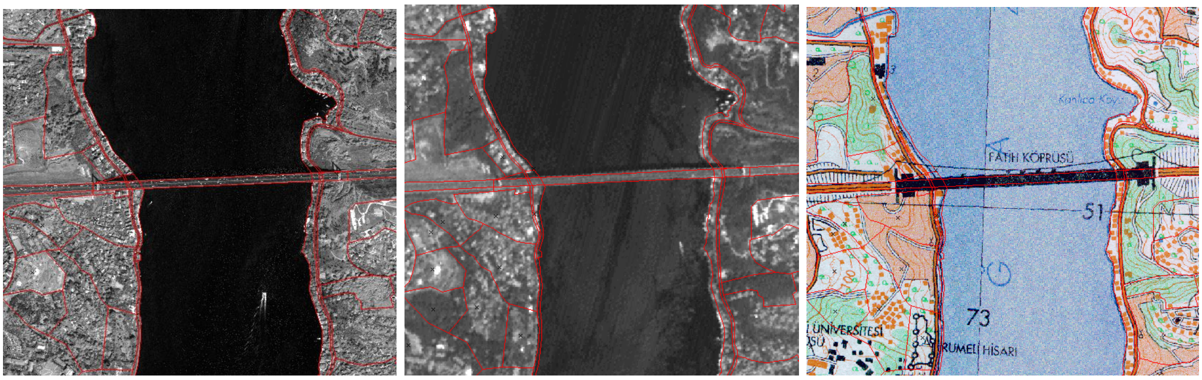


Figure 86: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is the highway cross the northern Bosporus-Bridge; class 1.2.2.1*

1.2.3 Port areas

Surrounded by two seas, the Bosporus and the Golden Horn, Istanbul needs several ports. Even traditional Istanbul is an important port-site, these ports are used for public inner-city transport, public international transport, commercial transport and private purposes. Several ports, used for public city transport, are smaller than 1 ha. The ports are often connected to sports, leisure and industry.

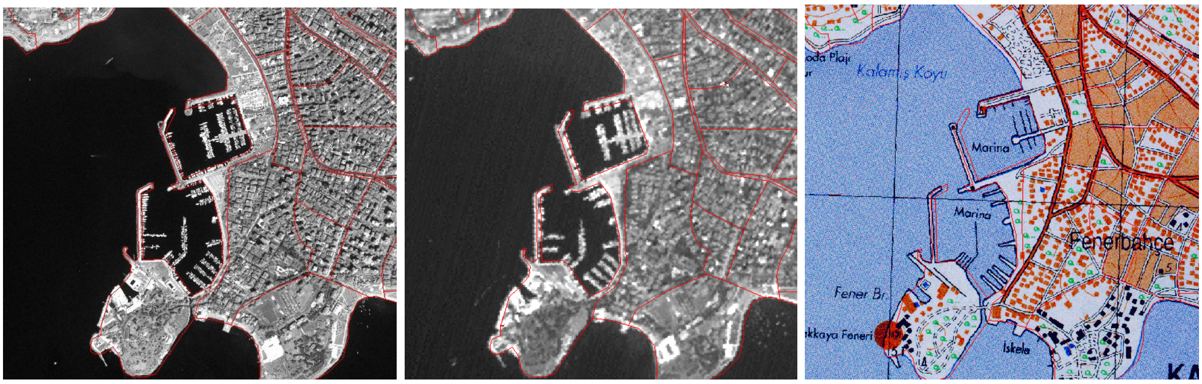


Figure 87: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is a port area on the Asiatic side of the Sea of Marmara, class 1.2.3*

1.3.4 Abandoned land

In both, centre and buffer zone, are many of these areas, where a particular use cannot be detected. Such areas seem to be free of planning, but anyway they have big potential for further development, either for residential, commercial or industrial, or green urban areas – a potential for urban planning strategies.

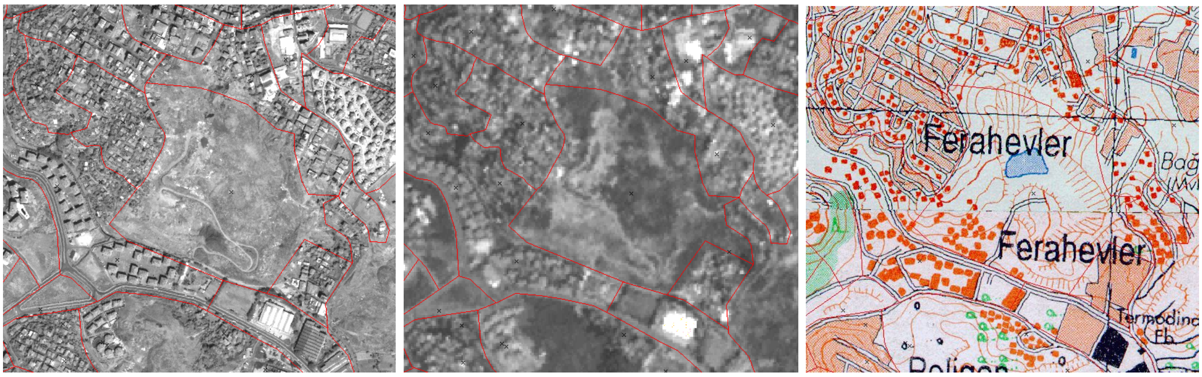


Figure 88: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is abandoned land; class 1.3.4*

1.4.1 Green urban areas

There are lots of city parks and green urban areas in Istanbul. They are mainly situated along the Bosporus and the Golden Horn.

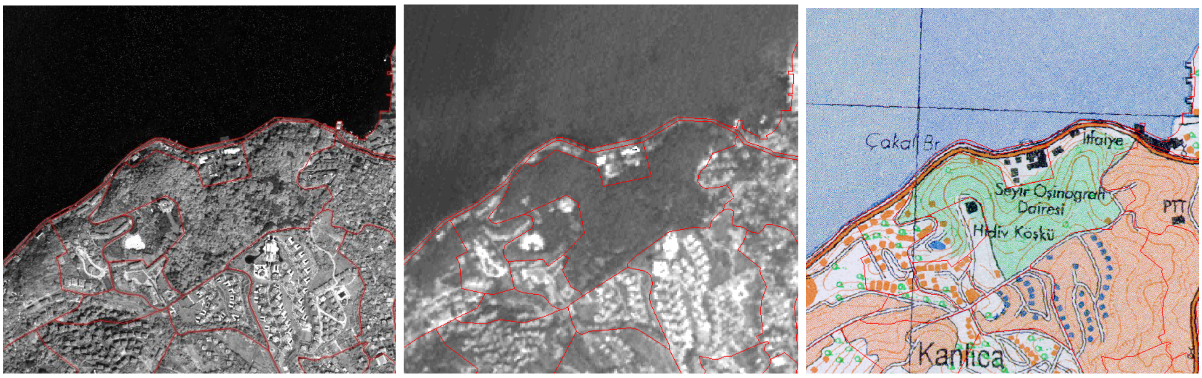


Figure 89: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is green urban areas; class 1.4.1*

1.4.2 Sport and leisure facilities

In this class are mainly stored public sport complexes, stadiums and some private sport centres.

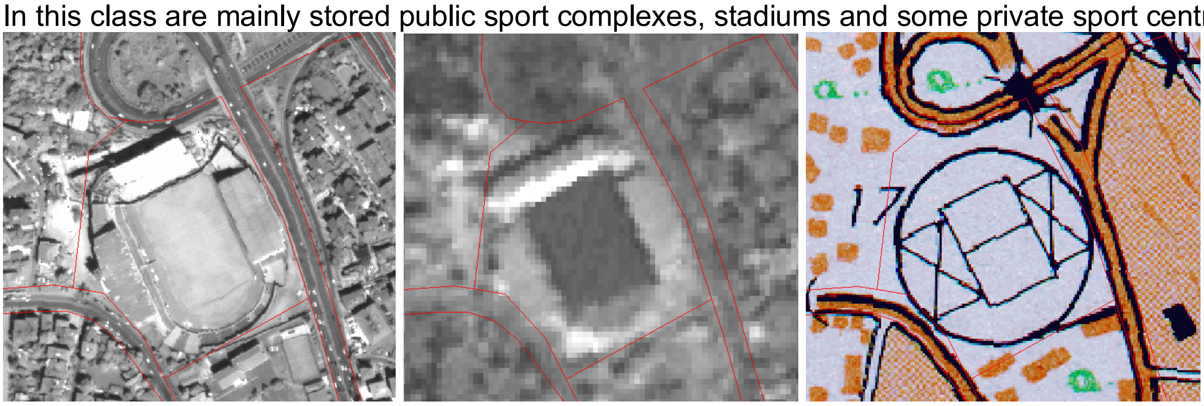


Figure 90: *left = IKONOS pan, middle = IRS-D pan, right = Map 1:25k : shown is a sporting facility; class 1.4.2*

2.16 Difficulties in the used classes

In the following chapter, some difficulties in the used classes will be described. These difficulties mostly depend on the conditions of urbanisation in Istanbul. As there are some fundamental problems concerning urbanisation, these problems are not easy to solve.

Defining of informal settlements "Gecekondu" areas.

This problem was and still is one of the most common ones. It is very hard to define an area as "Gecekondu", because this type of settlement has neither any exact or approximate physical condition nor a clear appearance. Another problem on this topic is to define the "Gecekondu" meaning exactly.

Per definition, Gecekondu is a small, mostly one roomed building with one story only. It can be built in one night. The term "Gecekondu" refers to this speciality. Gecekondu means, "It is settled in one night". The background is that once a roof is built over one's head, the Islamic law forbids destroying this. Therefore the state law is in conflict with religion.

According to several political decisions, lots of buildings have been taken redefined to other types since the late 80's. These buildings have the same physical conditions as real "Gecekondus" until the mid 1990's had.

Since the mid 1990's, "Gecekondu" owners began to make their buildings multi-storied. If observed in the images, it is significant that most "Gecekondu" buildings have no roof. That means its owner is waiting, maybe for savings to continue or for political election in order get the building legalized.

After the discussion about definition of "Gecekondu" and their brief history, it must be stated that in some regions of Istanbul, it is nearly impossible to distinguish these multi-storied "Gecekondu's" from legal settlements by using aerial photos or satellite images only. Anyway, "Gecekondo" houses cannot be compared to those of slums or favelas. These are well constructed buildings with normal bricks, stories, and roof. Only during construction and preparation they can be detected, but then they look like normal construction-site.

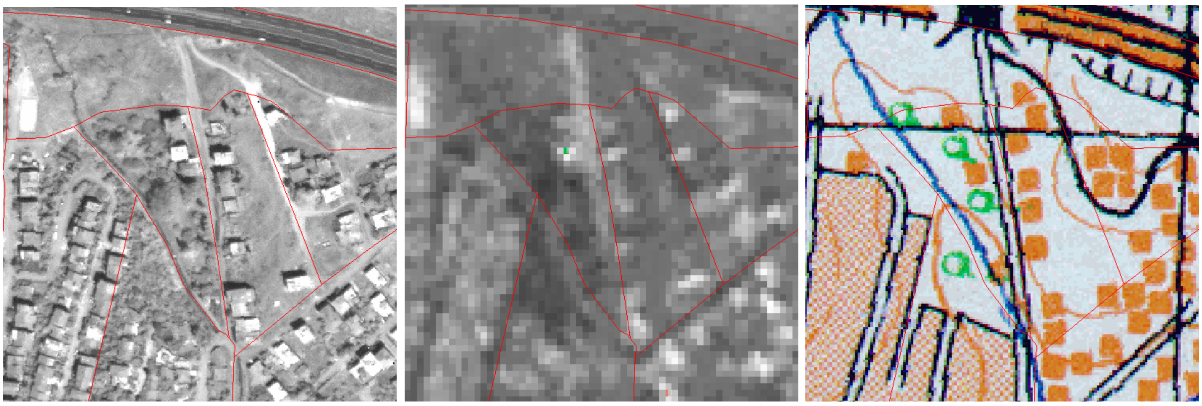


Figure 91: *left = IKONOS pan, middle = IRS-D, right = map 1:25k :shown are young, just built "Gecekondu"*

In Istanbul, "Gecekondus" are not always like informal settlements. There are many villas built without permission. These kinds of buildings are mostly sited on the Asian part of the Bosporus. They are made for high quality residence. They are illegal and they do not look like informal settlement. It is really a special feature in Turkey around big cities, with particular features in Istanbul.

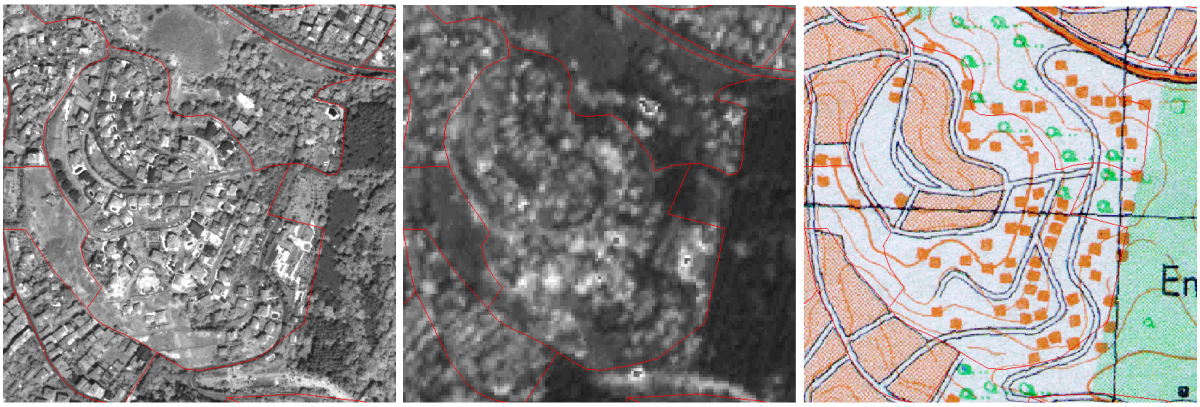


Figure 92: *left = IKONOS pan, middle = IRS-D, right = map 1:25k :shown are older, enlarged and comfortable built up “Gecekondu”*

Defining of roads

A problem appeared concerning a road on the Asian side. The corresponding road was not a typical highway, but it operates as a fast road with four lanes and is forbidden for pedestrians and bicycles. Bus stations do exist for public transport, which is atypical for highways. On some parts of it, there is no access control. Not being a fully access controlled road or highway, on the attributes table this road was indicated as “express road” and was defined as 1.2.2.1 .

Figure 93: *left = IKONOS pan, middle = IRS-D, right = map 1:25k shows a untypical but even looking as a highway*

Defining of continuous dense and continuous medium dense urban fabric

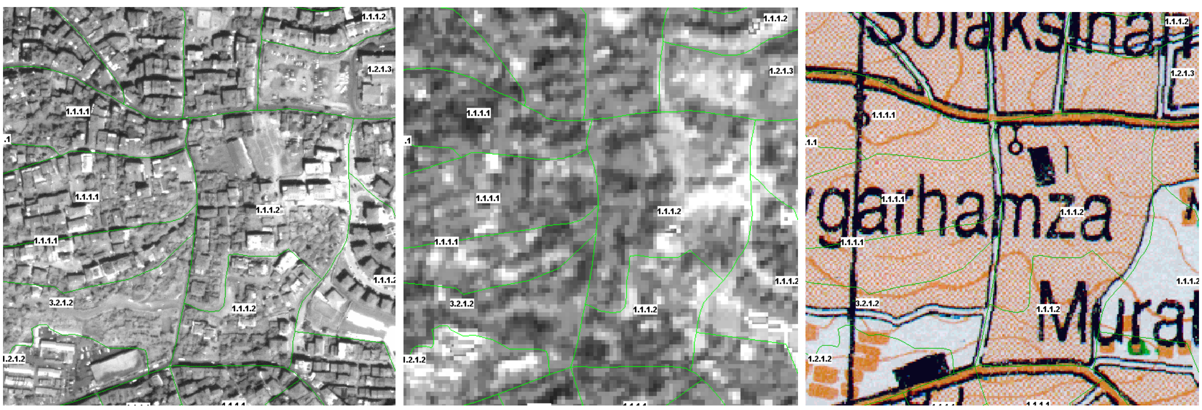


Figure 94: *left = IKONOS pan, middle = IRS-D, right = map 1:25k Classes 1.1.1.1 and 1.1.1.2*

In some parts, these two classes were not easy to define, especially bacause there was a high density of buildings but these buildings did not have enough stories to fit to class 1.1.1.1. Another problem was, that according to urbanisation condition of Istanbul, these two classes are used in the buffer zone too. Therefore, the interpretation was often influenced by this selection.

Separating residential and commercial classes

Especially in the centre zone, it was hard to distinguish these two land-use pattern. In most cases, they are clear to define, but there were some cases, where the word “mixed” had to be written on the attribute table. This was used for residentially defined areas only, which means that in these areas commercial and residential use is mixed, approximately to the same percentage.

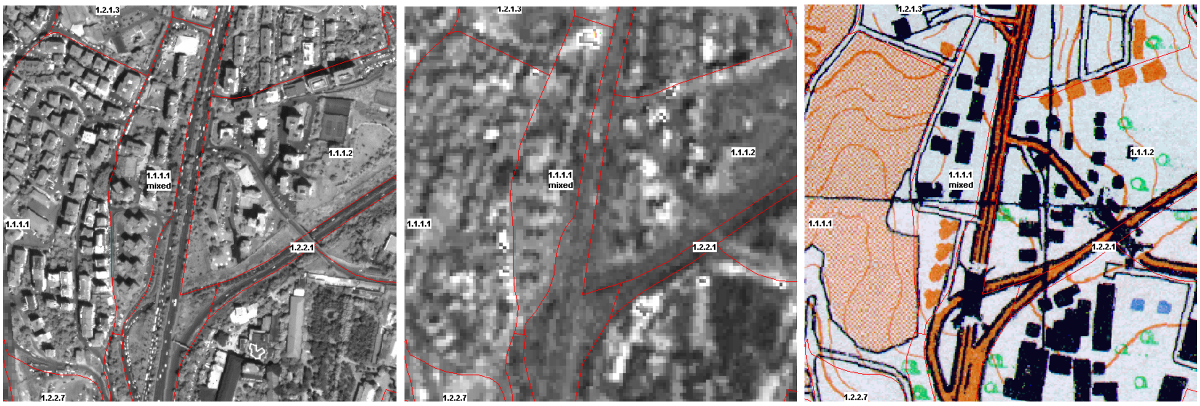


Figure 95: *left = IKONOS pan, middle = IRS-D, right = map 1:25k: business areas*

Borders of the Bosporus and Golden Horn

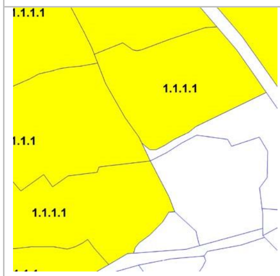
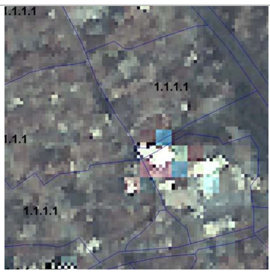
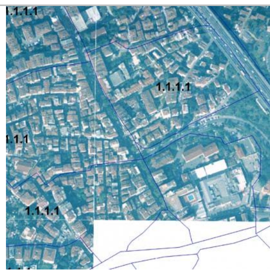
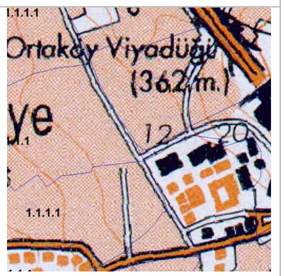
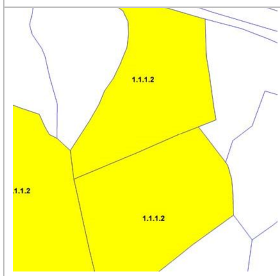
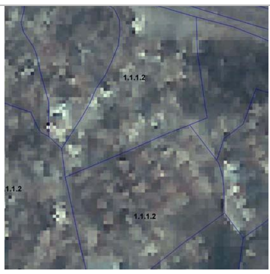
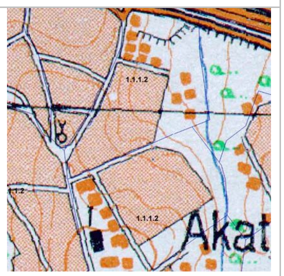
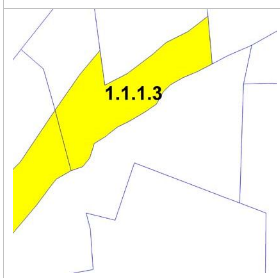
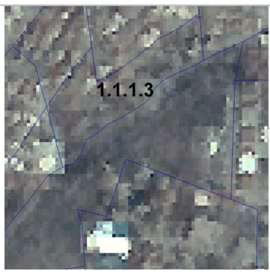
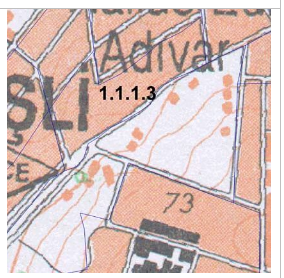
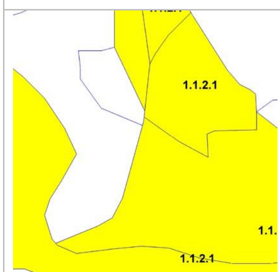
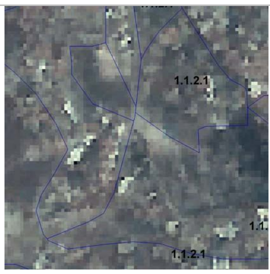
Even though the Golden Horn is part of the Bosporus, it has another use and meaning for Istanbul. Therefor it was defined as own area. But there is not any information concerning exact borders between them; a line was drawn to define the areas in a way, that the shapes of these two important water-ways would not be disturbed. The same was done with the Bosporus to separate it from the open sea.

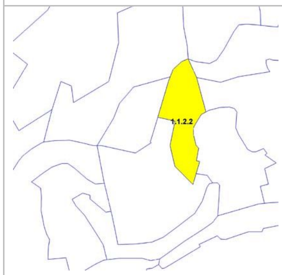
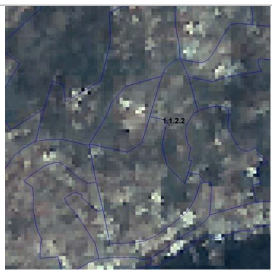
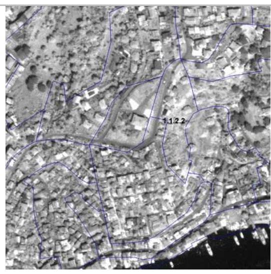
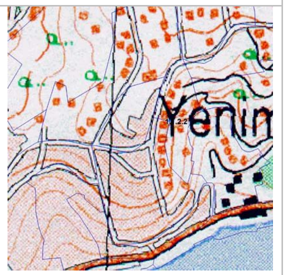
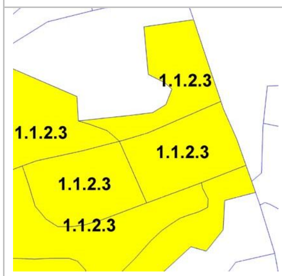
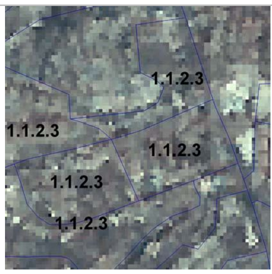
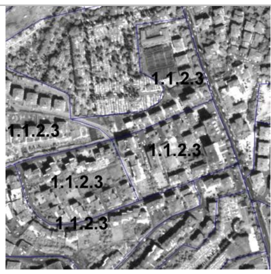
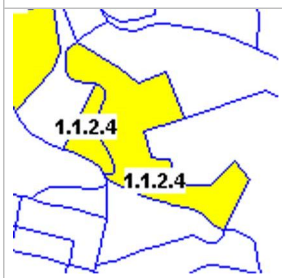
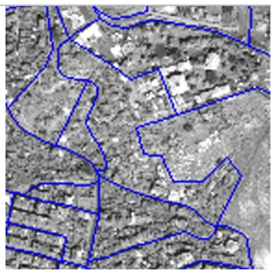
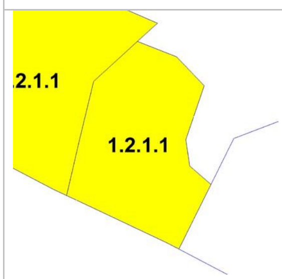
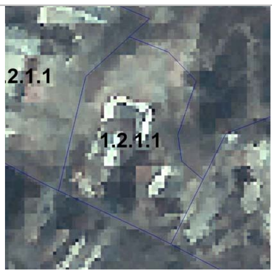
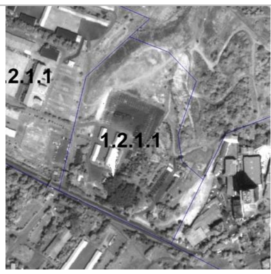
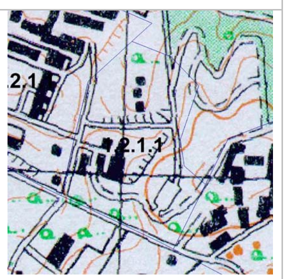
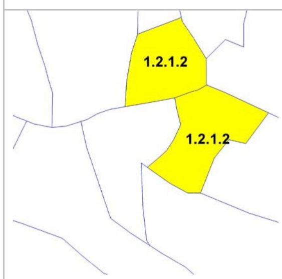
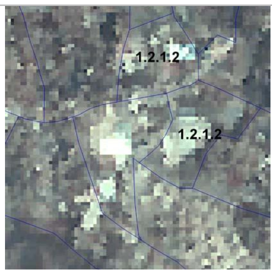
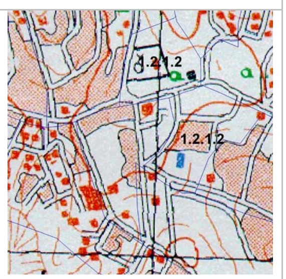
Figure 96:
left = IKONOS pan, middle = IRS-D, right = map 1:25k : Separation of the sea surfaces

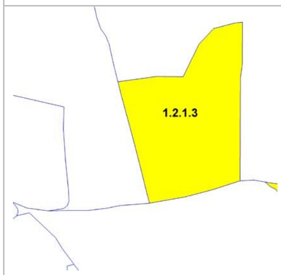
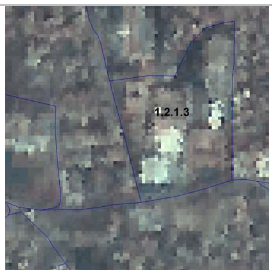
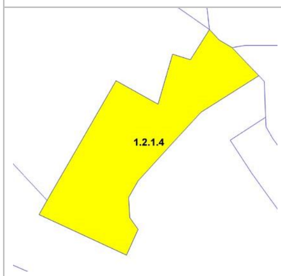
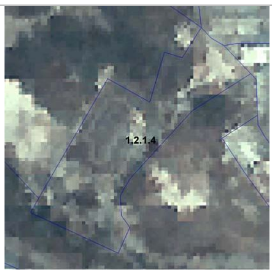
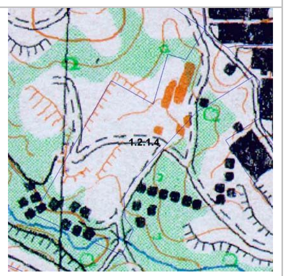
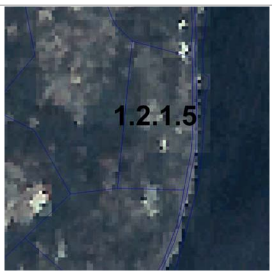
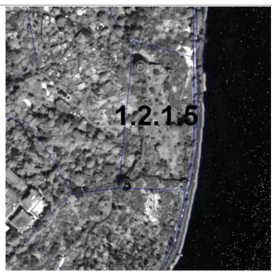
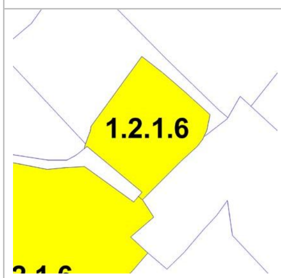
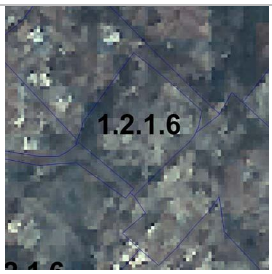
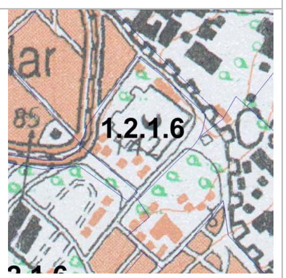
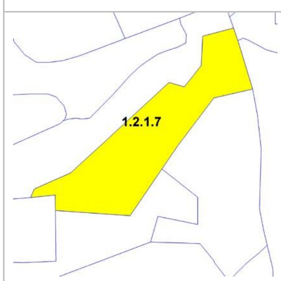
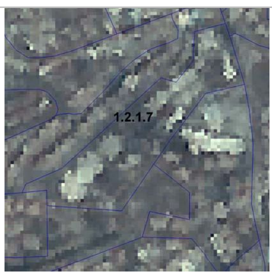
2.17 Examples of classes

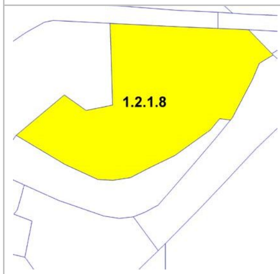
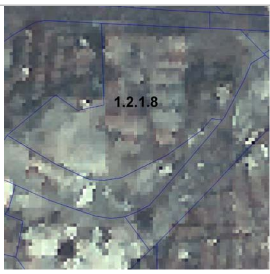
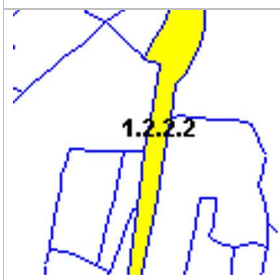
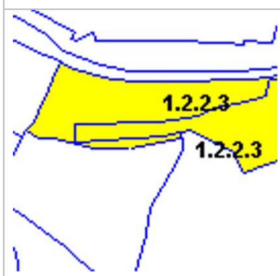
In the following chapter I want to give examples of various classes and how they look as vector-information and overlaid on the different imageries. Not all classes can be seen on IKONOS imageries or on the actual orthophotos, that is the reason why they are missing. I do not show the old ones because usually the classes have changed too much and the number of examples would have been too small. However, I believe that these clips give a good overview on the visibility of the different land-use classes on the different kind of imageries.

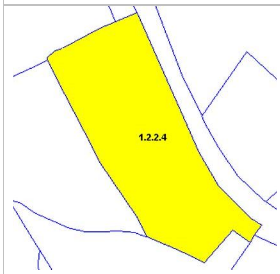
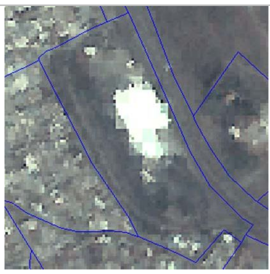
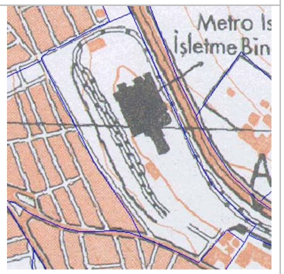
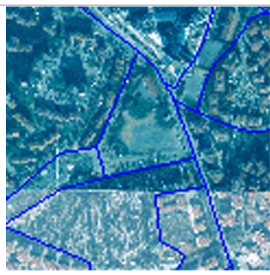
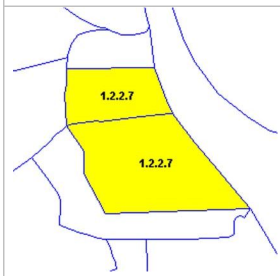
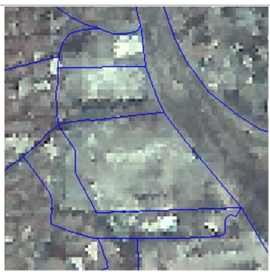
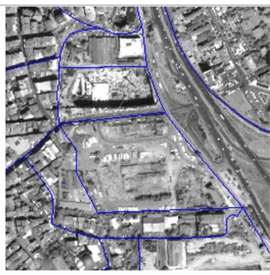
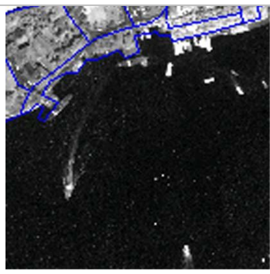
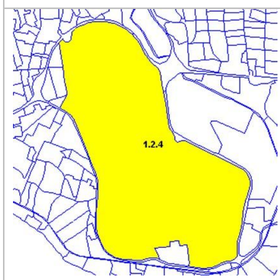
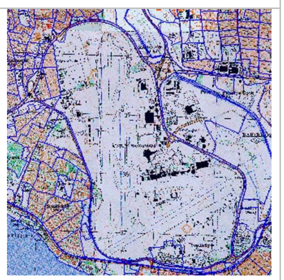
Table 16: *Chip Table of classes and imageries*

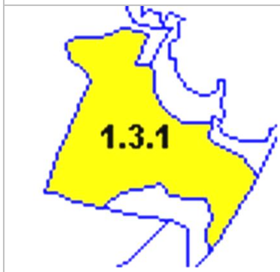
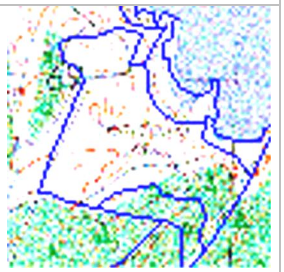
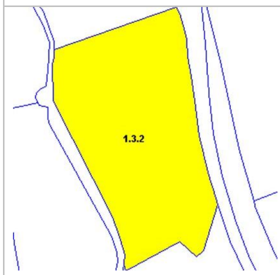
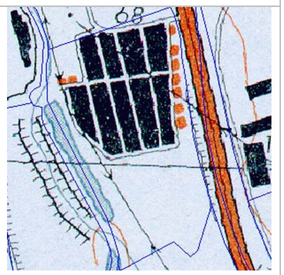
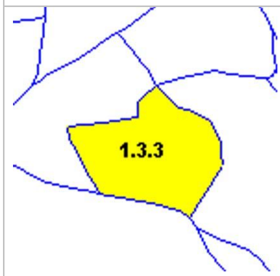
Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
Class 1.1.1.1	Residential continuos dense urban fabric			
				
Class 1.1.1.2	Residential continuous medium dense urban fabric			
				
Class 1.1.1.3	Informal settlements			
				
Class 1.1.2.1	Residential discontinuous urban fabric			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
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			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
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			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
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			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
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			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
Class 1.3.1	Mineral extraction sites			
				
Class 1.3.2	Dump sites			
				
Class 1.3.3	Construction sites			
				
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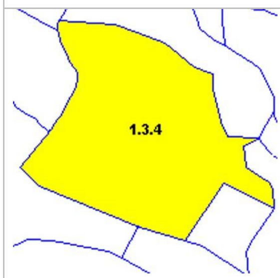
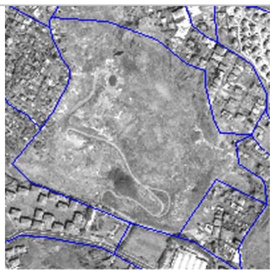
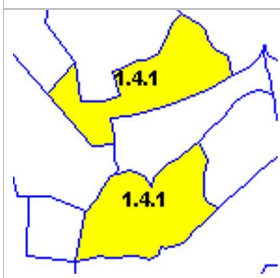
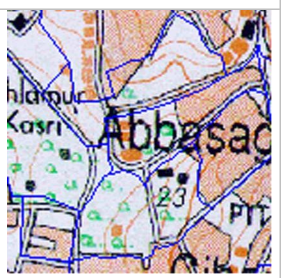
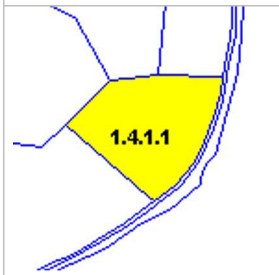
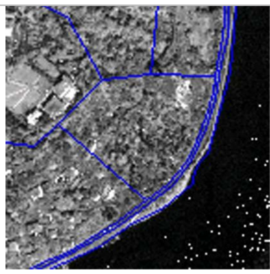
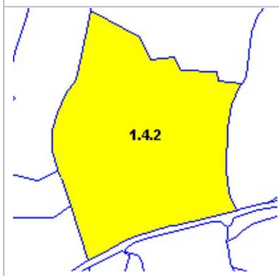
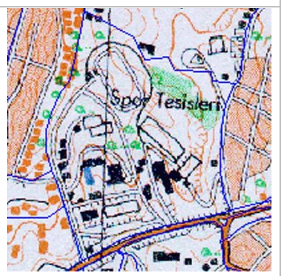
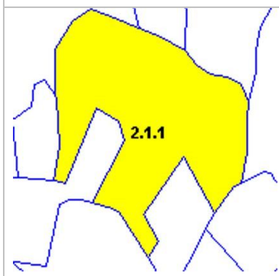
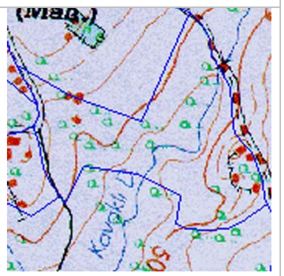
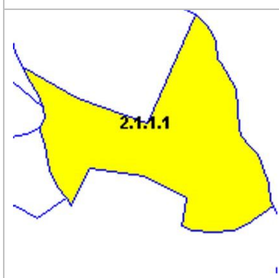
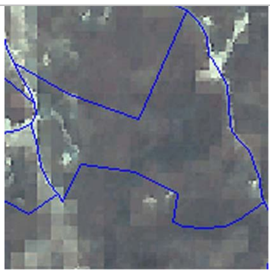
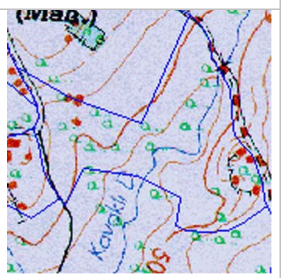
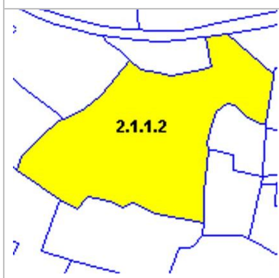
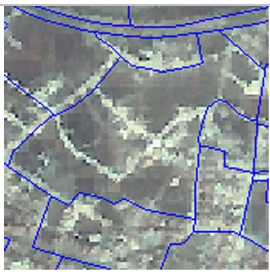
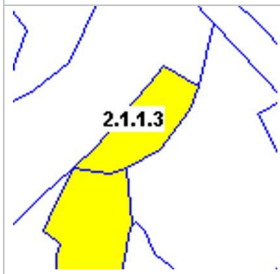
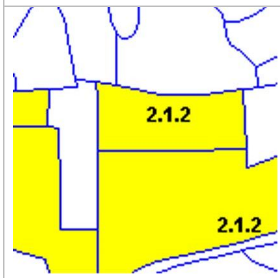
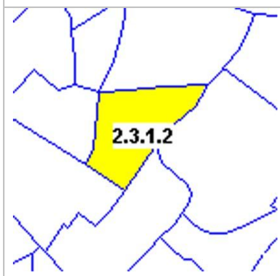
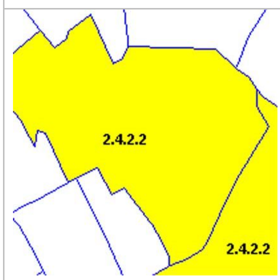
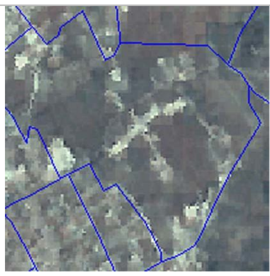
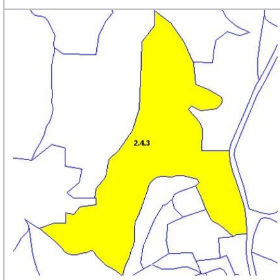
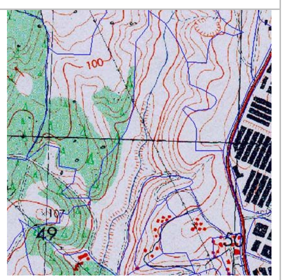
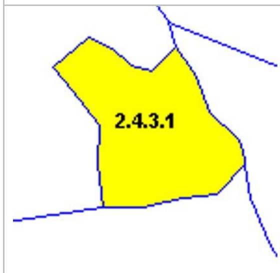
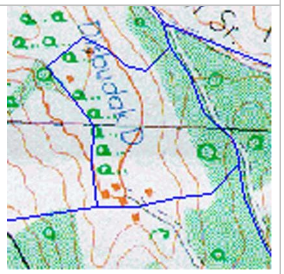
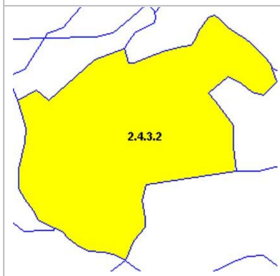
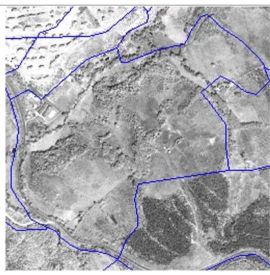
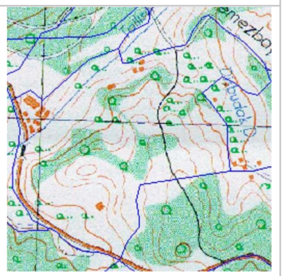
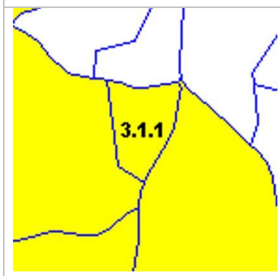
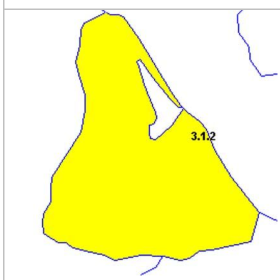
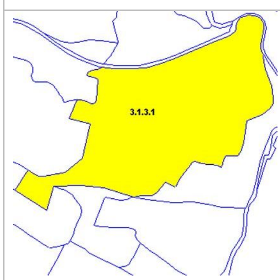
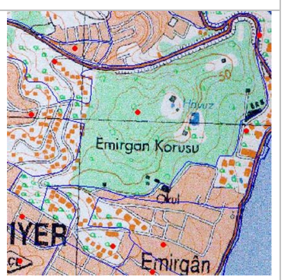
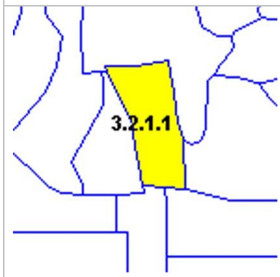
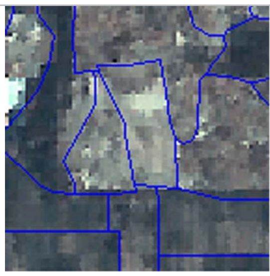
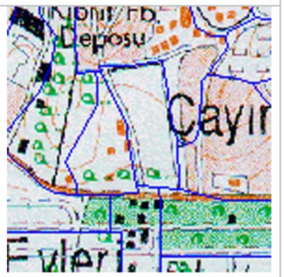
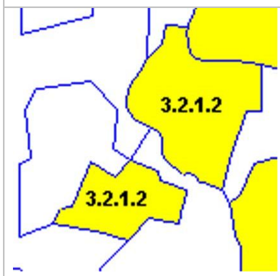
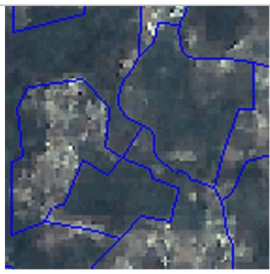
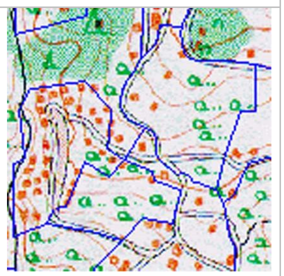
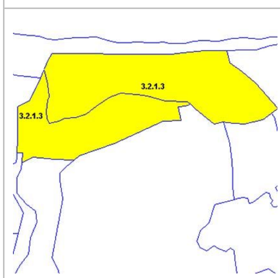
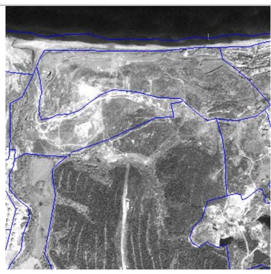
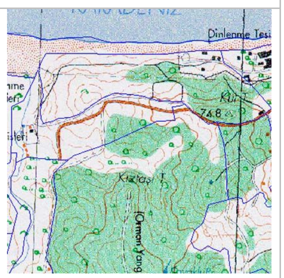
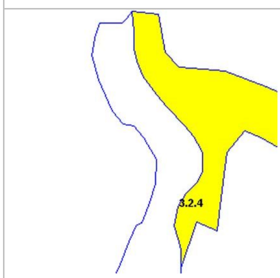
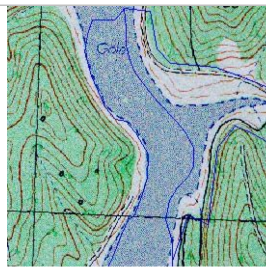
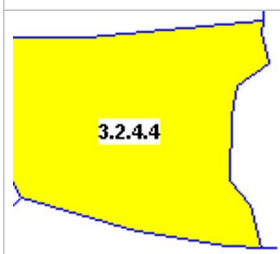
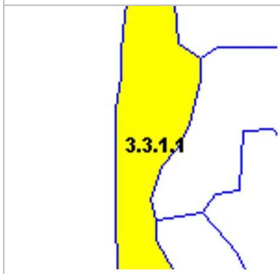
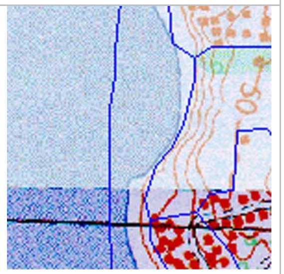
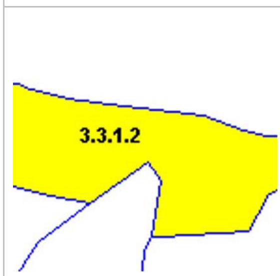
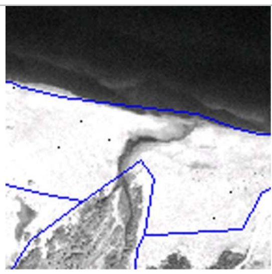
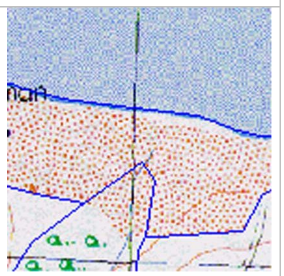
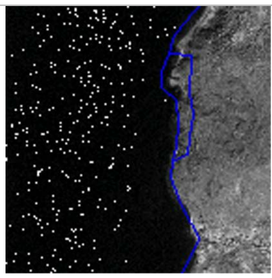
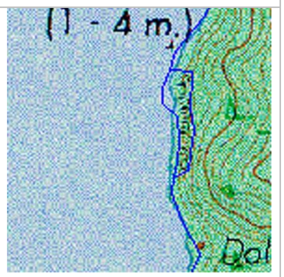
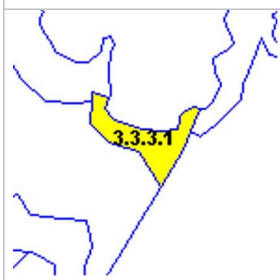
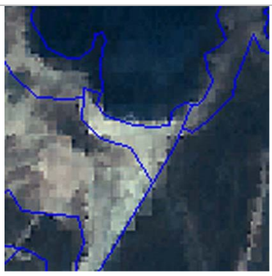
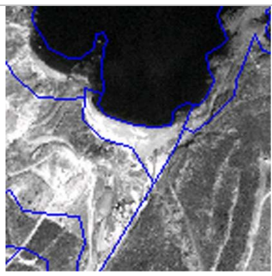
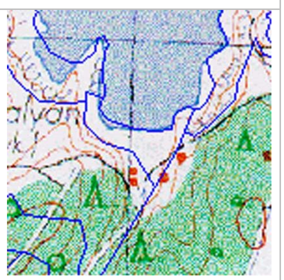
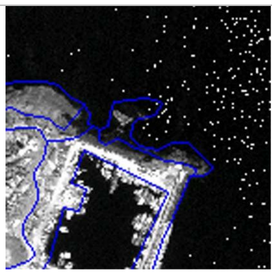
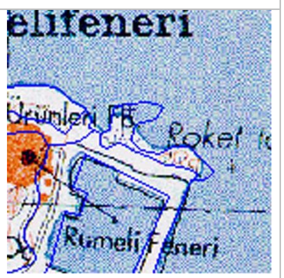
				
Class 1.4.1	Green urban areas			
				

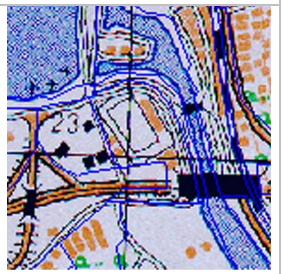
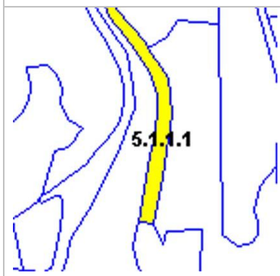
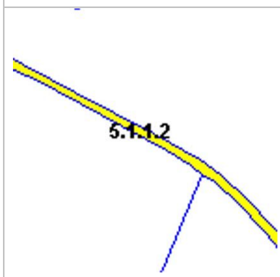
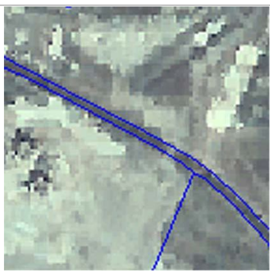
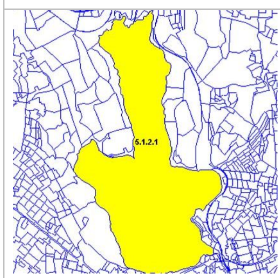
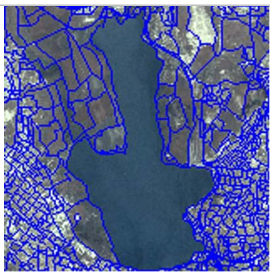
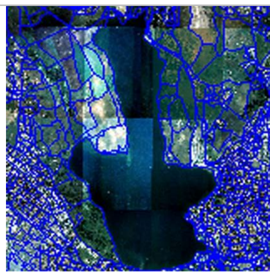
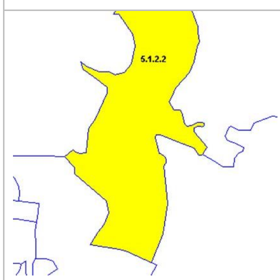
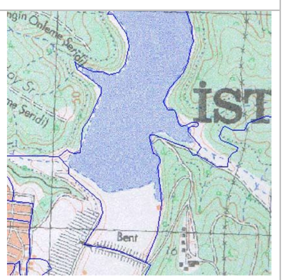
Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
Class 1.4.1.1	Vegetated cemeteries			
				
Class 1.4.2	Sport and leisure facilities			
				
Class 2.1.1	Non-irrigated arable land			
				
Class 2.1.1.1	Arable land without dispersed vegetation			
				
Class 2.1.1.2	Arable land with scattered vegetation			
				

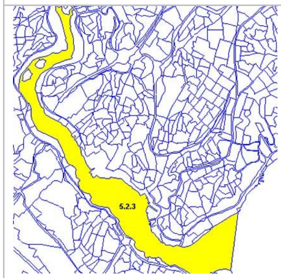
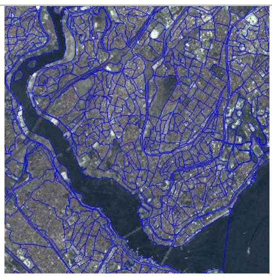
Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
Class 2.1.1.3	Greenhouses			
				
Class 2.1.2	Permanently irrigated land			
				
Class 2.3.1.2	Pastures with trees and shrubs			
				
Class 2.4.2.2	Complex cultivation patterns with scattered settlement			
				
Class 2.4.3	Land principally occupied by agriculture (LPOA), with significant areas of natural vegetation (			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
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			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
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			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
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			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
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			
				

Vector-Polygon	IRS-D merged	Ikonos Pan	Orthophoto	Map
Class 5.2.3	Sea and oceans			
				

2.18 Filtering and Data-Export

Before line-data and area-data were exported to create the final format to deliver to the JRC, a consequent filtering and validation had to be done. A first internal validation procedure solved the most evident questions and problems. After having corrected these mistakes, the validation team of the JRC in Ispra did a complex validation procedure on the results of the year 2000. Questions and mistakes were marked by them. All of these points have been commented, clarified or corrected.

Consequently, self validation and filtering procedure on the geometry were performed. In order to connect small line residuals, which should belong to a longer polyline or polygon, the automated post processing-function on topological data in TopoL was used to combine them. The number of lines decreased. Other small lines were detected by database queries in order to find residuals from the digitising procedure. Those lines were checked and either connected to others or deleted. More than 300 of such fragments with a length between 1 mm and 3 m were detected and corrected manually. In TopoL also small lines and open lines can be marked separately as blunders. This function was used to detect and to check these vectors. Nevertheless, open lines are possible in the line-feature dataset. To test the line-data in an independent way, the attributes were labelled by an automated legend procedure. During this operation, missing information and wrong codes could easily be detected. The database was filtered for those missing information and wrong content by sorting out and analysing the length of the fields-data.

The procedure to correct the geometry on the area-layer was much more complex. At the beginning, available tools in TopoL were used to create normal points from the label-points. After that, the database from the area-label-points were copied to these new points. This way, the database was stored redundantly. As a next step, the lines were imported into a new block by setting snap-parameter in order to remove small displacements and doubled lines. During this import topological vector-structure was built up again, every line was checked for its connection to others, and if necessary, they were snapped. Finally, open lines and small lines were made visible using the described visual flagging mode and after then corrected. All possible areas were created automatically. By a query on the size of the new areas, small ones were filtered out. These are usually residual areas from digitising operations, but only about 30 were detected. After that, the database was copied from the points to the areas. The same procedures with line-database were done with areas too. Doing this, all missing or incorrect fields of the database were detected and repaired.

These cleaned vector-data were exported to Arc/Info Generate format and then imported to Arc-Info. The import effected that the topological structure was built up again and was proved. Final deliverables were “Arc-Info Coverages”, the export-format “Arc/Info E00”, the “Arc/Info Generates” mentioned above and, to complete the data set, also exported directly from TopoL “Arc/View Shape-files”.

2.19 Reverse-correction (down dating)

To run **temporal analyses** on the extracted data, it is necessary to process the historical data from 1987/88, 1968 and the 1940ies in the same way as done for the reference year. In order to keep the geometric similarity on a high level, an upgrading of the changes of the 3 layers going backwards step by step was done – a so called down-dating.

First, the entire line layer of the year 2000 had to be down-dated using the older images. Additional line-objects had to be added and others erased. The database had to be checked if the objects attributes still fit to the legend. Significant modifications in the geometry were done as far as they were visible and realistic. Small corrections below the accuracy level of the geocoded raster data were not done in order to keep the best geometric correlation and to be reliable.

After that, the down-dated lines (1988) and the polygons of the newer area layer (2000) were imported into a new empty layer by using automated topological nod-creation. To identify the origin of each line, they were coloured differently. The label-points with the attached database of the year 2000 had been imported as points and the class-code had been displayed for supplementing information. In addition, the lines were corrected to build up clean polygons for the later area-creation. In the case that area and use remain still the same, the area was created automatically and the attributes can be taken from the point database. Otherwise the database was modified.

The modification of the 3D Objects was done parallel because they are closely connected to the area and the line layers of the actual and previous period. Only in the case of few objects, this was easy to perform.

All the other data were processed similarly, backward step by step. Finally, four line layers, four area layers and 4 3d area-layers was developed. By using database-analyses and GIS-intersections the changes have been detected and quantified in a further process.

2.20 Preparation of ancillary data

Ancillary data processing was done as far as possible in GIS or with the combination of other database software like MS-Access or dBase/Paradox. For the validation and pre-calculation of statistical data MS- Excel with dBase III-output allows geo-coding and combination with GIS. The results of this processing enables semi-quantitative modelling, which can answer questions like: how many people live in which kind of residential area. It helps to understand the distribution of citizens in Istanbul. Some other data, like public traffic and power-plants, are in different co-ordinate systems. In those cases, transformation had to be done before, either ellipsoidal or by grid-projection, sometimes both. Some historical maps are still in the line to be processed. Bringing all the data together is a long lasting job.

Scanned maps, as far as they have a reliable geometry and are not too much generalised, were geocoded by transformation methods related to the maps or the pre-processed satellite imagery. Those maps are e.g. the older 1:10k topographic maps of the historical city, historical aerial photographs, old maps, geological maps and other thematic maps. Some of these raster-data were processes to vector data.

Bus-Stations

The maps of the bus-stations were scanned and transformed by collinear transformation. As these maps had been stretched for printing purpose, their transformation was done for the Asiatic and European side separately, to minimise deviations. Bus-stations were digitised into a point vector-layer with an attached database. During the digitisation, the layer with the transportation network, already digitised using the reference imagery, was opened and used to snap the bus-station to the related roads in the vector-lines. In most cases it was possible to process and thus to optimise the geometry. Unfortunately, information about transport frequency were not available.

Geological map

The geological manuscript-map of the Bosporus area already mentioned above was scanned, geocoded and the areas of identical geological sites digitised into a vector layer. The data, however, cover only a small part of the study area. Two maps of smaller scale were used to complete these maps even in poor geometric quality and fewer details. They were processed in a similar way. In order to have the best correlation to the existing vector-data of the land-use, some lines were used to frame the geological formations. These are especially borders to water bodies, beaches and sand-plains. Some other much more generalised geological maps had no sufficient quality for additional processing. They had been used for common interpretation purposes in combination with other geological maps and sketches (i.e. bathymetry of the Marmara-Sea, earthquake risk…) only.

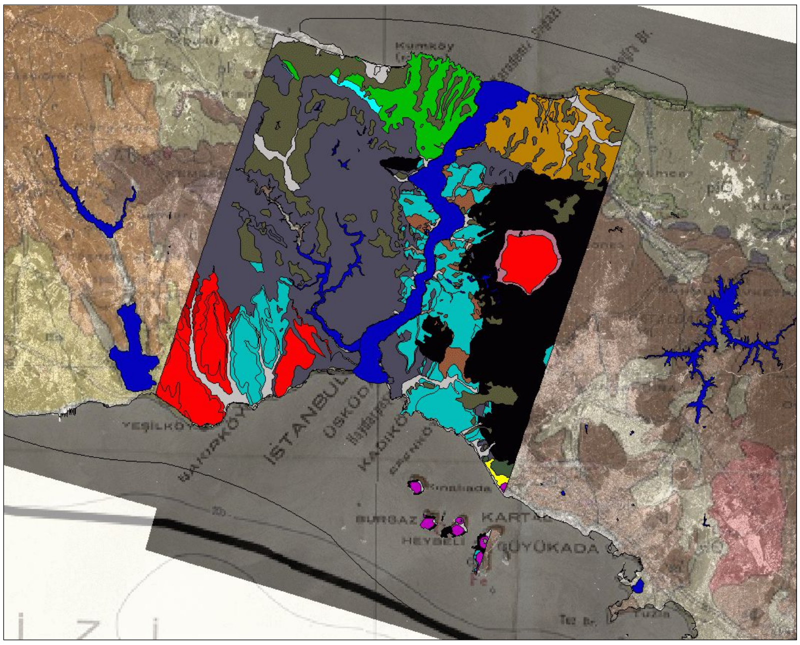
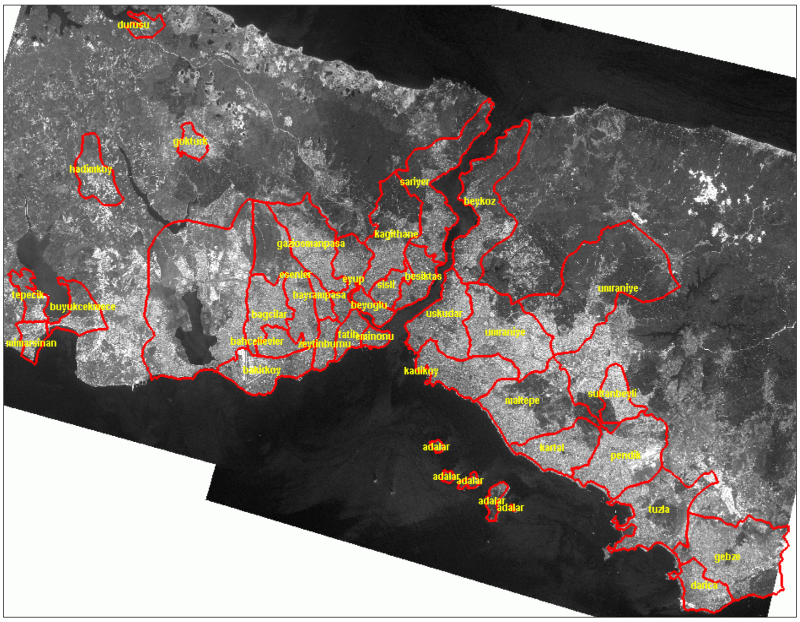


Figure 97: *Digitising the geological data into a new vector-dataset out from different sources.*

Thematic maps

Some thematic maps were found in literature, 2 of them on land-use change and urban sprawl. However, they were both strongly generalised and created for qualitative research. They have been scanned and geocoded and finally used for interpretation purposes only. A comparison was not found to be useful due to the different tasks of the studies.



District map

It is difficult to find any map about the responsibility of the administration. Some planning purposes cover other districts than the administrative ones. Demographic data are linked to different area definitions. Only one map with regions we searched for was defined as reliable. Since it covers most of the study area, it was scanned, geocoded and digitised for spatial statistical analyses.

Figure 98: *district map in vector form with database attached.*

Master-Plans

Common master plans for entire Istanbul are not available; we received only some plans from local administrative departments. There is a master plan for entire Istanbul of the water management company IGIS. These maps in small scale were scanned, geocoded, and used for the interpretation of the land-use data. Some data in the master plan handbook are also interesting from the statistical point of view. Some of these prognoses have been put into an Excel table to make it available for other operations.

Digital Terrain Model

DTM data were processed at the beginning of the project since they were needed to create orthophotos out of the aerial images. Main datasources for that were digital maps stored in DGN vector format based on scale 1:25,000. These data mainly contain contour lines as 3D vectors with a height-distance of 10m, in flat terrain even in 2,5 and/or 5 m. These DGN-files were imported to AutoCAD and changed to DXF. In TopoL these DXF-files were imported and finally edited. Labels, mainly symbols and vector-text descriptions, were deleted and the single files merged to one big block. In some parts, the data were uncomplete; in that case they were upgraded by digitised points out of the raster maps 1:25k. In other parts, the terrain model was completed by data of the global terrain model SRTM. This model has only a very poor resolution of 70-90 m grid, but is available as free data via internet. To add information on the sea level, the coastline has been digitised out of the satellite data as the 0 m contour line. Finally, all the data have been combined in a terrain-block.

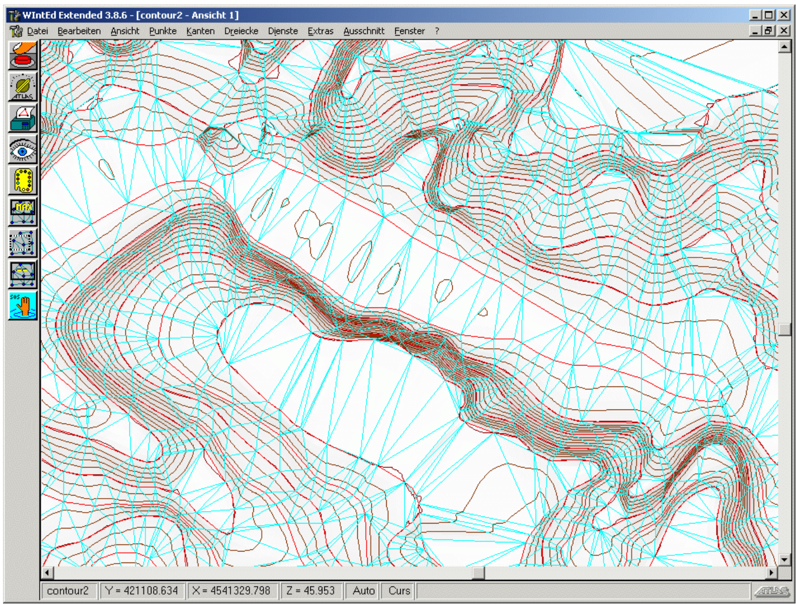


Figure 99: *Net-Editor of Atlas DTM for interactive manipulation of the Terrain-model*

To compute the DTM at one complete dataset, all single data-sources and map-sheets have been exported to Atlas-DTM. The contour lines and the digitised coastline have been used as break lines. The different points where added then. Based on all this information, Atlas computes an irregular triangulated network in order to keep all the 3d information precicely on their coordinates. The model received was very complex and then edited in order to remove poor points or to correct mistakes in the data. This was done interactive, using the Net-Editor of Atlas by displaying contour lines, slope shades and computed edges and break lines.

This model was not only used for the photogrammetic processing; it even became an important part of the Tsunami risk-estimation in the interpretation part of this study. Moreover, terrain is a very important part in any planning purposes and for environmental analyses essential as well.

Environmental data

Since environmental data were rarely available, they were not processed into GIS format or statistics. Some data, however, were extracted from the multi-spectral sources of the satellite imagery to receive some information e.g. hot spots of Istanbul, the vegetation distribution and the biomass activity. These data are geocoded as raster data and were used for interpretation purposes.

Statistical data

Statistical data from various sources were digitised into Excel-tables in order to run statistical analyses and to extract trends. Some data, which had some kind of spatial distribution by defined origin area, have been processed to thematic maps. In some other cases, using parametric modelling, statistic data have been combined to develop distribution maps. The big problem was that the data usually were either temporal for the entire study area or done as a distribution for entire Turkey with the complete Marmara region. Thus, these data are strongly limited for analyses and can just be used for common interpretations.

2.21 Methods of mixed data-processing

These very different data sources require a “multi-scaled” GIS, which is able to manage data of different origin, different scale, and different quality. Source can be raster and/or vector-data. Most commercial GIS already support mixed data-storage, however, they are not like a data warehouse or a Meta-data GIS. Overview over the various data can easily be lost and data used for an analysis that is not recommended in order to produce reliable results. Beside that, there is need for using non-spatial information like statistics, text-files, single photos or others in combination with the classic GIS data. For a purpose like that, it is necessary to have at least one geocode to implement a label-point for these data. In most commercial systems an information layer to store information about quality, accuracy, related distribution and others is missing. A layer about the data, or shortly named meta-layer, is not yet available.

This study tries to combine statistical data via geocoded modelling using parameters from the land-use data. This is surely a non-accurate extraction of new information, but due to lack of other possibilities and in the awareness of not being accurate, these data can assist valuably in the interpretation.

New improvements in order to integrate GIS completely in data-base-warehouses (e.g. like Oracle with Spatial options) show the way to manage this task. There is a need in modern planning and management to handle all data into one management system.

This study already makes this need of an integrated management system very clear. Many different methods have been used to reach an interpretable result. Beside those methods, classical intersections in GIS were done in order to receive data about the changes. If the data are of the same type (raster or vector), of the same quality, and of the same content, they can be analysed easily. Even different attributes can be analysed, but not non-spatial data sets with spatial ones.

3 Results of data-extraction

In this chapter, results of data-extraction for the land-use classification and analyses of the their quality are described. Quality estimation on the accuracy of the source-data, mainly the geometry, and the reliability of the digitised lines and areas related to geodetic measurements is done. For the reference data, it was done in detail, for the historical ones more generally. In the first part, the definition of the project areas had to be performed. To define borders of the city was a very special task. Finally, the land-use data for every year will be presented with a first statistical overview and tables that show the distribution of every land-use class.

3.1 Demarcating the study area

For spatial analyses with vector data, an exact demarcating of the study area had to be done in order to receive a compatible set of temporal data for all years. The ancillary data should fit into this border as well. To define the borders of an urban area like Istanbul is not as easy as it looks like. Maps usually show political borders of provinces and administrative areas, other information on the maps are generalised and do not allow detection of the building structure. Furthermore, these maps are not up to date since former separated cities and villages are now in the middle of the agglomeration. It is the result of the uncontrolled growth of “Gecekondu” areas all around Istanbul, which are the biggest in the west and eastside of the city. In that case, the study area can only be detected by using satellite-imagery or airborne photographs.

As a first step while proposing the project, a generalised coloured CIR spot-image was used. Other data, especially accurate maps, were not available at this stage of the project. In the ITT (Invitation to Tender) a predefined area was given, which is shown below in cyan coloured lines. A pink line shows the administrative borders of the central Istanbul city that corresponds with the traditional and historical part of Istanbul. A first interpretation of the dense urbanised area and its buffer zone was done and represented by yellow lines – obviously a big difference.

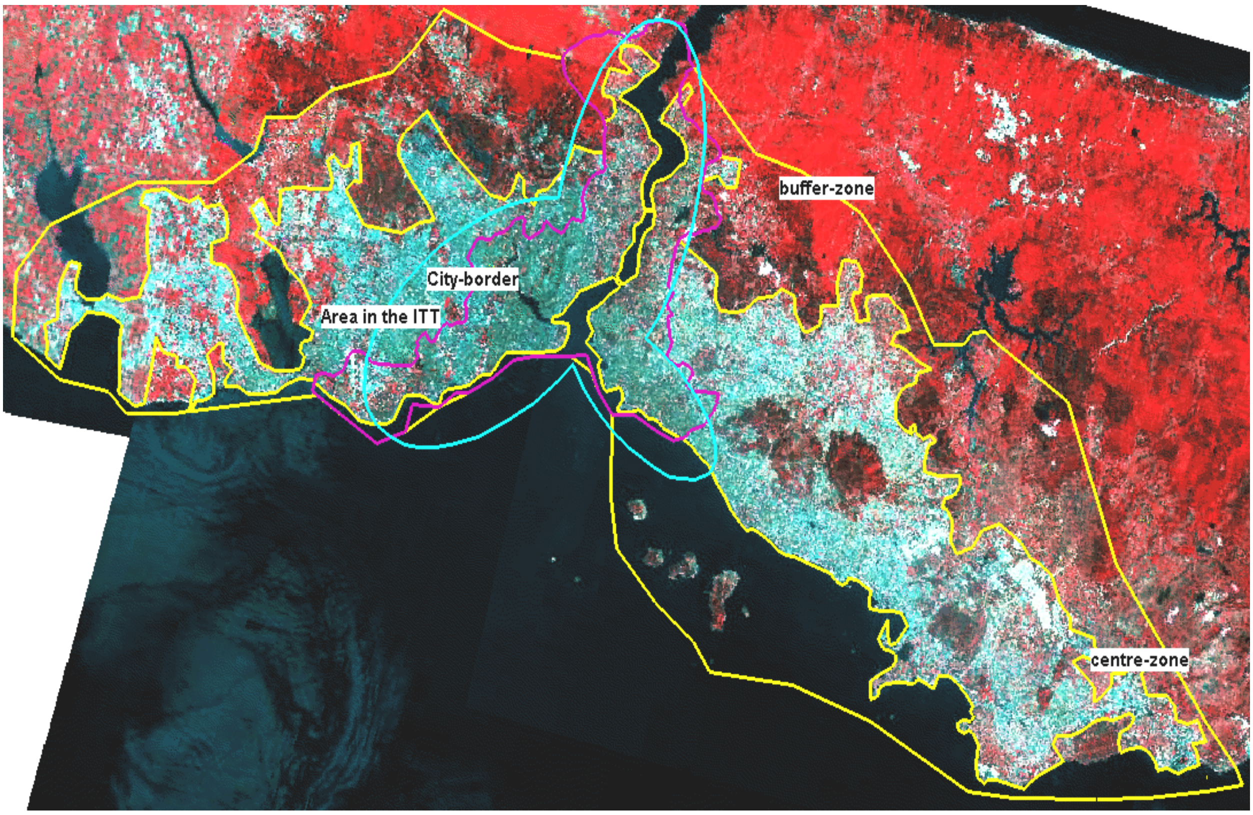


Figure 100: *A generalised CIR Spot image of the year 1997 with the proposed study area in yellow, the area of the tender in cyan and the administrative area of the Istanbul downtown in pink.*

Inner administrative City-border:	34,000 ha
Istanbul in the year 1970:	39,000 ha
Example-Area in the ITT:	43,.000 ha
Core Urban zone:	107,000 ha
Buffer Zone:	108,000 ha
Proposed area incl. buffer-zone:	**215,000 ha**

Table 17*: Overview of the proposed zonation*

As an obligatory part of the project, a zonation had to be done for the study area. Like in the project proposal, a centre zone with a continuous urban fabric had to be defined, representing the historical city with grownup areas directly connected to it. The buffer zone, enclosing the centre zone, shows the surrounding with rural land and areas of first impact of the urbanisation here. During the beginning of the project, IRS/D Satellite Image in combination with local knowledge was used to define a centre zone by a dense continuous urban fabric. This task is complex, since Istanbul has several sub-centres in the Asian part, the historical centre, and the business-district of “Taksim”. The growth of the urban fabric is focused along the seaside of Marmara and the Bosporus and along some axes in valleys. The dense urbanised zone encloses former separate ancient cities and villages, which now belong by this definition to the centre zone. The buffer zone was defined by the rules of the MOLAND-program where the buffer-distance (D) is calculated by the size of the centre-zone (a):

$$D\ [m] = \sqrt{(a\ [m^2] / 4)}$$

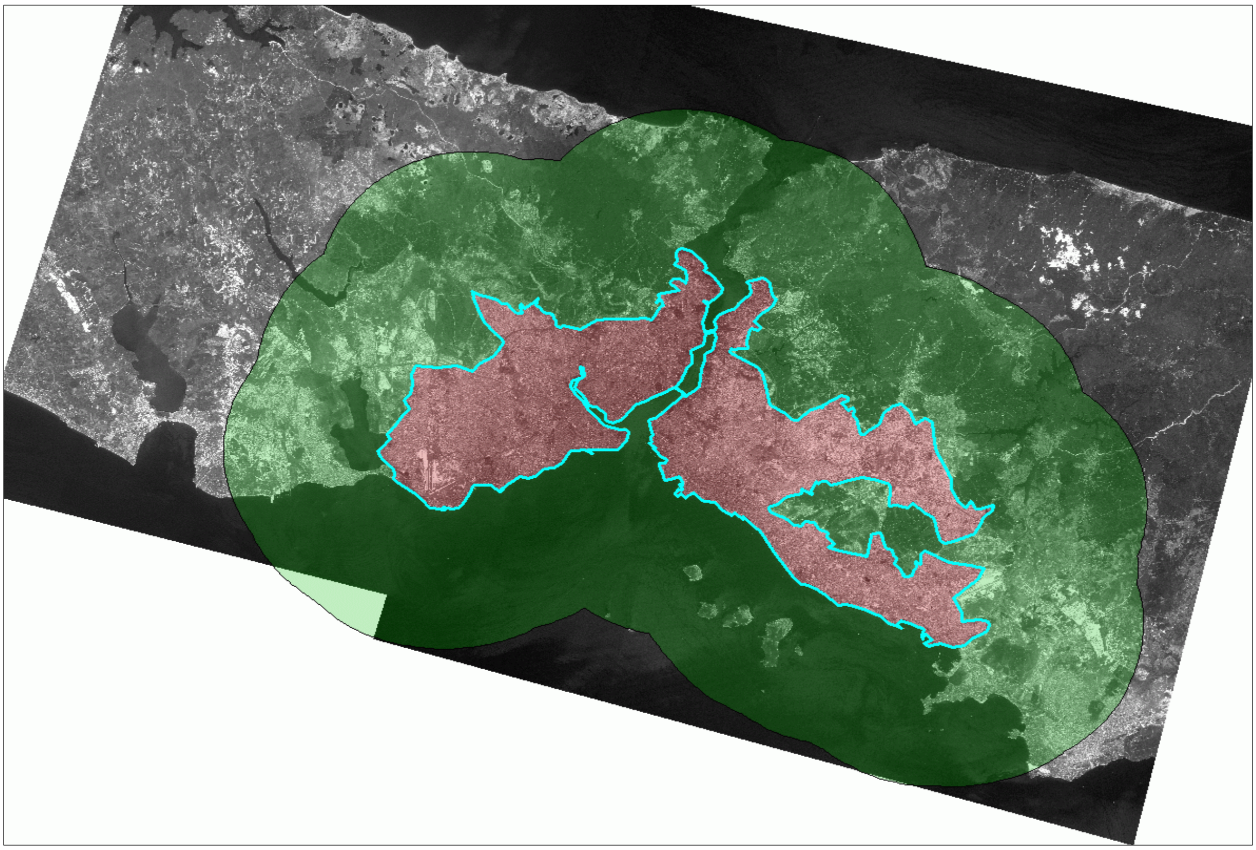


Figure 101: *the automated computation of the buffer-zone (green) of 220,000 ha around a first estimated centre-zone (red) of 55,000 ha.*

This first estimation is not really satisfying because in reality areas of additional continuous urban fabric are bridged by other urban structures similar to in the region of Büyükcekmece.

A more reliable method was needed. During the process of the digitisation and interpretation of the reference year, the project area had been redefined several times, also in agreement with the JRC. So far the final definition of the zonation was updated after the reference land-use was extracted. In the SE, the buffer zone was defined by the border of the Istanbul province and on other places by areas of spare urban fabric and agricultural land. It is ingenious using unchanging structures like streets, rivers, valleys and others for demarcating this border on the reference data especially when re-observing this border in the historical data too. The buffer zone is not totally free of urban fabric, but continuous urban fabric stops within the centre-zone. The buffer zone includes new settlements and whenever it was possible, the border was adapted to administrative frontiers. Also within the centre zone less dense urban fabric can be detected, but in relatively small unit-size. It has to be mentioned that urban fabric is extends continuously along the coast of the Marmara Sea. Therefore there is a lack of buffer zones, otherwise the area to be analysed would reach up to Izmit in the east and other 100 km on the west of istanbul. These axis are obviously the main urbanisation vectors. The total area covers 3,100 km^2. To define the urban area, the natural shape of Istanbul along the Mamara-Sea, on both sides of the Bosporus and south of the Black-Sea, was taken into account. Some new settlements arise in the forests although if it is forbidden. These small houses cannot be seen on IRS-Imagery but as far as they are known or found by field checks, they were mapped.

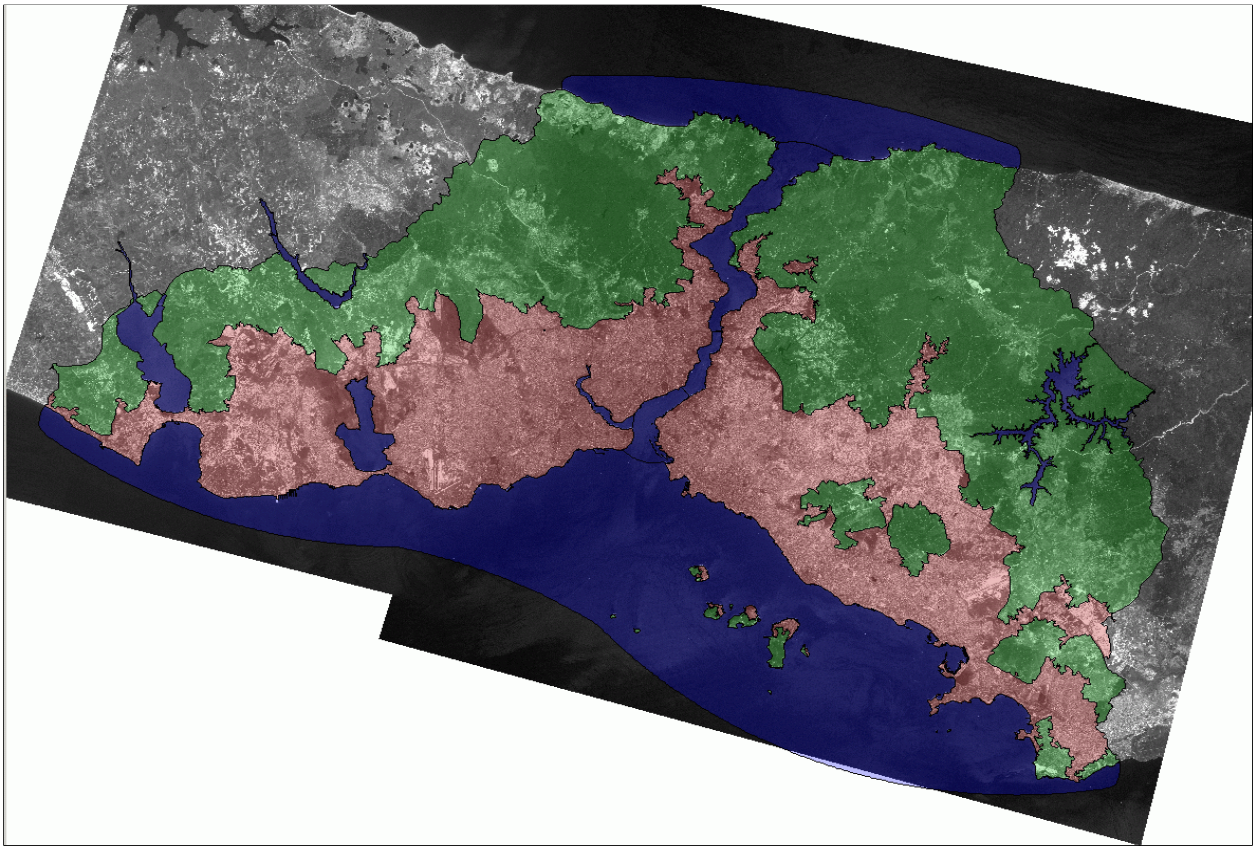


Figure 102: *The centre- (red) and the buffer zone (green) and the water bodies (blue)*

To get a more objective overview of the different zones, the water-zones were counted separately. The total size of the project area is 31,0751 ha = 3,108 km². According to the reference year, the centre zone with urban fabric has 30%, the buffer-zone 40% and the zone covered by lakes and sea 30%.

	in ha	in km²	in %
Centre-zone	91,883	919	29.6
Buffer-zone	124,937	1,249	40.2
Water-zone	93,931	939	30.2
Total	**310,751**	**3,108**	**100.0**

Table 18: *The finally chosen zonation of the project area*

3.2 Results for the reference year 2000

The reference year is the base for all the other data-analyses. These data define the minimum accuracy and quality of all the others. If this data is of poor quality, all other steps cannot improved in quality significantly. Therefore it is necessary to achieve the best results possible in geometry and land-use information for the reference year. For the reference year, the accuracy estimation will be described much more detailed, for the historical ones representatively. The historical data should meet the same accuracy as the reference data; they shouldn't be worse but might be slightly better.

3.2.1 Geometric and thematic accuracy

The results on the accuracy have two components. The first one is geometric accuracy, whereas the second is thematic accuracy of the land-use definition. These two components have their own techniques and methods, which were analysed by Murat CELIKOYAN in 2004 for this project.

3.2.1.1 Geometric accuracy

Geometric accuracy has three main components:

- Accuracy of points
- Accuracy of lines and polylines
- Accuracy of areas

The accuracy of an area depends on the accuracy of polygon delimiting it while the accuracy of such polygons depend on accuracy of the lines and their points. In the study area, there are 36,705 lines in the polygon layer for the year 2000. This reflects a point number of 73,510 for the same layer. This large number of points makes full inspection for the geometric accuracy inapplicable. Because of this, a sampling method was adapted to select representative points in the database.

Geometric accuracy of points

For points, 60 samples were selected at random from the attached database, where the samples define 30 lines overall. This was done in order to make investigation on the accuracy for lines easier. After that, the positions of these 60 points i.e. 30 lines were compared with maps of 1:1000 scales. In this step, the positions of points from 1:1000 maps were defined as true values, where:

$$\varepsilon_{x_i} = x_i - X_i \quad \text{and} \quad \varepsilon_{y_i} = y_i - Y_i$$

With these deviations, the following statistical values related to geometric accuracy have been calculated. Theoretical standard deviations are:

$$\sigma_{\varepsilon_x} = \sqrt{\frac{\sum \varepsilon_{x_i}^2}{n}} = 5.027\,m. \qquad \sigma_{\varepsilon_y} = \sqrt{\frac{\sum \varepsilon_{y_i}^2}{n}} = 6.187\,m.$$

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

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

Mean square positional error: $MSPE = \sqrt{2\sigma_c^2} = 1.4142\,\sigma_c = 7.971\,m.$

Circular map accuracy standard: $CMAS = \sqrt{4.610\sigma_c^2} = 2.146\,\sigma_c = 12.102\,m.$

Circular near certainty error: $CNCE = 3.5\sqrt{\sigma_c^2} = 3.5\,\sigma_c = 19.728\,m.$

Geometric accuracy of lines

As mentioned above, the accuracy of lines depends on the accuracy of start and endpoints. A positional accuracy of a line can be shown using the accuracy of the midpoint of it and/or the deviations of the start- and endpoints. A general positional accuracy can be calculated as follows:

$$\sigma_{\varepsilon_x} = \sqrt{\frac{\sum \varepsilon_{x_i}^2}{n}} = 3.554\,m. \qquad \sigma_{\varepsilon_y} = \sqrt{\frac{\sum \varepsilon_{y_i}^2}{n}} = 4.375\,m.$$

$$\sigma_c = \sqrt{\frac{1}{2}\frac{\sum \varepsilon_{x_i}^2 + \sum \varepsilon_{y_i}^2}{n}} \quad = \quad \sigma_c = \sqrt{\frac{\sigma_{\varepsilon_x}^2 + \sigma_{\varepsilon_y}^2}{2}} = 4.712m.$$

Geometric accuracy of areas

For the areas, the geometric accuracy can be calculated:

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

where F is the value of the area and n is number of edges. Using this equation, geometric accuracy of areas are calculated and shown graphically in the figure below.

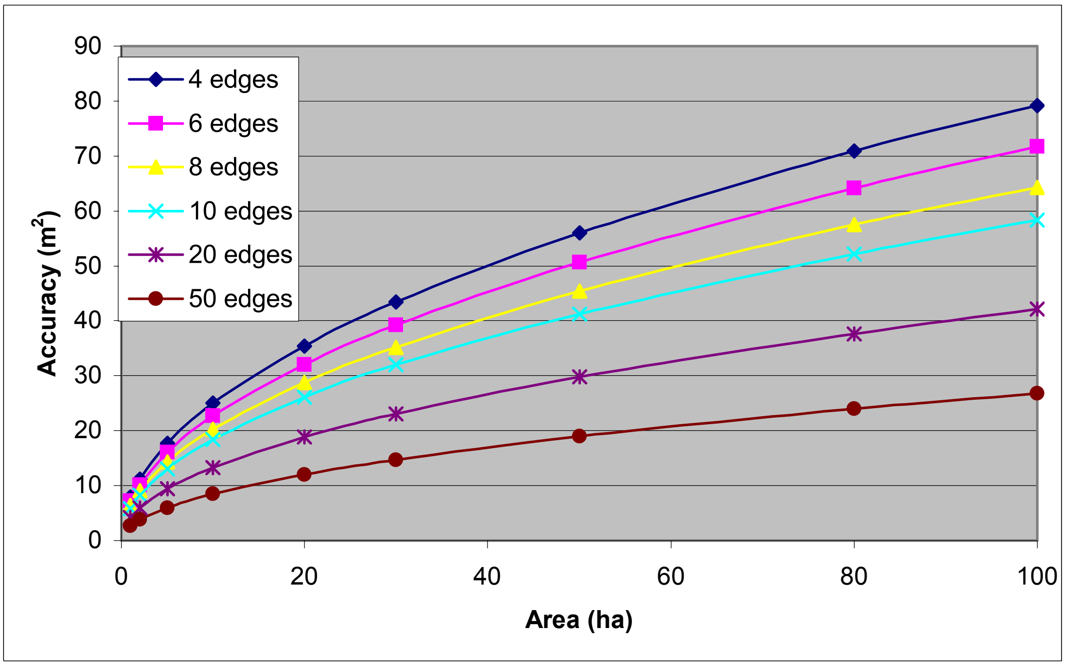


Figure 103: *Geometric accuracy variation of areas from different edge numbers and size (M.Celikoyan 2004)*

As it can be seen from the equation, the accuracy of an area depends on the size of the area and the number of edges of its polygon.

3.2.1.2 Thematic accuracy

In order to make an accuracy investigation, the database had to be revised and some of the statistical values had to be redefined. For the year 2000, 12816 areas were digitised and classified. An accuracy investigation is not applicable for all these areas, for that reason, sampling groups were created from the database at random for all the land use types. The rule for sampling is illustrated in the following table:

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

Table 19: *Sampling rule for thematic accuracy investigation*

Applying this rule for the database for the year 2000, the samples are calculated as shown in the following table:

Class	Samples		Class	Samples		Class	Samples
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**

Table 20: *Number of Samples for the land use types*

After calculating the number of samples, they were generated using the random property of microprocessors. Their unique number in database identifies the sample areas.

For all these areas in the sampling group, a thematic accuracy process was performed manually. All the areas were checked manually if they were defined correctly by digitisation process. As a result, some defining errors on the land use were detected. The amounts of errors are given in the table below with the number of errors and the error-percentage with regard to the sampling groups.

Class	Samples	Errors	Error %	Class	Samples	Errors	Error %	Class	Samples	Errors	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 21: *Amount of errors with their percentages related to the land-use samples*

Table 21 gives information on the accuracy of the results analysed. The land use type 1.1.1.1 (Residential continuous dense urban fabric) was defined with an error of 6.7% whereas the land use type 3.1.3 (Mixed forest) was defined without error.

48 land use types were shown as “totally true”. 30 of these 48 land use types have 10 or fewer errors i.e. a small number in total. This defines them as much more correct than other land use types. 18 land use types, which are defined as “totally true”, store specific information on their land use on the 1:25,000 maps (e.g. vegetated cemeteries) or they are clearly visible and detectable from aerial or satellite imagery (e.g. industrial areas or seas). The use of additional data like 1:25,000 maps or 1:16,000 city plans by digitisation and defining the areas, leads to accurate results. Another parameter, which influences the quality, is the operators regional knowledge of the area. Defining the fast transit road and associated land can be a suitable example for this parameter.

In the table, it can be seen that a total error percentage with 3.3% is given. This value is only a vague result for the total accuracy. In order to give more precise results on accuracy, weighting error percentages for individual land use types have to be investigated further. The weight is selected as a ratio of number of land use type to the total number of defined areas.

In order to derive a total accuracy result, “Bayes” theorem must be used for the results given in the equation:

$$P(F) = \sum \left[P(F / L_i) * P(L_i) \right]$$

where P(F) denotes the percentage of false defined polygons in total area, $P(L_i)$ the percentage of the land use type within all areas and $P(F/L_i)$ the percentage of false defined areas within the land use type. These values are given in the following table.

Class	P(Li)	P(F/Li)	P(F/Li)*P(Li)	Class	P(Li)	P(F/Li)	P(F/Li)*P(Li)	Class	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**

Table 22: *Calculation of parameters in "Bayes" theorem for individual land use types*

Using the results, the land use type of a randomly selected polygon is with a ratio of 94.31% correct compared to reality. This is an excellent result. Considering wrong decisions of the analysis, the residuals of 5.69% are wrong on a small-scale level. This means that the density of a residential area differed by one level which is not really bad .

3.2.1.3 Limits in interpretation

Apart from these mathematical methods, general problems exist. To define the land-use of an area is also a partly subjective decision of the operator. The MOLAND-Legend gives a good and very often-validated classification method that guides to a reliable decision. However, some areas are used in very different ways as above mentioned. In case that no additional classes could be defined, it was absolutely necessary to decide which class should be used. But these methods do not offer any other alternatives. Moreover, related to the investigation of the accuracies mentioned above, the result was even reproducible with different operators.

Limits in visibility caused other problems. Not every structure was clear enough so that the satellite imagery could solve the classification independently. In many cases the aerial images in combination with topographic maps were used for this purpose. Very useful was the knowledge of the local situation or the relation to people, we could interview. Only with an information mixture like that, which has a redundancy, the quality of the thematic definition attains a high degree of reliability.

3.2.2 Land-Use in the year 2000 for areas

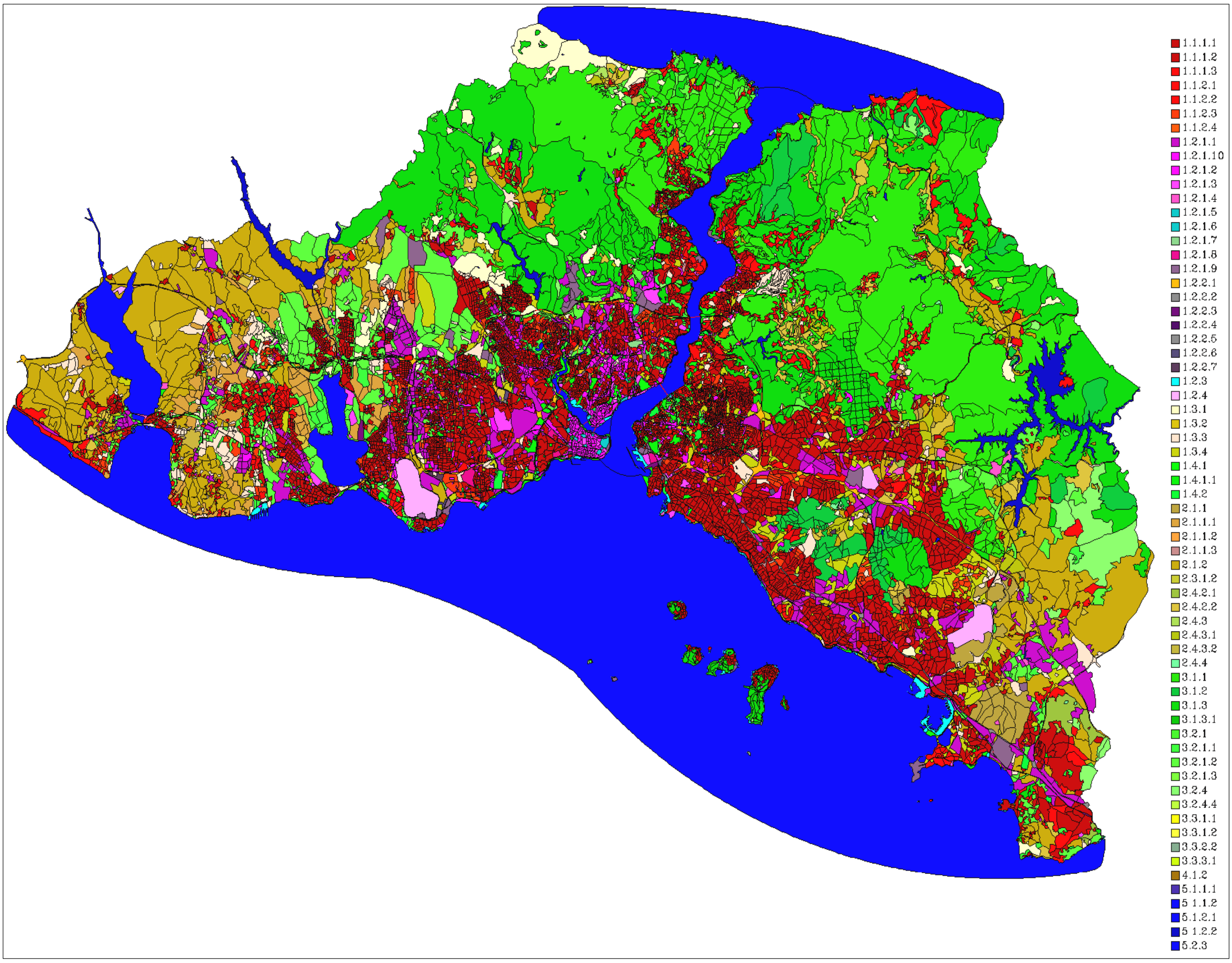


Figure 104: *Land-use areas with legend for the reference year 2000*

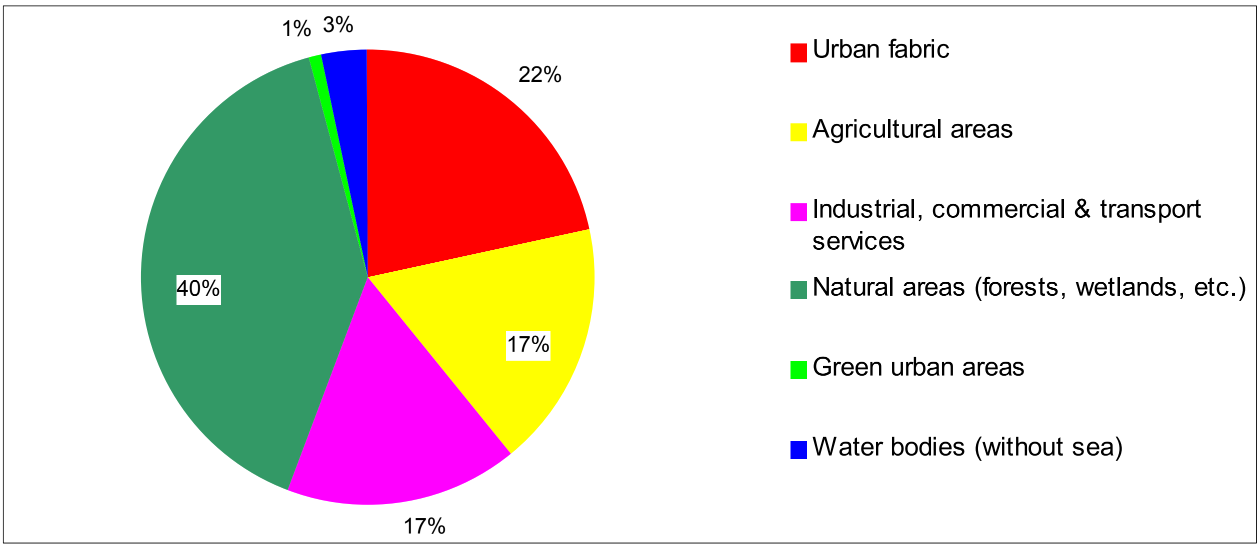


Figure 105: *Land use characteristics and statistics for 2000*

Table 23: *Statistical overview on areas and lines of the reference years:*

Total area size in ha	310,762.225
Number of areas	12.816
Area classes	65
Largest area	0.102
Biggest area	69,517.973
Areas per km²	4.124
Mean area-size in ha	24.248
Total line length in km	16,559.228
Number of lines	117,529
Lines per km²	37.820
Mean length in m	141.0
Line density in km/km²	5.329
Number of 3d objects	23
Total size in ha	43.306

Table 24: *Statistical overview on the land- use areas by classes for the reference year*

Areas 2000	Class-size in ha	No. of areas/class	Mean-size /area/class in
1.1.1.1	21,141.111	3,332	6.345
1.1.1.2	13,886.323	1,589	8.739
1.1.1.3	385.841	103	3.746
1.1.2.1	5,841.648	674	8.667
1.1.2.2	4,238.708	379	11.184
1.1.2.3	3,003.208	429	7.000
1.1.2.4	9.477	3	3.159
1.2.1.1	9,669.110	621	15.570
1.2.1.2	3,361.853	726	4.631
1.2.1.3	1,288.678	282	4.570
1.2.1.4	376.182	25	15.047
1.2.1.5	91.291	14	6.521
1.2.1.6	68.557	25	2.742
1.2.1.7	73.502	10	7.350
1.2.1.8	223.810	11	20.346
1.2.1.9	1,662.577	57	29.168
1.2.1.10	114.321	11	10.393
1.2.2.1	1,443.408	43	33.568
1.2.2.2	1,264.568	71	17.811
1.2.2.3	249.172	19	13.114
1.2.2.4	11.866	1	11.866
1.2.2.5	2.664	1	2.664
1.2.2.6	160.965	46	3.499
1.2.2.7	120.447	26	4.633
1.2.3	721.667	64	11.276
1.2.4	1,502.286	4	375.572
1.3.1	3,947.684	85	46.443
1.3.2	12.014	1	12.014
1.3.3	5,480.435	532	10.302
1.3.4	5,118.123	374	13.685
1.4.1	1,075.306	155	6.937
1.4.1.1	378.766	47	8.059
1.4.2	571.407	106	5.391

Areas 2000	Class-size in ha	No. of areas/class	Mean-size /area/class in
2.1.1	2,361.321	55	42.933
2.1.1.1	4,099.154	122	33.600
2.1.1.2	54.533	5	10.907
2.1.1.3	27.392	3	9.131
2.1.2	26,163.280	487	53.723
2.3.1.1	0.000	0	
2.3.1.2	9.095	4	2.274
2.4.2	0.000	0	
2.4.2.1	726.401	4	181.600
2.4.2.2	3,574.202	144	24.821
2.4.3	168.193	4	42.048
2.4.3.1	1,391.002	50	27.820
2.4.3.2	177.887	2	88.944
2.4.4	58.219	7	8.317
3.1.1	32,292.347	289	111.738
3.1.2	5,055.004	92	54.946
3.1.2.1	0.000	0	
3.1.3	34,514.801	425	81.211
3.1.3.1	47.855	1	47.855
3.2.1	3.595	2	1.798
3.2.1.1	2,472.645	361	6.849
3.2.1.2	12,073.014	734	16.448
3.2.1.3	149.695	10	14.970
3.2.4	2,831.214	18	157.290
3.2.4.3	0.000	0	
3.2.4.4	53.954	2	26.977
3.3.1.1	10.201	1	10.201
3.3.1.2	75.662	13	5.820
3.3.2.2	135.902	48	2.831
3.3.3.1	2.435	2	1.218
3.3.3.2	0.000	0	
4.1.2	8.273	2	4.137
5.1.1.1	59.327	6	9.888
5.1.1.2	111.402	8	13.925
5.1.2.1	4,224.923	17	248.525
5.1.2.2	3,069.461	27	113.684
5.2.3	87,262.861	5	17,452.572
Total	**310,762.225**	**12,816**	**24.248**

3.2.3 Land-Use in the year 2000 for linear elements

2000 European Side	Length in m	Number of lines	Mean line length in m		**2000 Asian Side**	Length in m	Number of lines	Mean line length in m
1.2.2.1	167,165	587	285		1.2.2.1	111,886	347	322
1.2.2.2	6,245,620	41,915	149		1.2.2.2	9,697,223	73,839	131
1.2.2.3	55,533	86	646		1.2.2.3	50,506	92	549
1.2.2.4	12,733	42	303		1.2.2.4	0	0	0
5.1.1.1	42,642	71	601		5.1.1.1	19,201	67	287
5.1.1.2	9,400	24	392		5.1.1.2	147,319	459	321
Total	**6,533,093**	**42,725**	**153**		**Total**	**10,026,135**	**74,804**	**134**

Table 25: *Statistic of the linear features by different sides for the reference year 2000.*

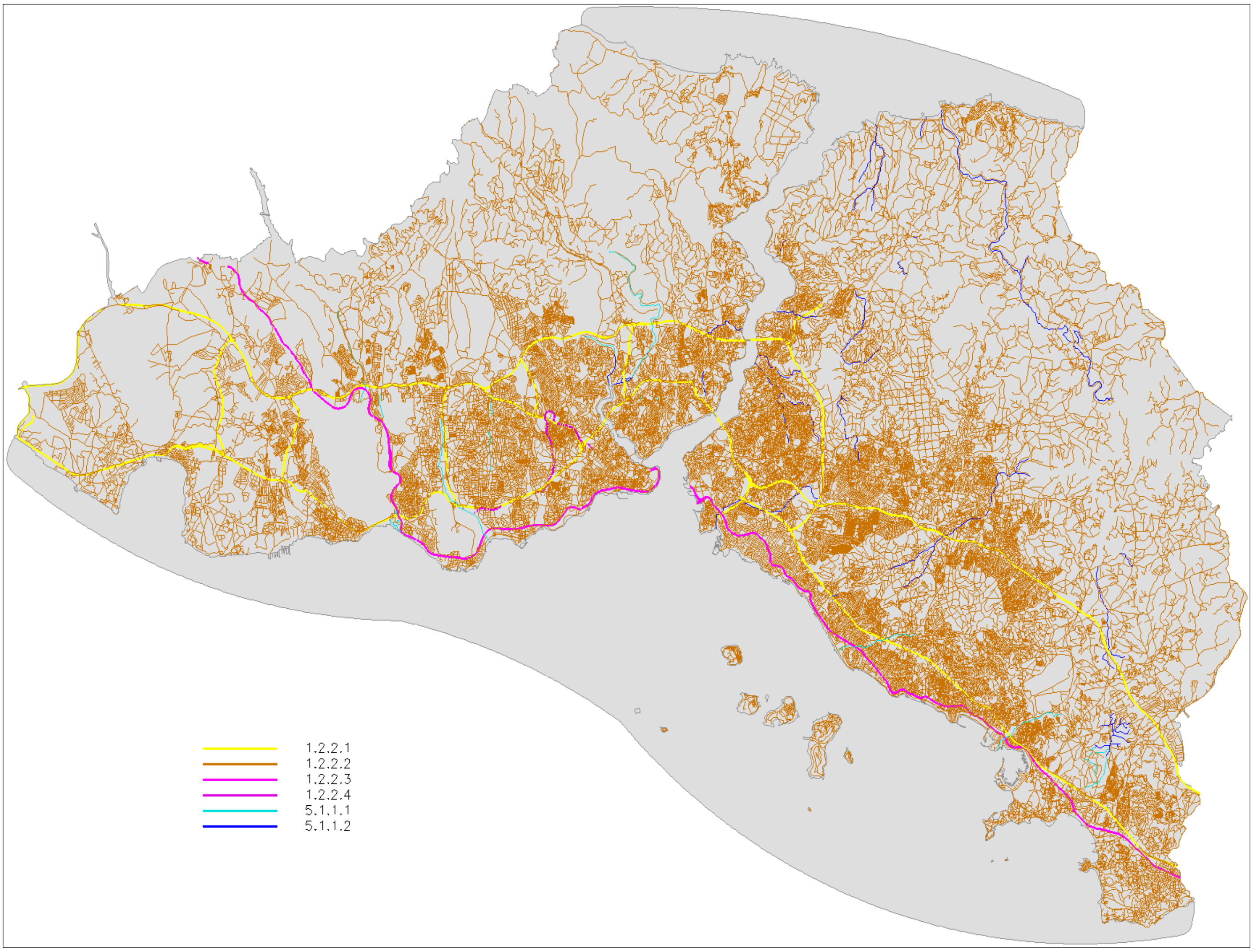


Figure 106: *The transport-network with legend for the reference-year 2000*

3.2.4 Land-Use in the year 2000 for 3D Objects

3D Area Class	Class-size in ha	No. of areas/class	Mean-size /area/class in ha
1.2.2.5	43.306	23	1.883

Table 26*: Statistic of the areas of the 3d-Objectsin the reference year*

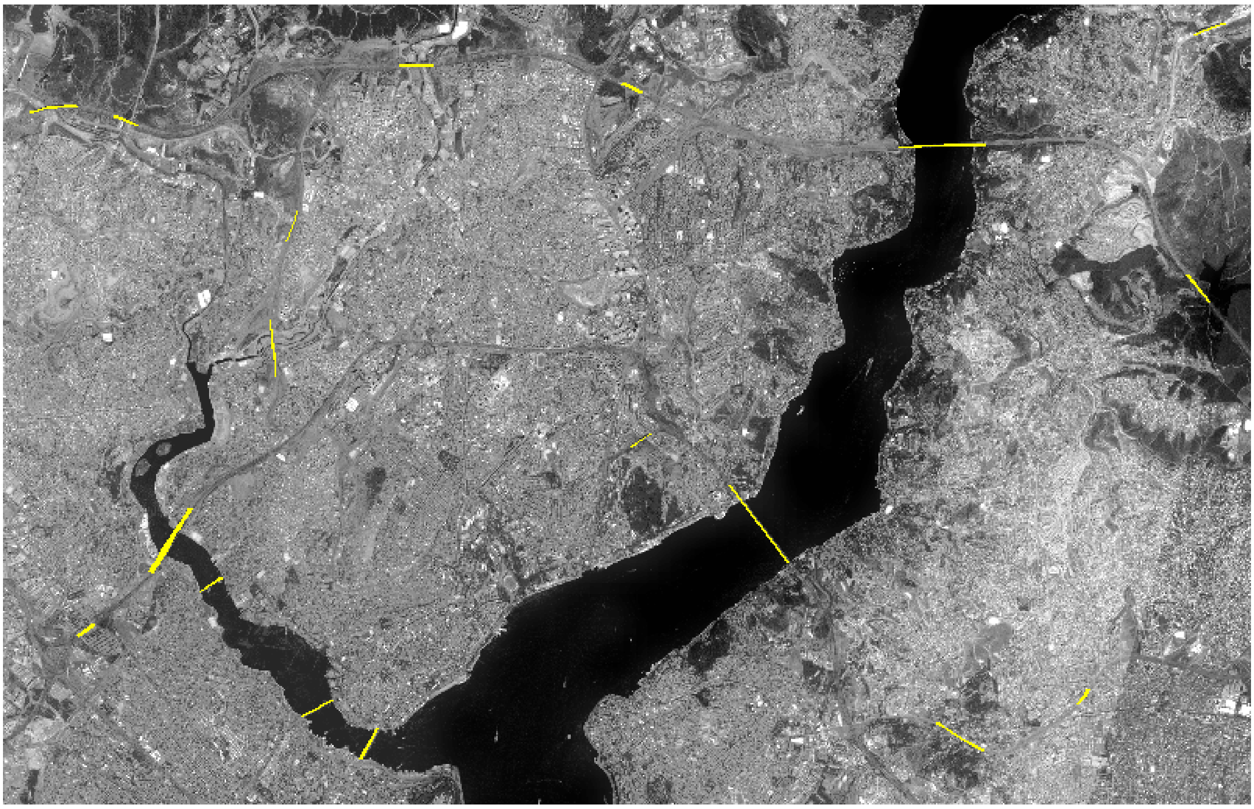


Figure 107: *The areas of the 3D Objects placed over the IRS-Imagery for the year 2000*

The 3D layer of areas helps to store information normally coverd by bridges or above tunnels. So far it is an additional layer of the reference land-use layer. 23 areas were created like this. The digitised middle line in the vector-layer supports the connection of the areas.

In this separate layer structures that are superimposed to other surfaces (e.g. bridges and viaducts), or that are hidden by other surfaces (e.g. tunnels) are stored. The typology of the mapped superimposed or hidden structures are pointed out and described in the column “Integrative information” of the Arc-Info attributes table. The words used in the “Integrative Information” column are BRIDGE, VIADUCT, or TUNNEL.

3.3 Results for the year 1987/88

3.3.1 Land-Use in the year 1987/88 for areas

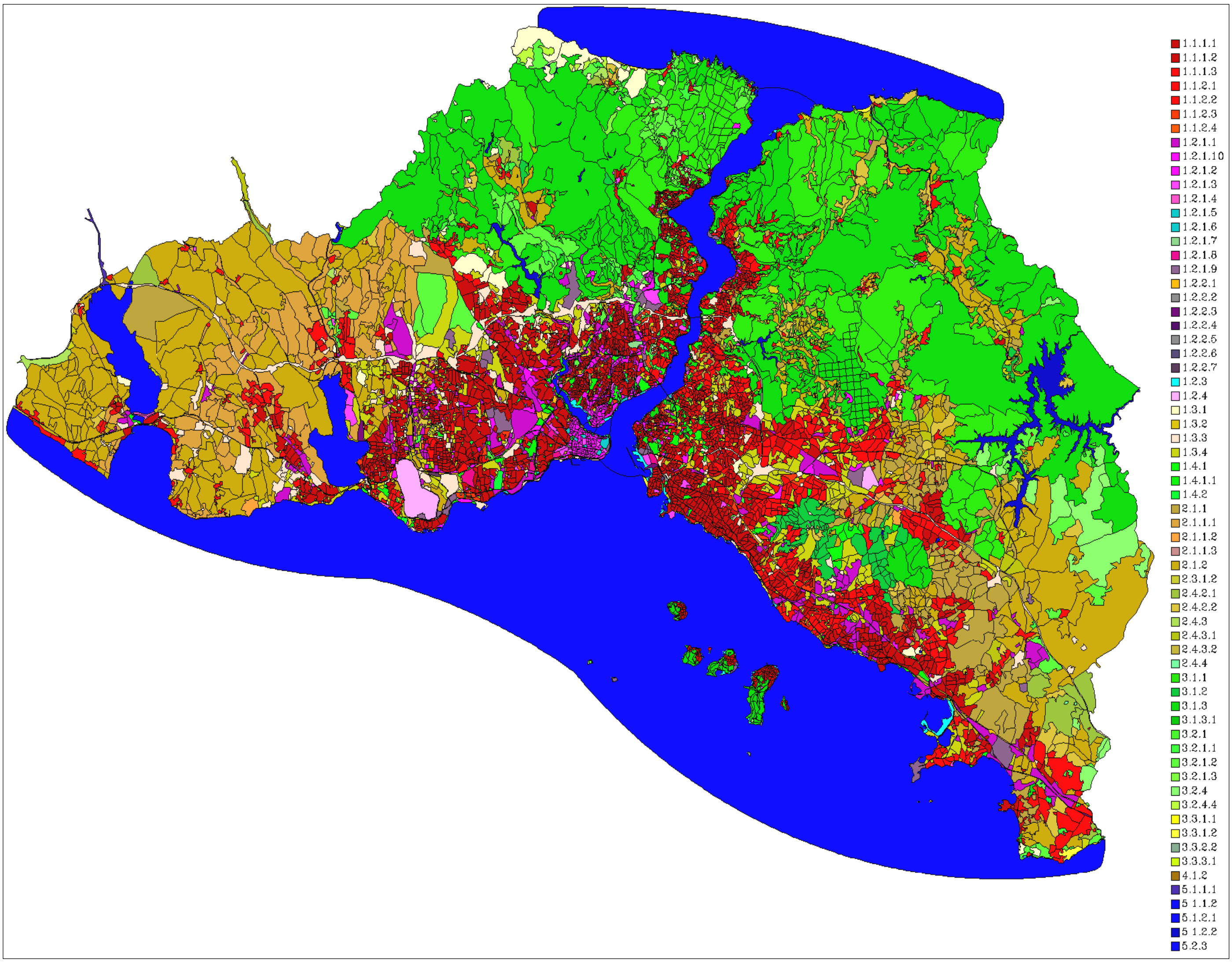


Figure 107: *Land-use areas with legend for the year 1987/88*

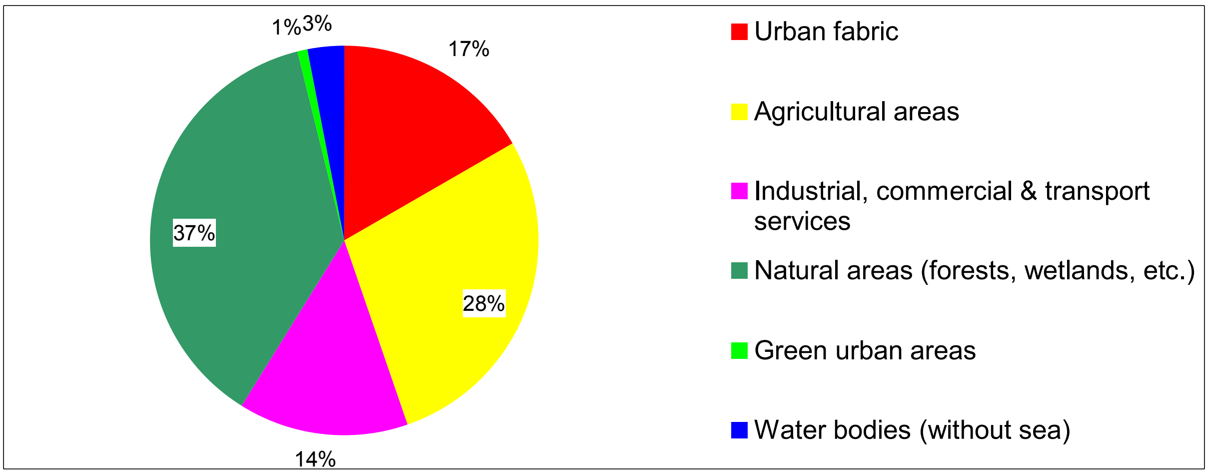


Figure 108: *Land use characteristics and statistics for 1987/88*

Table 27: *Statistical overview on areas and lines for the years 1987/88:*

Total area size in ha	310,753.835
Number of areas	8,543
Area classes	62
Largest area	0.222
Biggest area	69,977.382
Areas per km²	2.749
Mean area-size in ha	36.375
Total line length in km	14,684.661
Number of lines	106,186
Lines per km²	34.170
Mean length in m	138,0
Line density in km/km²	4.725
Number of 3d objects	17
Total size in ha	29.791

Table 28: *Statistical overview about the land-use areas by classes for the years 1987/88*

Area 1987/88	Class-size in ha	No. of areas/class	Mean-size /area/class in
1.1.1.1	8,655.013	994	8.707
1.1.1.2	11,412.937	956	11.938
1.1.1.3	99.379	20	4.969
1.1.2.1	5,954.347	505	11.791
1.1.2.2	10,130.285	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	5,536.812	317	17.466
1.2.1.2	2,163.754	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	1,452.134	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	2,273.432	49	46.397
1.3.2	6.942	1	6.942
1.3.3	5,948.830	407	14.616
1.3.4	9,797.446	896	10.935
1.4.1	1,621.758	213	7.614
1.4.1.1	315.834	29	10.891
1.4.2	242.357	36	6.732

Area 1987/88	Class-size in ha	No. of areas/class	Mean-size /area/class in
2.1.1	9,954.781	256	38.886
2.1.1.1	9,139.731	154	59.349
2.1.1.2	230.334	8	28.792
2.1.1.3	0.000	0	0.000
2.1.2	36,717.753	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	2,094.433	14	149.602
2.4.2.2	3,072.653	105	29.263
2.4.3	275.189	3	91.730
2.4.3.1	1,048.041	29	36.139
2.4.3.2	0.000	0	0.000
2.4.4	41.814	5	8.363
3.1.1	21,946.449	244	89.944
3.1.2	2,310.495	70	33.007
3.1.2.1	18.674	1	18.674
3.1.3	48,209.833	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	5,386.959	198	27.207
3.2.1.3	197.931	10	19.793
3.2.4	3,246.828	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	3,993.455	11	363.041
5.1.2.2	2,381.315	24	99.221
5.2.3	87,728.897	4	21,932.224
Total	**310,753.835**	**8,543**	**36.375**

3.3.2 Land-Use classification for linear elements

1987/88 European Side	Length in m	Number of lines	Mean line length in m		**1987/88 Asian Side**	Length in m	Number of lines	Mean line length in m
1.2.2.1	78,419	305	257		1.2.2.1	48,398	204	237
1.2.2.2	5,314,085	37,084	143		1.2.2.2	8,929,132	67,973	131
1.2.2.3	55,475	79	702		1.2.2.3	50,496	93	543
1.2.2.4	2,777	11	252		1.2.2.4	0	0	0
5.1.1.1	45,996	71	648		5.1.1.1	18,972	67	283
5.1.1.2	2,563	7	366		5.1.1.2	138,348	292	474
Total	**5,499,315**	**37,557**	**146**		**Total**	**9,185,346**	**68,629**	**134**

Table 29*: Statistic of the linear features by different sides in the year 1987/88*

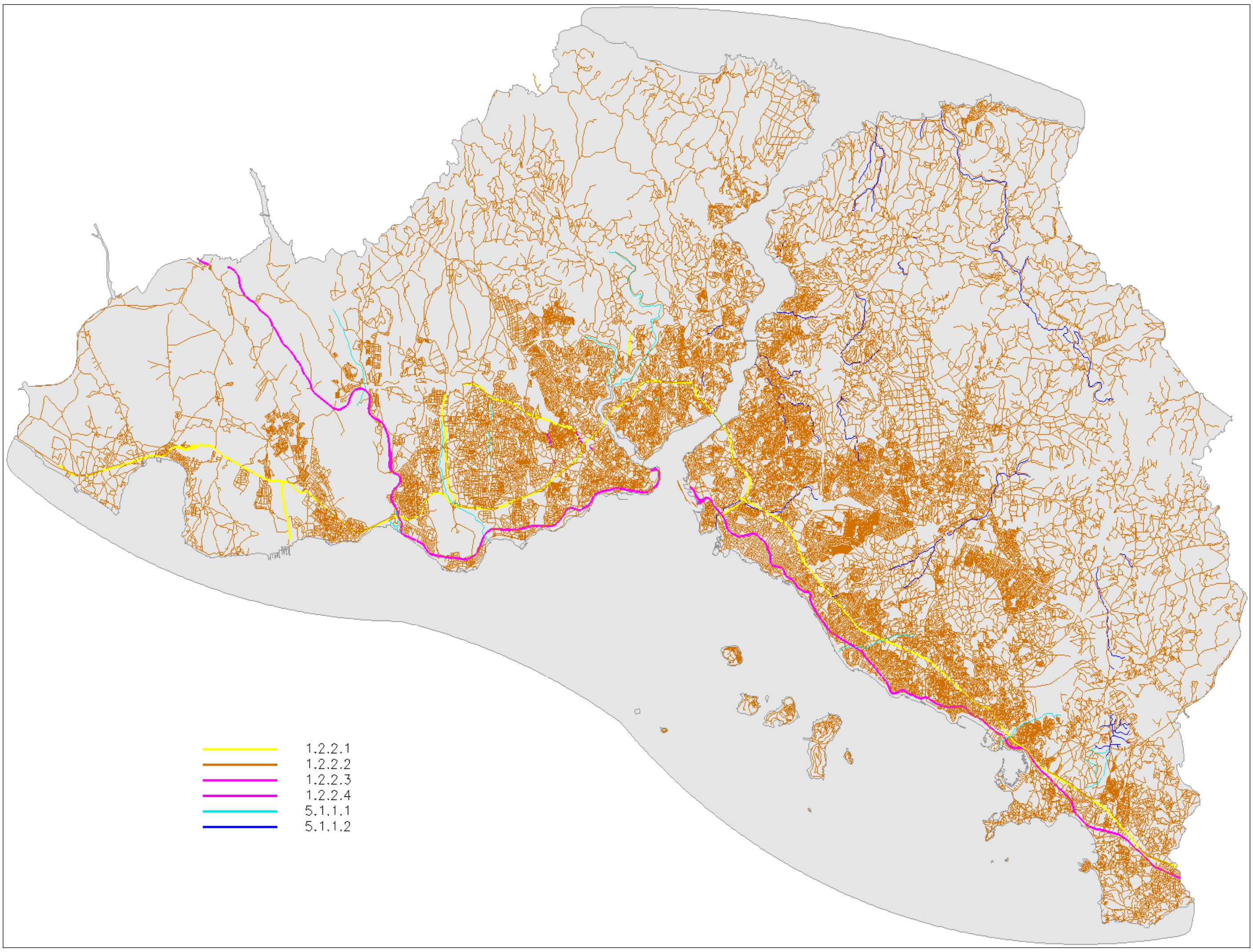


Figure 109: *The transport-network with legend for the years 1987/88*

3.3.3 Land-Use classification for 3d Objects

3D Area Class	Class-size in ha	No. of areas/class	Mean-size /area/class in ha
1.2.2.5	29.791	17	1.752

Table 30: *Statistic of the areas of the 3d-Objects in the year 1987/88:*

3.4 Results for the year 1968

3.4.1 Land-Use in the year 1968 for areas

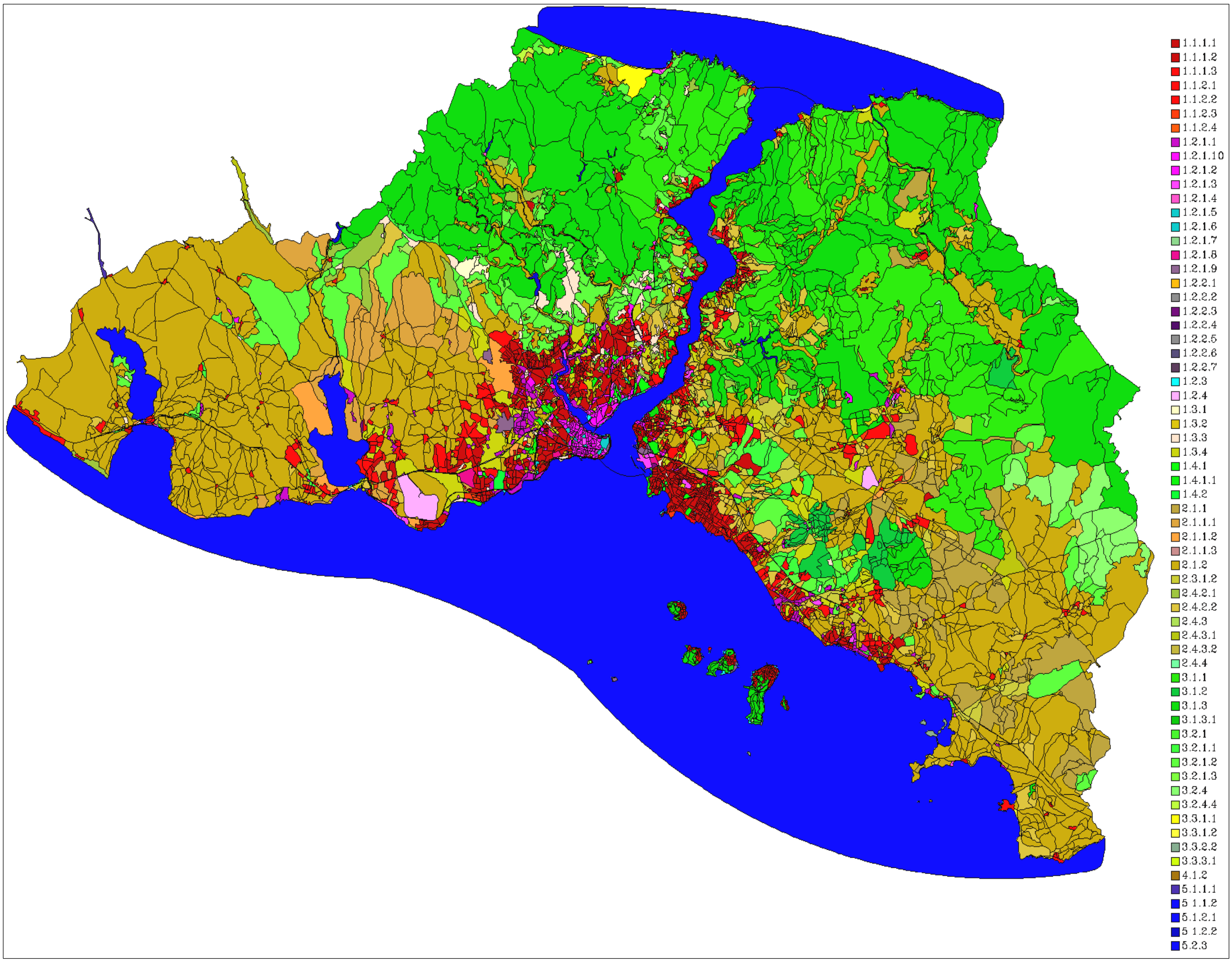


Figure 110: *Land-Use areas with legend for the year 1968*

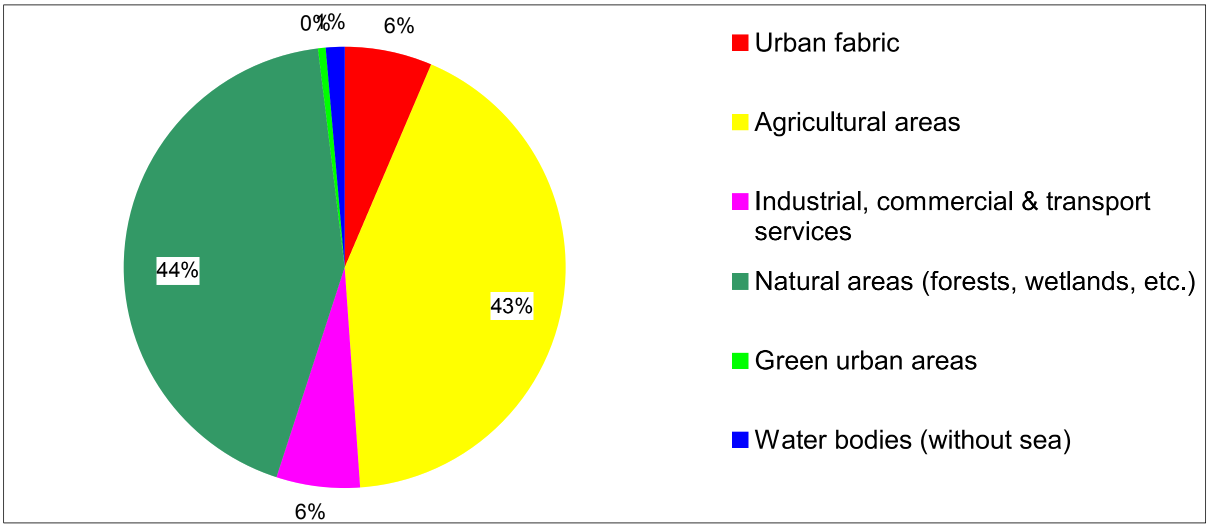


Figure 111: *Land use characteristics and statistics for 1968*

Table 31: *Statistical overview on areas and lines for the year 1968*

Total area size in ha	310,753.630
Number of areas	5,855
Area classes	57
Largest area	0.213
Biggest area	70,559.585
Areas per km²	1.884
Mean area-size in ha	53.075
Total line length in km	10,184
Number of lines	62,226
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

Table 32: *Statistical overview on the land-use areas by classes for the year 1968*

Areas 1968	Class-size in ha	No. of areas/class	Mean-size /area/class in ha
1.1.1.1	2,228.343	318	7.007
1.1.1.2	4,967.680	512	9.703
1.1.1.3	0.000	0	0.000
1.1.2.1	2,797.559	250	11.190
1.1.2.2	4,237.065	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	1,597.150	174	9.179
1.2.1.2	1,063.250	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	1,607.121	133	12.084
1.3.4	6,156.060	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

Areas 1968	Class-size in ha	No. of areas/class	Mean-size /area/class in ha
2.1.1	8,350.504	121	69.012
2.1.1.1	5,349.926	56	95.534
2.1.1.2	1,462.418	16	91.401
2.1.1.3	0.000	0	0.000
2.1.2	68,942.586	1304	52.870
2.3.1.1	228.701	5	45.740
2.3.1.2	2,283.269	95	24.034
2.4.2	0.000	0	0.000
2.4.2.1	1,945.172	39	49.876
2.4.2.2	5,024.678	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	25,916.873	187	138.593
3.1.2	2,385.485	63	37.865
3.1.2.1	0.000	0	0.000
3.1.3	48,133.118	378	127.336
3.1.3.1	45.253	1	45.253
3.2.1	27.713	3	9.238
3.2.1.1	1,866.537	74	25.223
3.2.1.2	12,852.414	259	49.623
3.2.1.3	89.578	6	14.930
3.2.4	3,615.349	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	2,797.590	4	699.398
5.1.2.2	214.436	9	23.826
5.2.3	88,564.598	4	22,141.150
Total	**310,753.630**	**5,855**	**53.075**

3.4.2 Land-Use classification for linear elements

1968 European Side	Length in m	Number of lines	Mean line length in m	1968 Asian Side	Length in m	Number of lines	Mean line length in m
1.2.2.1	0	0	0	1.2.2.1	0	0	0
1.2.2.2	3,903,531	23,671	165	1.2.2.2	5,808,168	37,688	154
1.2.2.3	51,334	98	524	1.2.2.3	50,551	94	538
1.2.2.4	0	0	0	1.2.2.4	0	0	0
5.1.1.1	39,376	48	820	5.1.1.1	15,814	57	277
5.1.1.2	179,487	292	615	5.1.1.2	135,324	278	487
Total	**4,173,728**	**24,109**	**173**	**Total**	**6.009.857**	**38,117**	**158**

Table 33: *Statistic of the linear features by different sides for the year 1968*

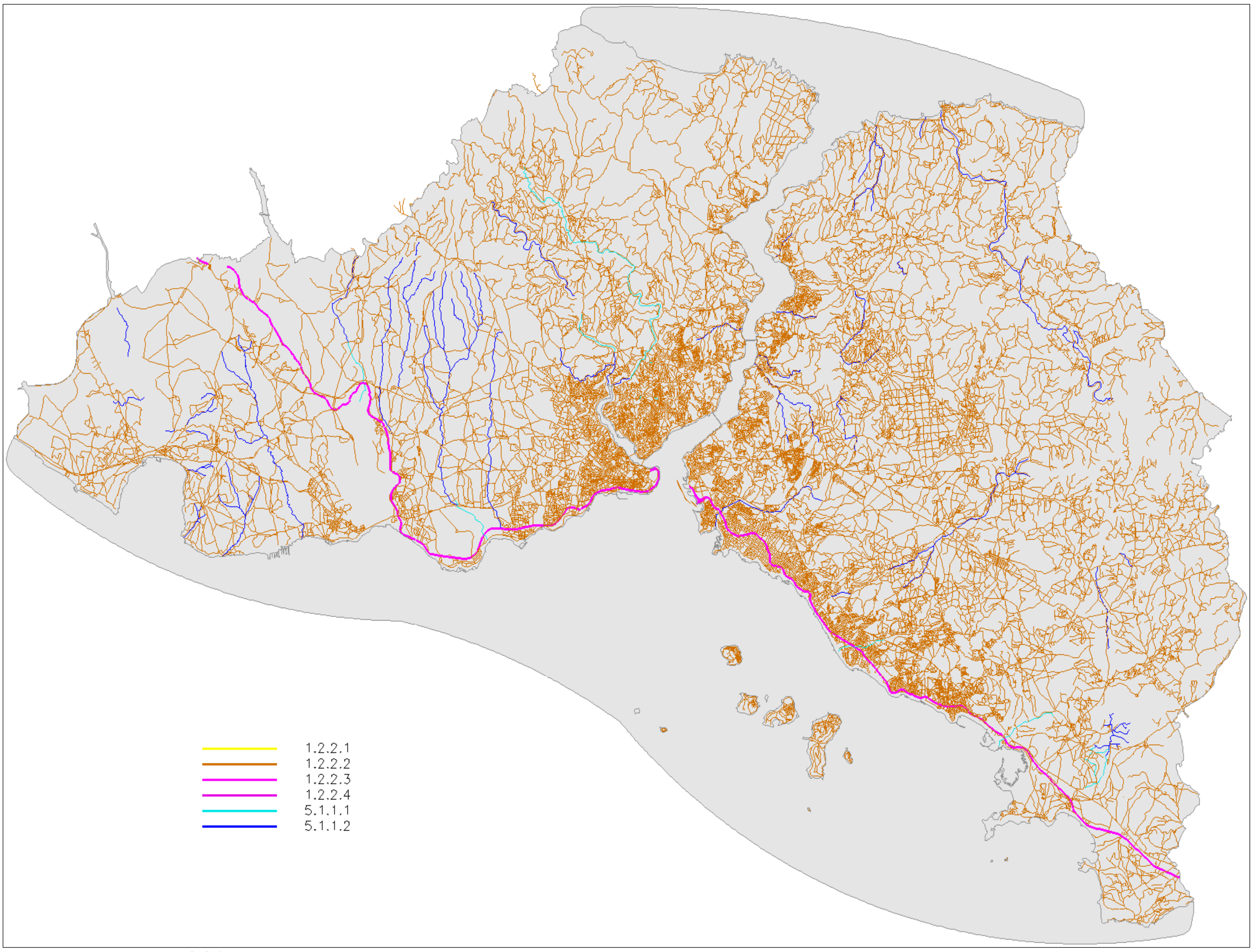


Figure 112: *The transport-network with legend for the year 1968*

3.4.3 Land-Use classification for 3d Objects

3D Area Class	Class-size in ha	No. of areas/class	Mean-size /area/class in ha
1.2.2.5	4.361	3	1.454

Table 34: *Statistic of the areas of the 3d-Objects in the year 1968:*

3.5 Results for the years 1940-49 (1945)

3.5.1 Land-Use in the average year 1945 for areas

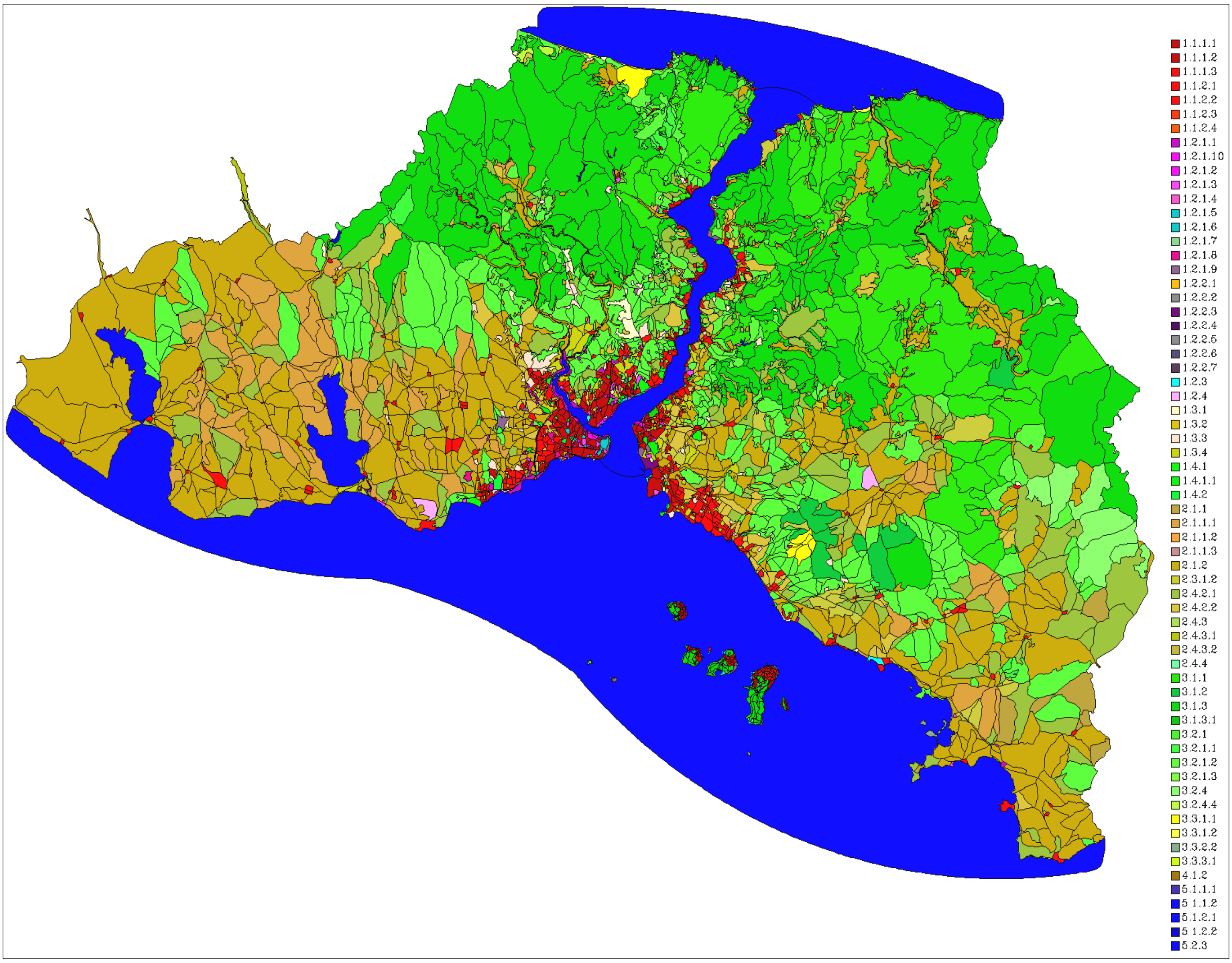


Figure 113: *Land-Use areas with legend for the average year 1945*

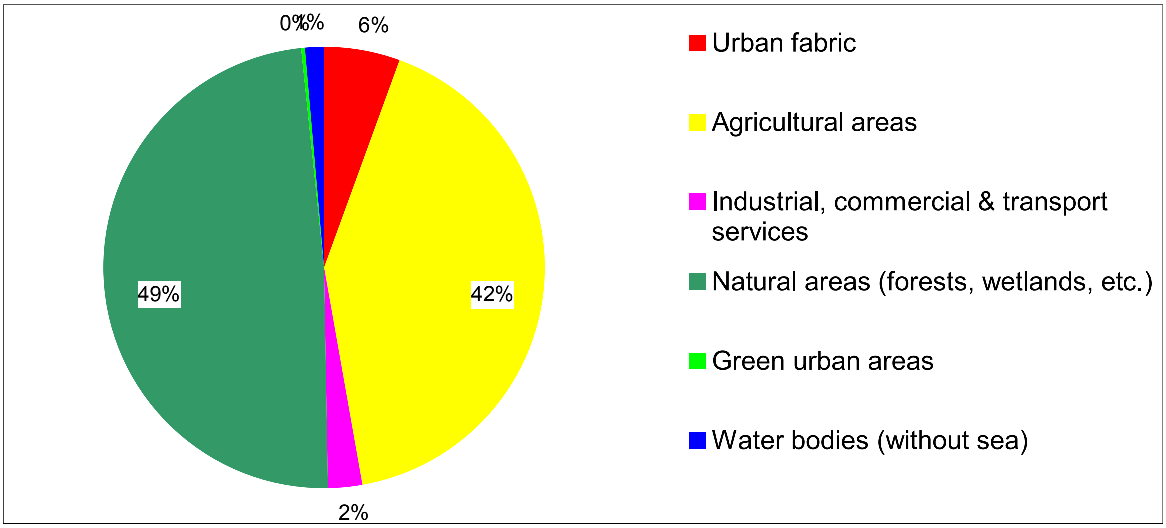


Figure 114: *Land-Use characteristics and statistics for the average year 1945*

Total area size in ha	310,753,899
Number of areas	3,821
Area classes	55
Largest area	0.222
Biggest area	70,499.826
Areas per km²	1.230
Mean area-size in ha	81.328
Total line length in km	7,414.810
Number of lines	40,225
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

Table 35: *Statistical overview on areas and lines for the average year 1945*

Table 36: *Statistical overview on the land-use areas by classes for the average year 1945*

Areas 1945	Class-size in ha	No. of areas/class	Mean-size /area/class in
1.1.1.1	709.195	32	22.162
1.1.1.2	1,423.319	149	9.552
1.1.1.3	0.000		
1.1.2.1	1,418.775	116	12.231
1.1.2.2	2,986.040	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	1,220.427	142	8.595
1.3.4	1,773.780	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

Areas 1945	Class-size in ha	No. of areas/class	Mean-size /area/class in
2.1.1	1,568.917	10	156.892
2.1.1.1	12,108.581	128	94.598
2.1.1.2	0.000	0	0.000
2.1.1.3	0.000	0	0.000
2.1.2	54,167.827	722	75.025
2.3.1.1	0.000	0	0.000
2.3.1.2	2,097.941	49	42.815
2.4.2	0.000	0	0.000
2.4.2.1	20,453.821	253	80.845
2.4.2.2	4,462.965	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	24,848.525	133	186.831
3.1.2	2,430.162	11	220.924
3.1.2.1	0.000	0	0.000
3.1.3	49,491.764	275	179.970
3.1.3.1	45.777	1	45.777
3.2.1	1.919	1	1.919
3.2.1.1	1,255.939	71	17.689
3.2.1.2	28,554.432	497	57.454
3.2.1.3	86.199	5	17.240
3.2.4	3,369.168	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	2,845.768	3	948.589
5.1.2.2	72.823	8	9.103
5.2.3	88,720.972	5	17,744.194
Total	**310,753.899**	**3,821**	**81.328**

3.5.2 Land-Use classification for linear elements

1945 European Side	Length in m	Number of lines	Mean line length in m	1945 Asian Side	Length in m	Number of lines	Mean line length in m
1.2.2.1	0	0	0	1.2.2.1	0	0	0
1.2.2.2	3,531,592	19,909	177	1.2.2.2	3,394,249	19,410	175
1.2.2.3	51,872	116	447	1.2.2.3	48,566	96	506
1.2.2.4	0	0	0	1.2.2.4	0	0	0
5.1.1.1	35,563	42	847	5.1.1.1	13,776	49	281
5.1.1.2	230,890	371	622	5.1.1.2	108,302	232	467
Total	**3,849,917**	**20,438**	**188**	**Total**	**3,564,893**	**19,787**	**180**

Table 37: *Statistic of the linear features by different sides for the year 1945*

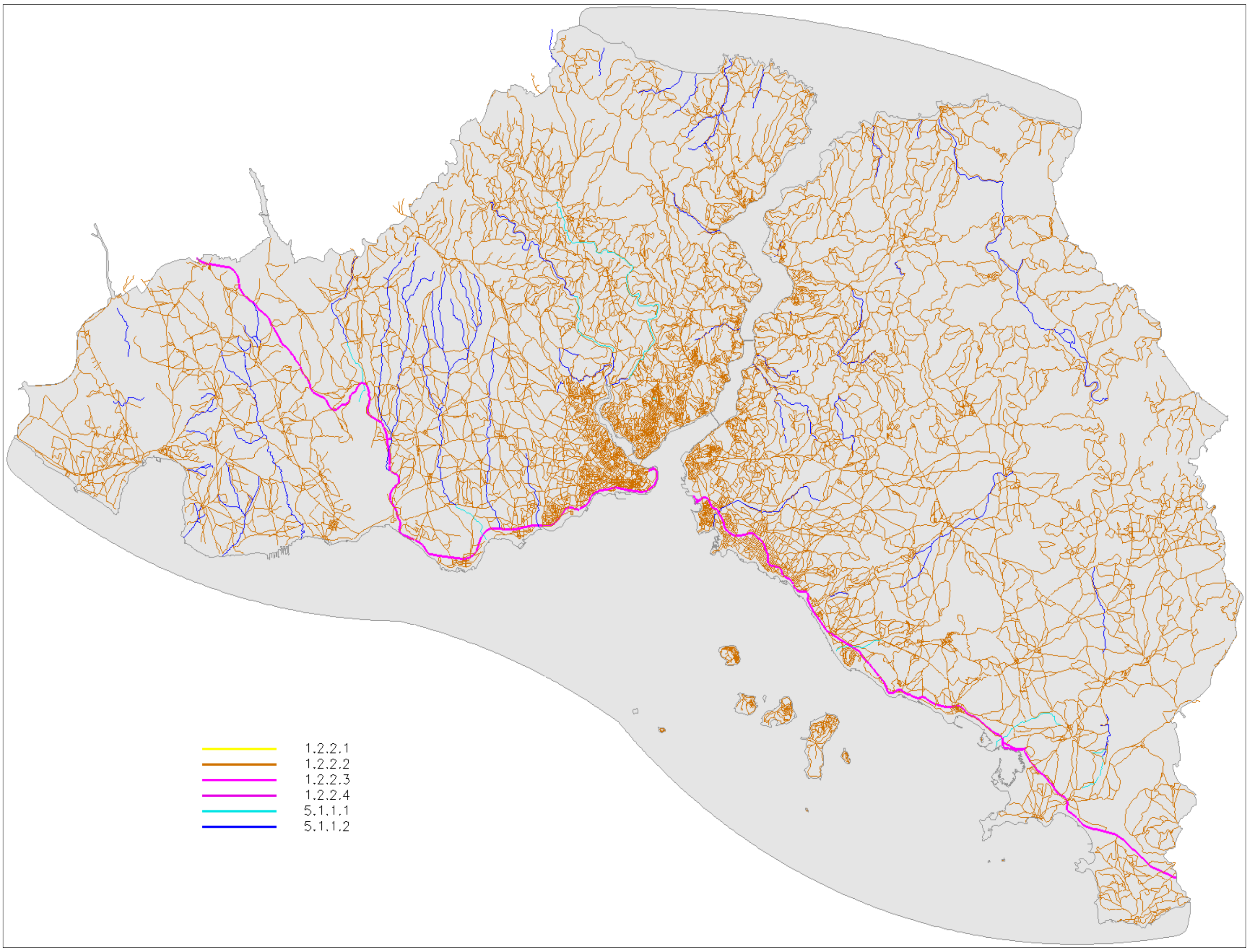


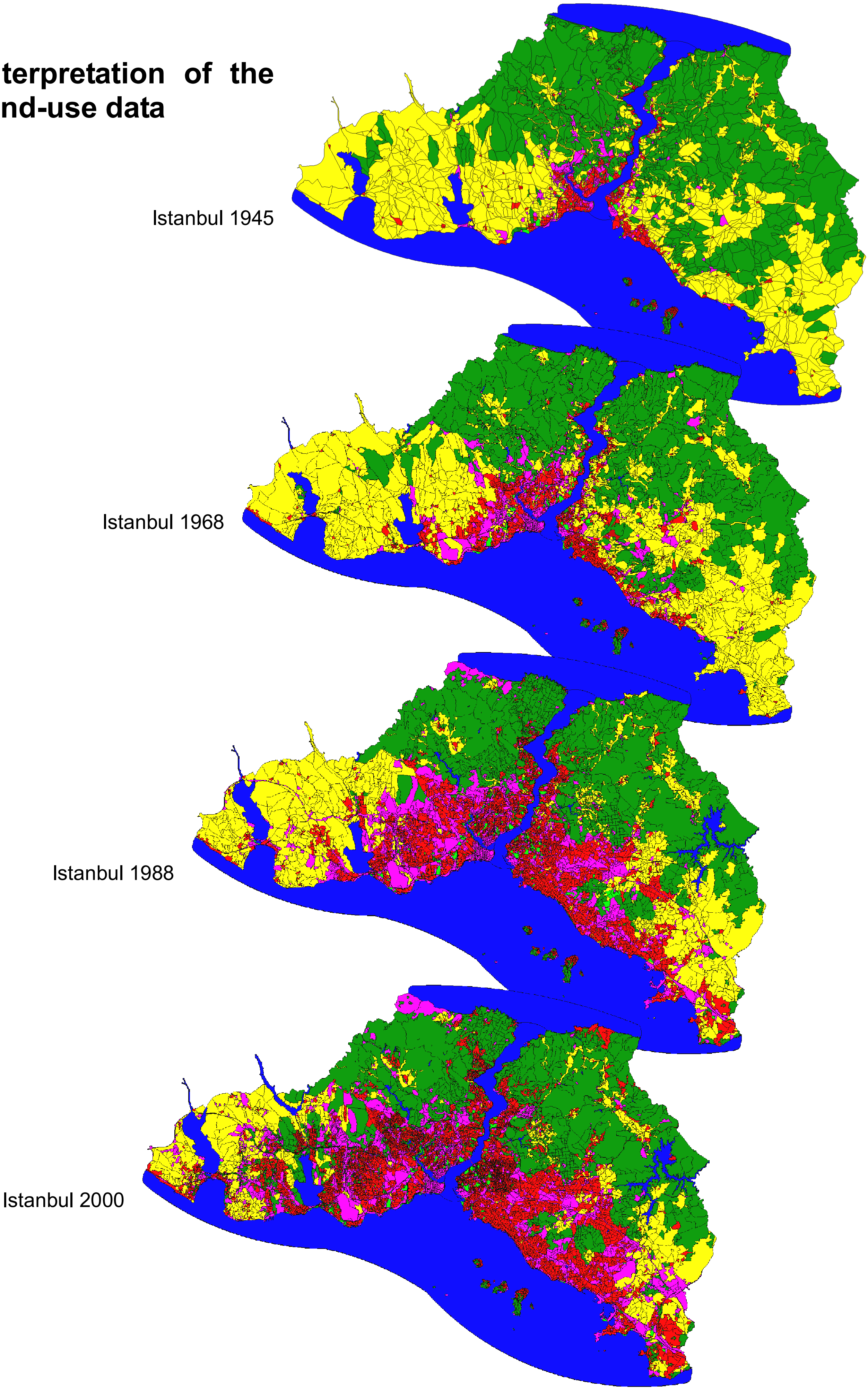
Figure 115: *The transport-network with legend for the year 19645*

3.5.3 Land-Use classification for 3d Objects

3D Area Class	Class-size in ha	No. of areas/class	Mean-size /area/class in ha
1.2.2.5	3.640	2	1.820

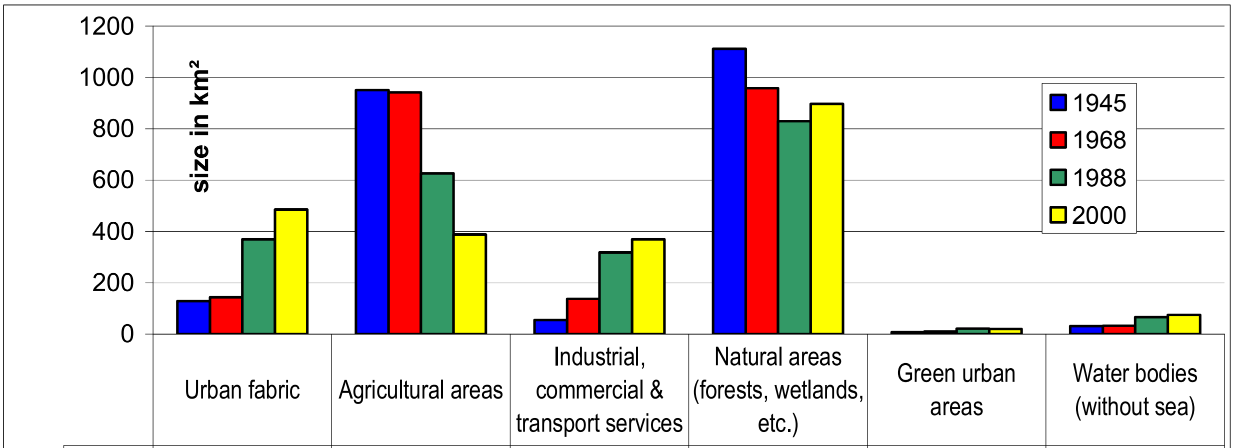
Table 38: *Statistic of the areas of the 3d-Objects in the year 1945*

4 Interpretation of the land-use data



4.1 Land-use change in an overview

The following chapter gives a first impression of the land-use change. Statistical analyses mainly on the extracted land-use data were done in order to receive a quantitative result on increase or decrease of land-use classes.



	Urban fabric	Agricultural areas	Industrial, commercial & transport services	Natural areas (forests, wetlands, etc.)	Green urban areas	Water bodies (without sea)
1945	128	950	55	1112	7	31
1968	144	941	137	958	10	33
1988	369	626	317	830	22	66
2000	485	388	370	897	20	75

Figure 116: *Growth in different groups from 1945 to 2000*

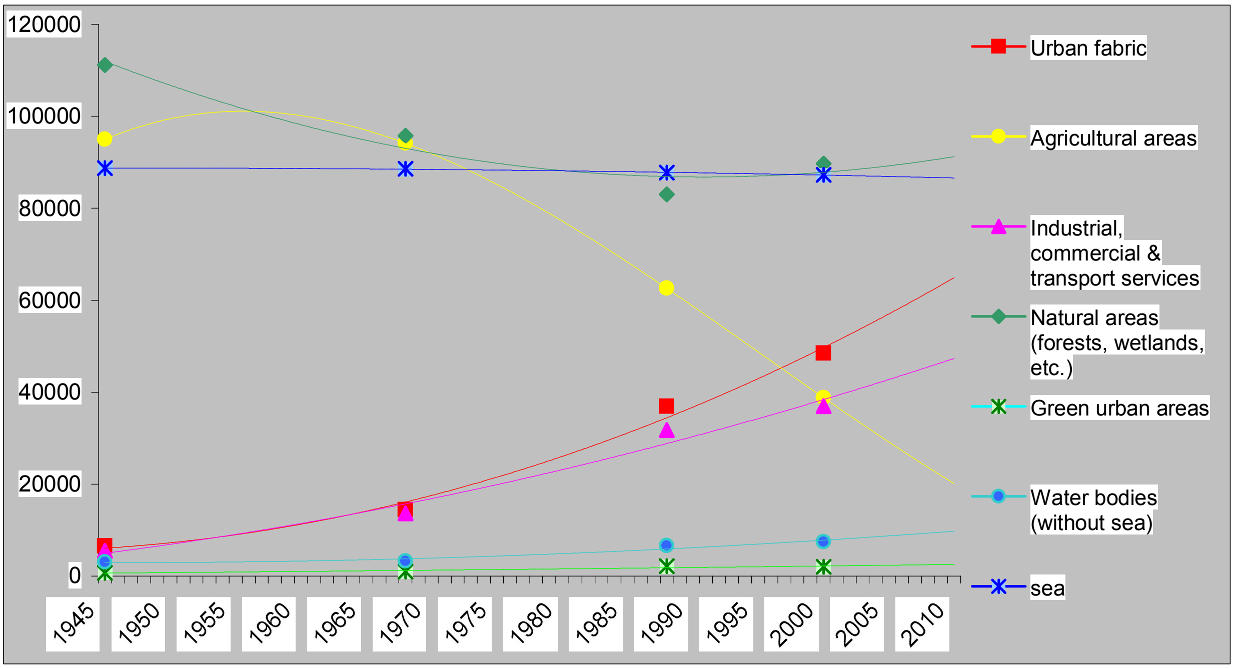


Figure 117: *Growth of the different groups by linear time-scale and trend-graphs*

These two graphics show the change from the agricultural land-use to the urbanised area of Istanbul. The single classes were grouped in order to get a first overview. “Urban fabric” represents the residential area (classes 1.1.*), industrial, commercial & transport services the classes 1.2.* and 1.3.*. All classes 2.*. are combined as agricultural land. As natural areas all classes 3.* and 4.*. were summarized. Water bodies 5.* were split up into 5.1.* and the sea-surface 5.2.3. In the upper graphic, a standard block graph shows the table with the size per class in ha. The time-stamps cut the entire dataset in different (not equal) periods, which makes the direct comparison difficult. In the graphic shown below the time-scale was developed linear to perform trend-analyses by using polynomial function of second degree. The trend, however, might be over-sized, but shows an effective visualisation of the future. Nevertheless, not all the points were represented very well. Land-use change cannot be described by simple regression analyses.

The urbanisation is dramatically high and therefore the loss of agriculture drastic. The biggest change, however, was between 1968 and 1988. Therefore Istanbul is compatible with other big cities in European context, which will be shown later. Even when the growth-rate after 1988 is smaller, the city grows very fast every year according to the urbanised area. The size of the forest area stagnates and shows small loss only. After 1988 some small increase in forestry occurred, may be on unprofitable small agricultural areas.

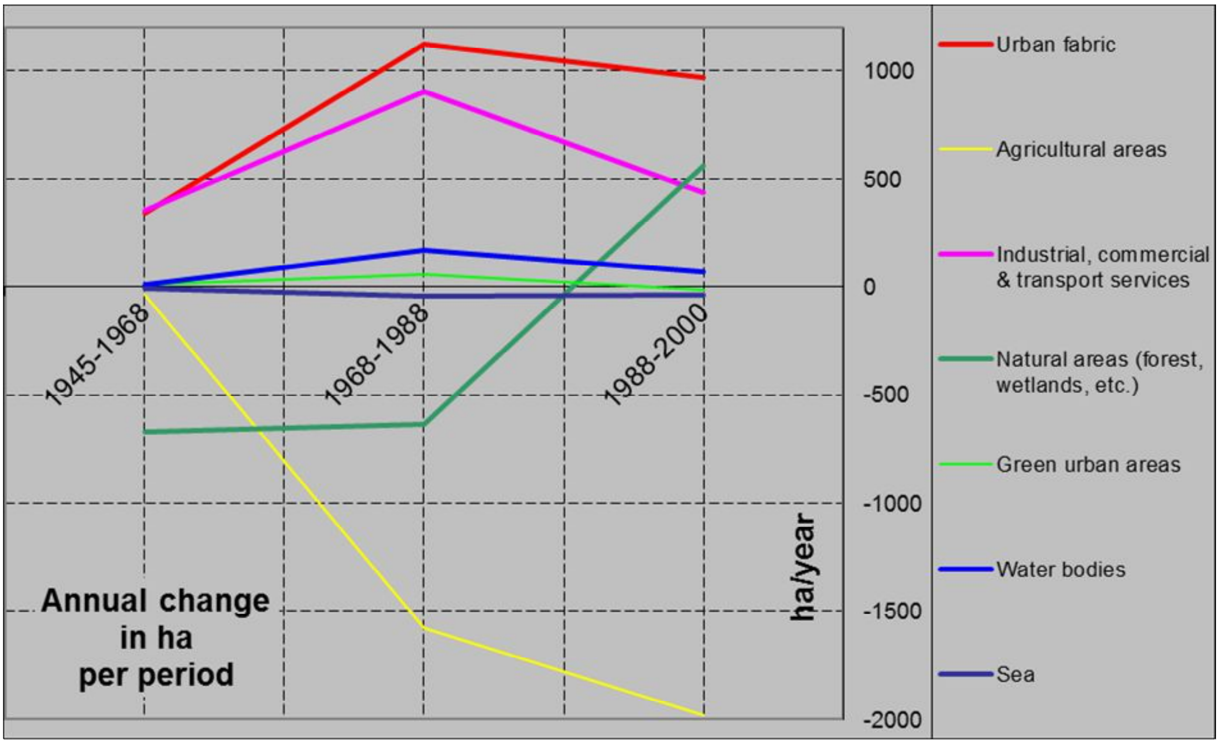


Figure 118: *Annual growth rates of the different groups in ha per year shown for the 3 periods*

This figure points out the effective change of the different groups. The visible change is calculated as an absolute annual change in ha.

The growth rate of the residential areas is all the time on a high level, with its highest peak between 1968 and 1988. The same refers to industrial areas, but since 1988, they has been slowing down considerably. In the first 2 periods, the loss of natural areas was on a constant relatively strong level. After 1988, the policy for protecting the forest became effective and the forest increased again, also due to the decrease of agricultural space.

The decrease of agricultural land is accelerating and builds the basis for increasing other classes. This change is dramatically high and reaches nowadays up to the loss of 2000 ha per year. The agricultural land is not only stressed by the residential and commercial areas, even by natural areas like forest and grassland, this decrease is compensated. Agriculture does not seem to be very profitable in those industrialised areas, so that the trend of leaving these areas unexploited facilitates land speculations.

Class size in ha	1945	1968	1988	2000	Class size in ha	1945	1968	1988	2000
1.1.1.1	709.195	2,228.343	8,655.013	21,141.111	2.1.1	1,568.917	8,350.504	9,954.781	2,361.321
1.1.1.2	1,423.319	4,967.680	11,412.937	13,886.323	2.1.1.1	12,108.581	5,349.926	9,139.731	4,099.154
1.1.1.3	0	0.000	99.379	385.841	2.1.1.2	0	1,462.418	230.334	54.533
1.1.2.1	1,418.775	2,797.559	5,954.347	5,841.648	2.1.1.3	0	0.000	0.000	27.392
1.1.2.2	2,986.040	4,237.065	10,130.285	4,238.708	2.1.2	54,167.827	68,942.586	36,717.753	2,6163.28
1.1.2.3	0	161.389	622.174	3,003.208	2.3.1.1	0	228.701	0.000	0
1.1.2.4	0	0.000	11.629	9.477	2.3.1.2	2,097.941	2,283.269	4.472	9.095
1.2.1.1	408.219	1,597.150	5,536.812	9,669.110	2.4.2	0	0.000	1.121	0
1.2.1.2	194.88	1,063.250	2,163.754	3,361.853	2.4.2.1	20,453.821	1,945.172	2,094.433	726.401
1.2.1.3	285.864	645.638	899.393	1,288.678	2.4.2.2	4,462.965	5,024.678	3,072.653	3,574.202
1.2.1.4	26.794	28.721	125.148	376.182	2.4.3	0	51.004	275.189	168.193
1.2.1.5	95.257	103.323	96.318	91.291	2.4.3.1	114.478	478.794	1,048.041	1,391.002
1.2.1.6	47.887	48.144	56.548	68.557	2.4.3.2	0	0.000	0.000	177.887
1.2.1.7	8.083	31.963	67.148	73.502	2.4.4	16.803	15.761	41.814	58.219
1.2.1.8	88.212	201.100	222.865	223.81	3.1.1	24,848.525	25,916.873	21,946.449	32,292.347
1.2.1.9	222.415	353.758	1,452.134	1,662.577	3.1.2	2,430.162	2,385.485	2,310.495	5,055.004
1.2.1.10	4.873	86.192	176.244	114.321	3.1.2.1	0	0.000	18.674	0
1.2.2.1	0	0.000	670.156	1,443.408	3.1.3	49,491.764	48,133.118	48,209.833	34,514.801
1.2.2.2	55.428	424.797	579.866	1,264.568	3.1.3.1	45.777	45.253	47.855	47.855
1.2.2.3	80.594	95.626	244.162	249.172	3.2.1	1.919	27.713	9.873	3.595
1.2.2.4	0	0.000	0.000	11.866	3.2.1.1	1,255.939	1,866.537	999.044	2,472.645
1.2.2.5	0	0.000	0.000	2.664	3.2.1.2	28,554.432	12,852.414	5,386.959	12,073.014
1.2.2.6	2.596	3.875	40.797	160.965	3.2.1.3	86.199	89.578	197.931	149.695
1.2.2.7	1.267	11.062	40.986	120.447	3.2.4	3,369.168	3,615.349	3,246.828	2,831.214
1.2.3	167.278	152.738	441.331	721.667	3.2.4.3	309.73	0.000	0.000	0
1.2.4	287.380	694.448	908.349	1,502.286	3.2.4.4	109.984	122.417	217.171	53.954
1.3.1	562.655	354.362	2,273.432	3,947.684	3.3.1.1	362.593	405.666	0.000	10.201
1.3.2	0	0.000	6.942	12.014	3.3.1.2	117.201	91.828	257.924	75.662
1.3.3	1,220.427	1,607.121	5,948.830	5,480.435	3.3.2.2	201.261	201.123	148.965	135.902
1.3.4	1,773.780	6,156.060	9,797.446	5,118.123	3.3.3.1	3.608	4.703	14.406	2.435
1.4.1	477.815	625.380	1,621.758	1,075.306	3.3.3.2	1.494	0.000	0.000	0
1.4.1.1	170.153	221.823	315.834	378.766	4.1.2	0	0.000	0.000	8.273
1.4.2	75.147	133.064	242.357	571.407	5.1.1.1	20.655	96.930	166.680	59.327
					5.1.1.2	118.259	157.575	76.385	111.402
					5.1.2.1	2,845.768	2,797.590	3,993.455	4,224.923
					5.1.2.2	72.823	214.436	2,381.315	3,069.461
					5.2.3	88,720.972	88,564.598	87,728.897	87,262.861
					Total	310,753.89	31,0753.63	310,753.83	310,762.22

Table 39: *Statistic classification of the area-size by classes per year*

The table above shows the change of single classes in detail. Trends mentioned above look different in detail because classes might have changed to others, e.g. low dense residential area developed to more dense ones. There were problems in detecting the correct use by visibility, especially in the earlier years. So far, a more specifically used area can be taken as a more common one in the historical years in order to be honest in the thematic resolution of the data-sources. Anyway, there are many specific changes, the most interesting ones will be analysed later.

4.2 Examples of the change by images

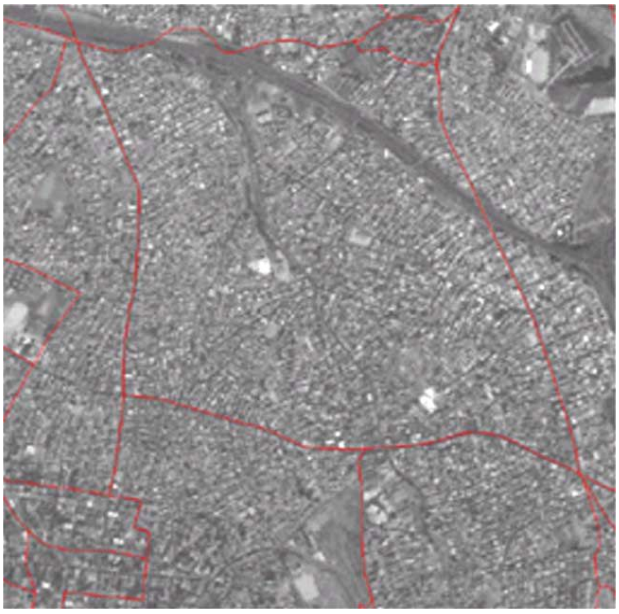
Since the foundation of the Turkish Republic, Istanbul has grown rapidly. Especially after the 40ies, this growth and the change of land use resulting from this phenomenon is enormous. This development is clearly visible on the imagery, which are presented in this chapter.

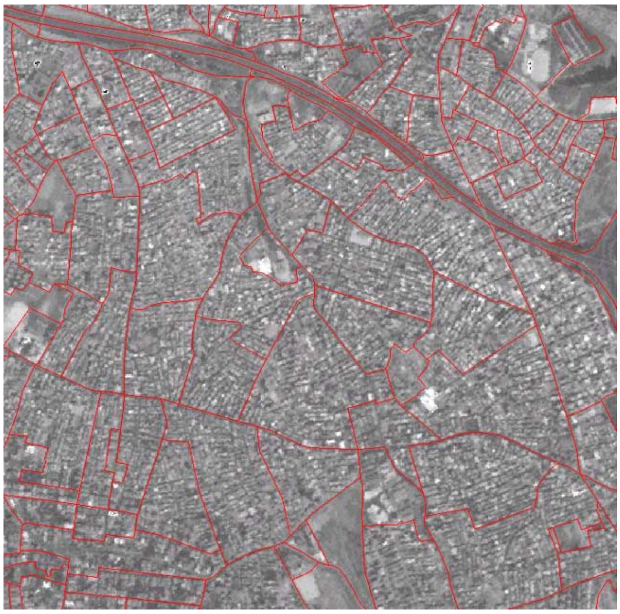
4.2.1 Change from agriculture to residential surface

All the agricultural surfaces in 1945 have a total size of 950 km², the residential surface counts to 65 km². In 2000, there are only 388 km² under agricultural use, but 485 km² under residential fabric. This shows the typical change of agricultural areas into urban settlements.

Figure 119: *on the left an Orthophoto of an area of agricultural use (class 2.1.2) in 1945. The polygons surrounding this area are shown in red.*

Figures 120 and 121: *The images below are IRS-Pan of the year 2000. The same area than shown before with the land use boundary in 1945 (left) and in 2000 (right), where new residential areas were built.*





Only few parts of the old geomorphological structures have remainined. The old rivulet can still be detected, the village-structure still exists and some of the old roads are used inside the residential area. All the other structures have totally been removed. Especially the highway cuts the former landscape without recognition of the former structure.

4.2.2 Change from agriculture to business surface

Dramatic changes can be seen in former agricultural land that was transformed into business areas like industrial, commercial and transport units. In 1945, business areas covered only 55 km² of the study area, in 2000 these were 370 km². In the example below, the motorway and its crossing represent the business area, where industrial areas of different use are neighbouring. This highlights the importance of the road network for business, much more than the poor public transportation system. Many industrial areas were built up simultaneously with the motorways.

Figure 122: *on the left an Orthophoto of areas of agricultural use (class 2.1.2) in 1945. The polygons surrounding this area are shown in red.*

Figures 123 and 124*:* *The images below are IRS-Pan of the year 2000. The same areas than before with the land use boundaries from 1945 (left) and from 2000 (right) where industrial surfaces and residential areas were established*

This example shows how former structure has been entirely replaced. Only some former roads inside the residential surface persist. These are usually not removed areas of older buildings where perhaps "difficult" structures are combined, e.g. a small mosque with a small unit size. In the lower left corner of the area a crossroad can be detected that was integrated into the actual street-network.

4.2.3 Change from forestry to urban surface

The loss of areas used by forestry is relevant for the oldest analysed period and might be even for the time before. Recently, the change is small, moreover, as already mentioned there is some growth between 1988 and 2000, based on land-use change from agriculture to forestry. Nevertheless, forestry areas have declined due to urban fabric. One example is shown below.

Figure 125: *on the left an Orthophoto of an area of forestry (class 3.1.3) in the year 1945. The polygons surrounding this area are shown in red.*

Figures 126 and 127: *The images below are IRS-Pan of the year 2000. The same areas than before with the land use boundaries from 1945 (left) and from 2000 (right) with residential use took place.*

As in the examples before, the landscape has changed totally; only in the eastern part of this example the forest area has remained. But also its structure has changed from an open, more sparely dense forest with included pastures and grassland in 1945, to a more closed structure today. The terrain plays an important role in this development. In the past the flatter terrain was used as agricultural land and is now replaced by the motorway, some business areas and partly by residences. The slope, facing to the southwest, carries the residential area, clearly visible in the IRS-Image. The rougher terrain, facing to the east and northeast, is still covered by forest. The urban fabric ends at the summit-line of the hills.

4.2.4 Changes at the coastline

Another example for land use dynamics in Istanbul is given by this analysis of the coastline. Constructions for land winning or filling the sea to gain land can be seen especially along the coastline of the Marmara Sea. This was not done like artificial marches, it was directly connected with constructive activities. Because of some necessities like roads, ports etc., lots of hectares were filled in order to gain usable land. Examples for this process can be detected on both sides of the Marmara Sea, the Asian and European one.

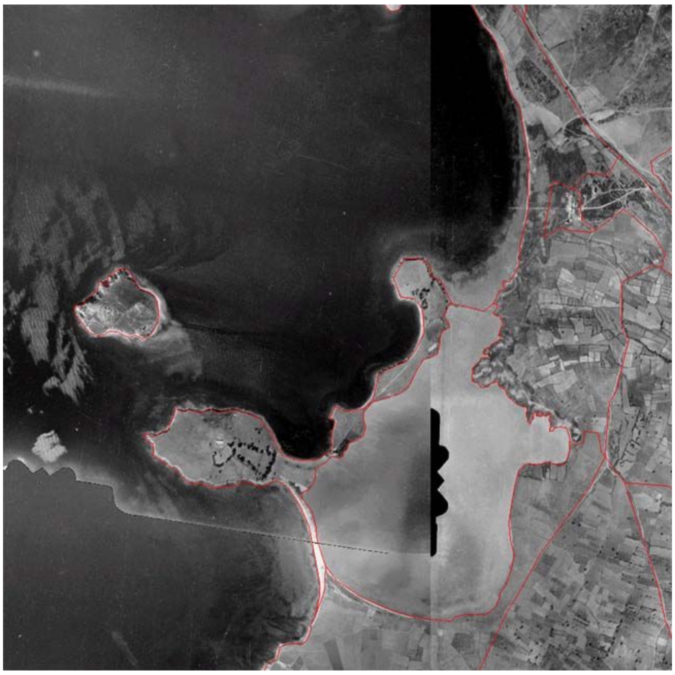


Figure 128: *on the left an Orthophoto of an area at the coastal line of the Marmara Sea on the South-eastern part from 1945*

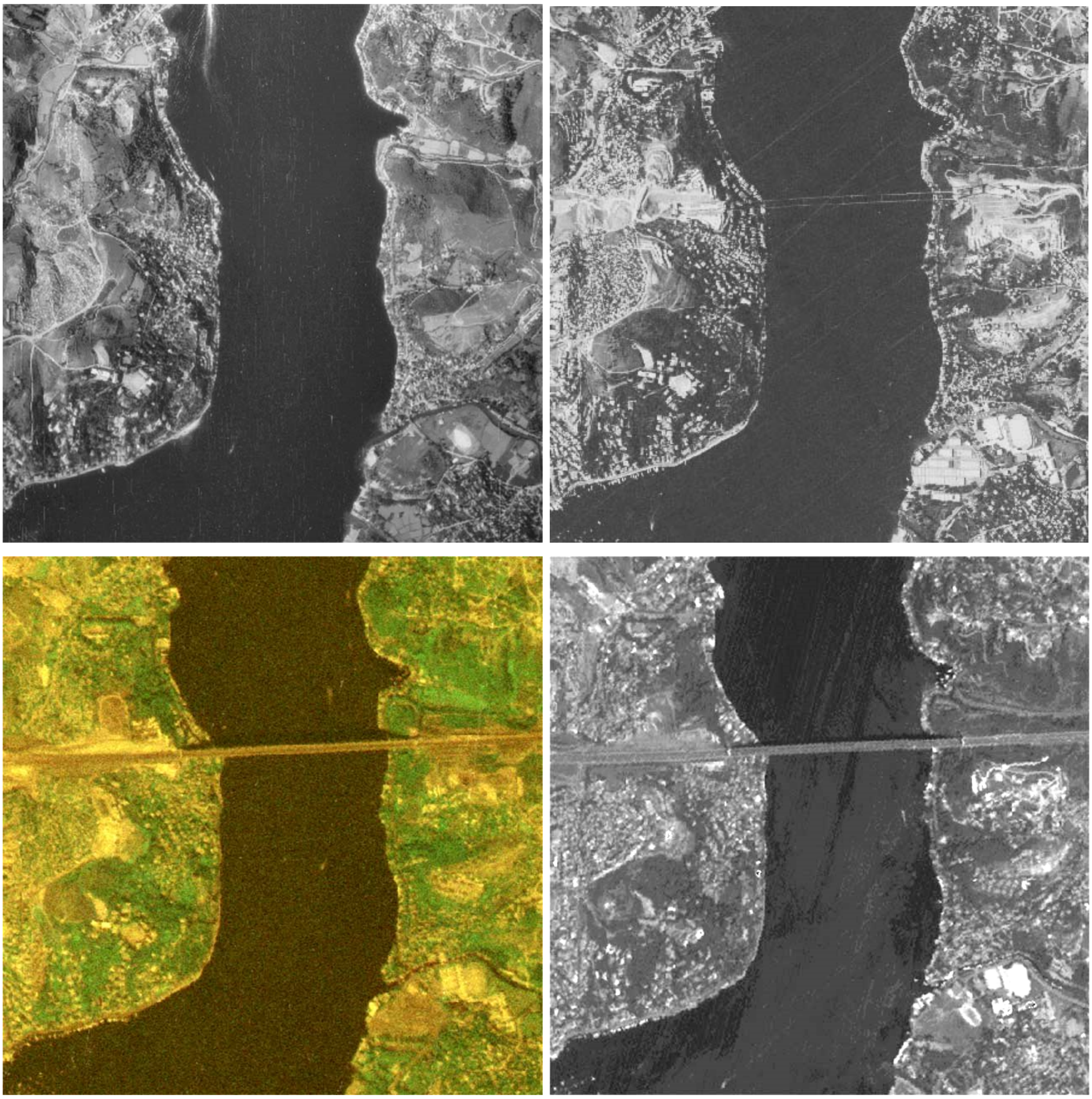
Figures 129 and 130: *The images below are IRS-Pan of the year 2000. The same areas than before with the land use boundaries from 1945 (left) and from 2000 (right) where port areas were constructed.*

This example shows, that under the actual surface, which seems completely artificial, a natural basis exists. The coastal cliffs and beaches were used for the establishment of port areas with related industry areas.

Those effects can be detected along the entire coastline. In many cases the small marinas of today were normal bays in the past. They were registered in the sporting facility class.

4.2.5 Changes in the transport-features; Bosporus Bridge

The Bosporus Bridge initiated a total change in the land-use. The Northern Bosporus Bridge, the Fatih Sultan Mehmet Bridge, was opened in the late 80ies. The photos show its growth:



Figures 131-134: *Top left the Orthophoto of the year 1942. Top right the KVR-Image of the year 1987, where the bridge was under construction. The catways are visible. Bottom left the KFA Image of the year 1988 where the bridge was nearly finished. The roads are still under construction. Bottom right the IRS image from 2000 with the today's situation*

The change in the residential structure took place between 1940 and 1987. For the construction of the bridge some related industrial areas were established (at the gates of the bridge and at the lower right corner of the KVR image) and, of course, there are the construction sites around the bridge and the connecting motorways visible. The construction of the bridges also transported the urban sprawl to the Asian side. While the residential surface was stronger in 1940 on the European side, it evolved to the same level during the construction period or even before.

4.2.6 Changes inside the residential surface

The residential structures also changed within the urban areas during the periods analysed. The following example shows a part of Üsküdar, placed on the Asian side at the mouth of the Bosporus to the Marmara Sea.

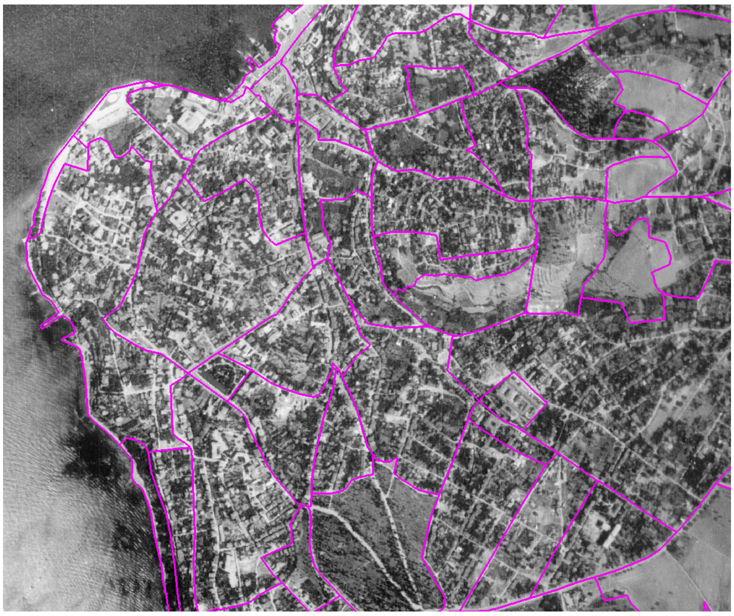


Figure 135: *on the left shows an Orthophoto of residential areas, placed on the Asian side on the Bosporus at its entry to the Marmara Sea in 1942*

Figures 136 and 137*: The images below are IKONOS MS of the year 2000. The same areas as before with the land use boundaries from 1942 (left) and from 2000 (right) where the residential areas were restructured and open spaces filled up.*

The former urban green areas and the free spaces were partly filled with buildings; the remaining ones are clearly restructured as urban greens, stronger than in the historical years. Density of buildings increased and the buildings became larger and higher. Some older structures containing small buildings were removed for residential blocks. Other structures were rebuilt in order to increase the number of flats. Changes in the coastline can by identified too: roads were constructed on areas of the former beach and docks for ships were established beside small marinas.

4.2.7 Changes at the costal lagoons

An extremely interesting example of urban change was detected near Büyückcekmece, where the former lagoon was dammed. The former village is placed in about 35 km distance west from the centre of Istanbul at the cost of the Marmara Sea.

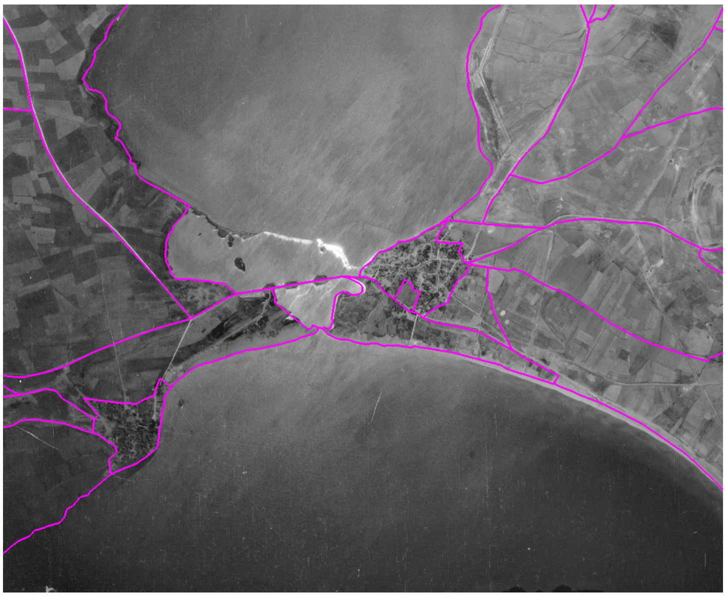
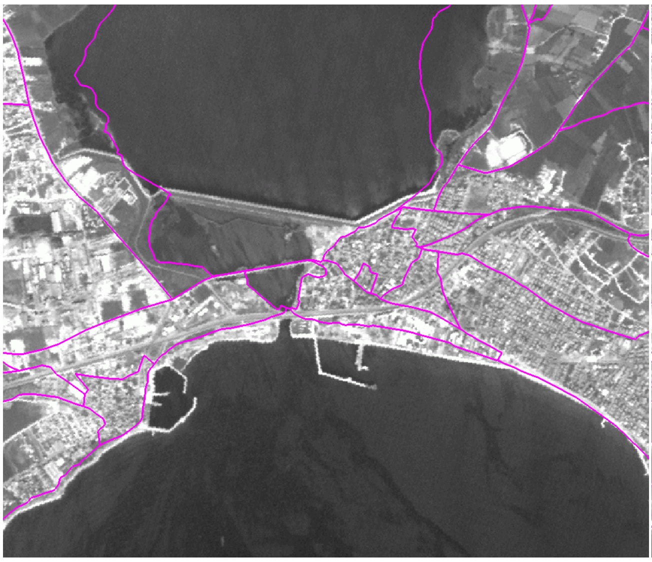
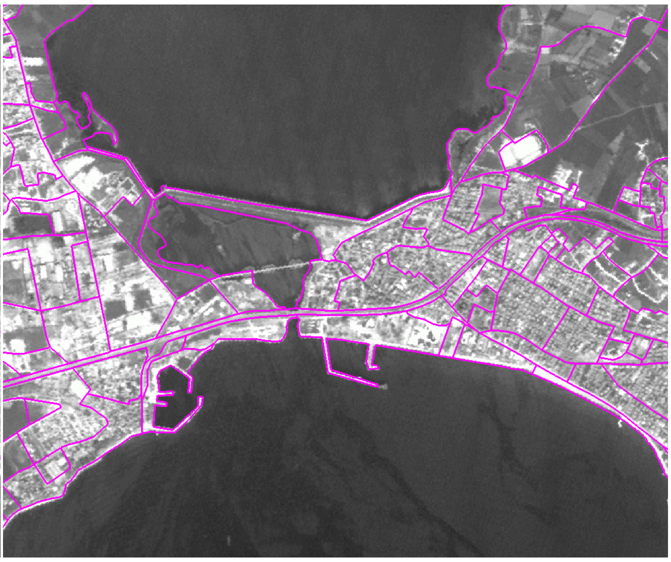


Figure 138: *on the left shows an Orthophoto of the 40ies of the Büyükcekmece lagoon with the 2 villages Büyükcekmece (right) and Mimarsinan (left).*

Figures 139 and 140*:* *The images below are IRS pan image of the year 2000 showing the same areas as before with the land use boundaries from the 40ies (left) and from 2000 (right) where the old structures are still visible*





In ancient times, the lake of Büyükcekmece was a river-delta, then a bay and finally a basin where the river meets saline water of the sea as a lagoon. This area was a typically rural one with plenty of arable land around the two villages of Büyükcekmece and Mimarsinan. The historical bridge from 1567, built by Sinan, was still in use during the 40ies. Since the dam cut the connection to the sea completely, the land-use structure changed.

Until the 1950ies, Büyükçekmece was a small village where people were involved in farming, vineyard growing, gardening, and breeding animals for producing milk and yoghurt as final products. Due to the construction of summerhouses and the appearance of a local tourism, an extreme change happened. The population of Büyükçekmece was about 1700 inhabitants and the population of its neighbour village Mimarsinan was about 1600 during the 1960ies. Today the larger area of the town accommodates more than 500,000 inhabitants; some of them just staying for the weekend.

4.2.8 Changes for the Water Supply

Due to the rapid growth of Istanbul, the supply of fresh water became an important task. The mountainous region especially on the Asian side offers suitable natural conditions for the use of such reservoirs. The following example shows the Ömerli Dam, constructed from 1968 to 1972. Its height is 52 meters.

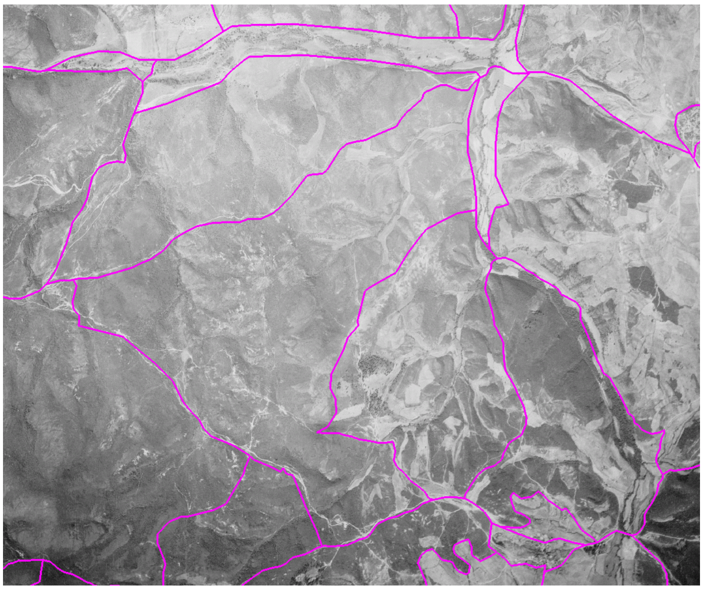
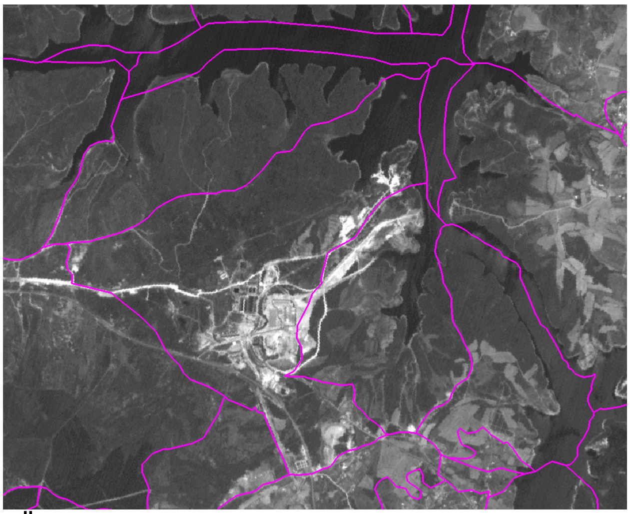
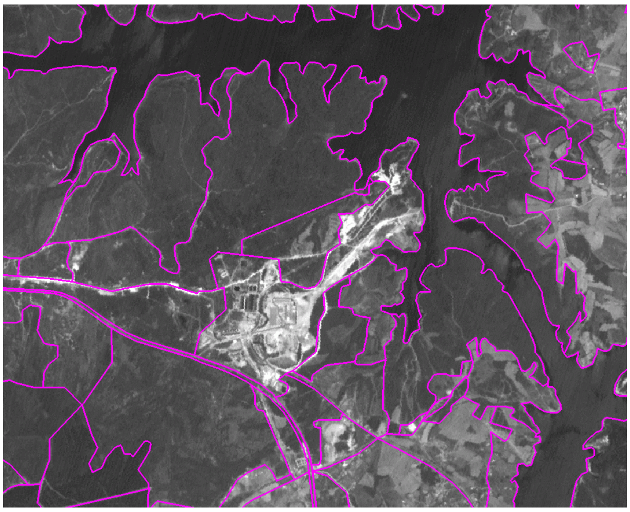


Figure 141: *on the left an Orthophoto of the 40ies with the area of today's Ömerli Dam covered by an open forestry and agricultural areas in-between. There are a small village in SE and some cottages.*

Figures 142 and 143*:* *The figures below are IRS pan images of the year 2000. They show the same areas than before with the land use boundaries from the 40ies (left) and from 2000 (right) The Ömerli dammed lake fills the valley and the agriculture areas got lost. The forest became denser on the remaining places and industrial plants were established.*





Ömerli Dam, located NW of the village Tepeören, is the main water supply of Istanbul. The rivers Riva, Degirmen, Koyderesi flow into it. The embankment type of the dam is filled with earth and its volume is 2,198,000 m^3. It supplies Istanbul with 180,000,000 m^3 of water annually, and over 900,000m^3 of water per day. It is important to keep the water as clean as possible since it affects directly the health of Istanbul citizens. The Ministry of public works decided that the valley should be preserved according to the Ömerli Drinking Water Basin Environmental Protection Plan, which was accepted on 13th August 1984.

Domestic and industrial wastes are released into the basin from the increasing number of buildings around, which release sewer water into the lake and the nearby factories, which seem, as they are unaware of the regulations that require filtering and screening of wastes before they are deposited. There are also some plans to build a runway or to open the basin for development and construction of public facilities, which means more population, legalization of the current buildings with the addition of more buildings and more factories. ISKI, Istanbul Water and Sewage System Management, has some restrictions on these kind of zone issues but it is not very determined to apply the rules and exceptions are made which harm the basin.

4.2.9 Changes around the Atatürk International Airport

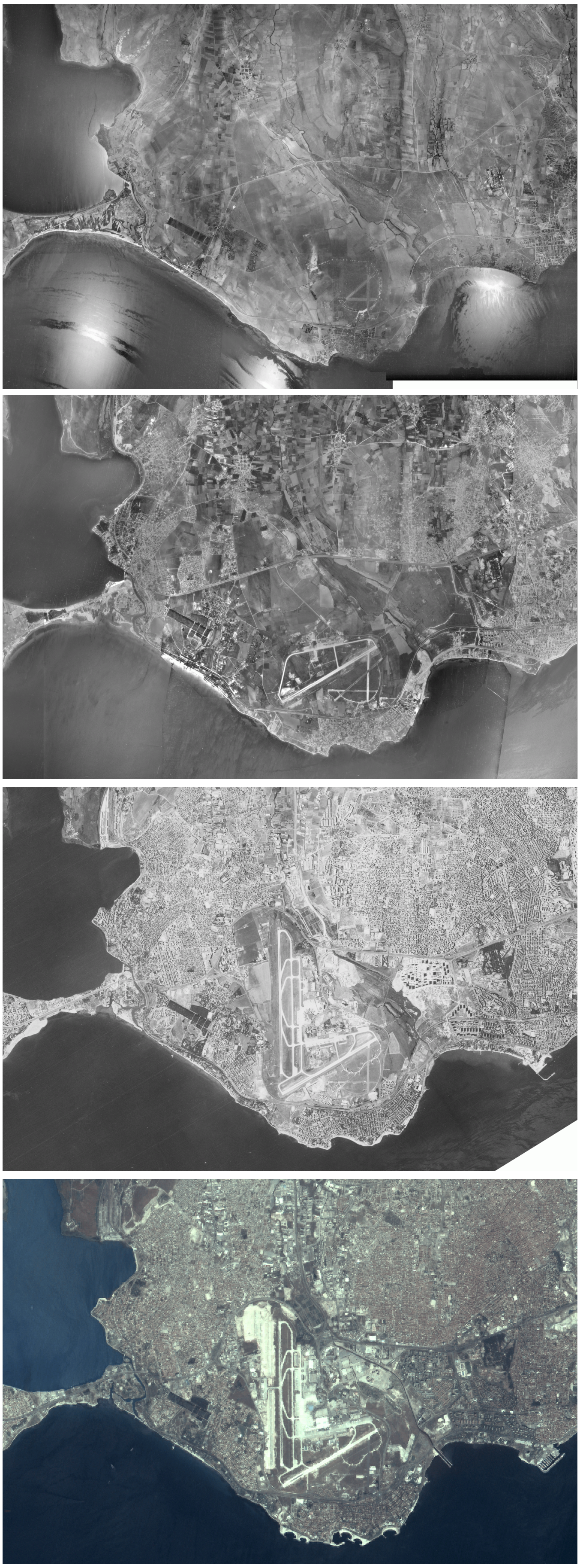


Figure 144 and 147*: from top to bottom the Istanbul International Airport (Atatürk Havalimani) with its surrounding. On top is an image from the 40ies, ahich shows the small airfield in a rural area. The image of the year 1968 shows a small Airport with a growing infrastructure. In 1987, the structure has already changed dramatically. In 2000, the open spaced land was filled up and the coastline modified.*

The international airport of Istanbul, located 15 km southwest of downtown on the European side, was named after the father of modern Turkey, Mustafa Kemal Atatürk. Istanbul's Airport is Turkey's largest and busiest one. All international Airlines offer regular flights to Istanbul. Turkish Airlines (THY), has regular direct flights to major European and Asian cities. In 2001 another airport, Sabiha Gokçen International Airport, was opened at Kurtköy on the Asian side of the city, though most flights still arrive and depart from Atatürk.

The Atatürk-Airport is an important knod-point in the international network of most airlines. The new terminal building was constructed with respect to the earthquake risk of this area. A special construction protects the glass-roof against damage from EQ-shocks. Public transport to the city is poor; just one tramline connects the airport with the city. The railway passes the airport and cars or busses solve transportation needs.

While the airport in the 1940ies was just an airfield, it changed until 1968 when the first international airport was already opened. Still far outside of Istanbul, the area around remained rural and the airport small. The villages grew slowly and some industry areas were established. This changed dramatically in the period to 1988, where the airport got its actual boundary. Almost the entire area around became urban fabric with a very dense structure. In the last period, this development was completed; the area is more or less filled entirely by urban fabric. The coastline starts to develop with new land and harbours.

4.2.10 Changes in pit mining activities

The rapid growth of the city correlates with the mining activities NE of Istanbul along the Black Sea coast. Strong changes can be seen in this area due to open mining activities. On the geological map Pliocene sediments containing continental deposits like gravel, sand, clay, peat, and coal can be detected. Consequently, we can also identify Cretaceous sediments containing lava, tuff, volcanic breccias interbedded with limestone. This area is intensively formed by activities like coal-mining and digging for winning constructions materials.

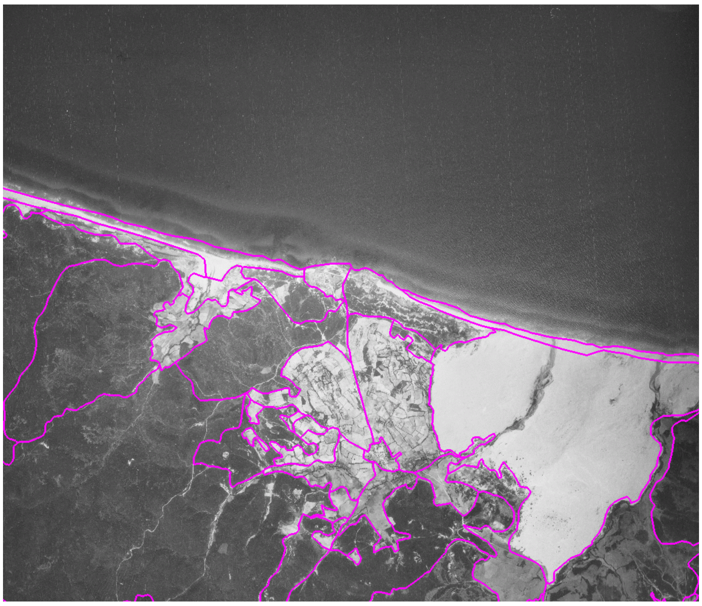
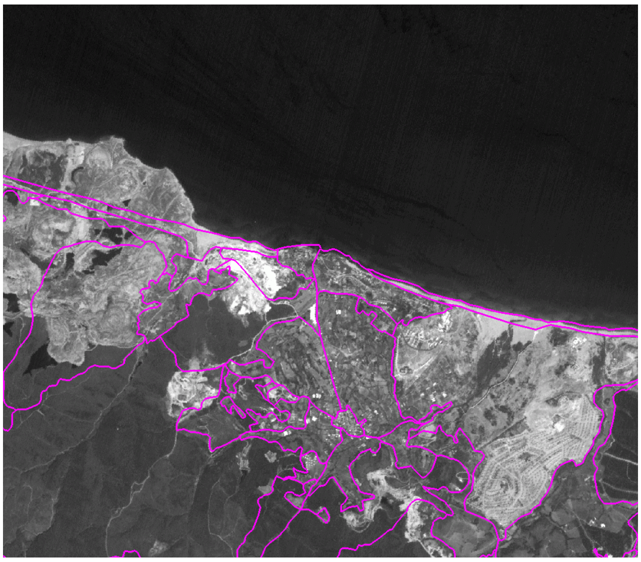
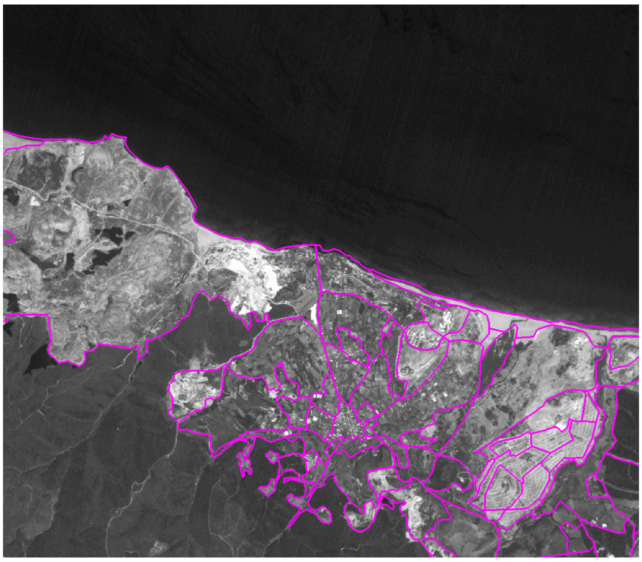


Figure 148: *on the left an Orthophoto of the 40ies of the Black Sea coast NW of Istanbul with the upcoming mining activities.*

Figures 149 and 150*: The images below are IRS pan images of the year 2000. Same areas than before are shown with the land use boundaries from the 40ies (left) and from 2000 (right). The landscape surface as well as the coastline has changed due to mining activities*





The mined areas already changed in some parts to urban fabric, the others are usually afforested. Remarkable is the change of the coastline due to the deposing sites around the mines. Even lakes, filled with groundwater or penetrating seawater, arose in some parts of this area. It is not really clear what was mined in these geological formations. In some cases, coal can be found, but not in a sufficient quality to a larger extend. These Pliocene Sediments might be suitable for gravel and sand that can be extracted for various materials supporting construction activities, probably the most important economic factor. On the nearby formations, cretaceous sediments, limestone for cement-production is of great importance. This correlates with the construction activities in Istanbul. These limestones-sediments are underlying the Pliocene ones; so far, they are mined below for cement-production.

5 Spatial Statistics and Combined Analyses

The following chapter demonstrates spatial analyses of the change using distribution and temporal algorithm for tend-computations. Those data are related to spatial and non-spatial statistical methods in order to highlight the trend. They were mainly prepared in MS-Excel. In order to focus on main actions, only common groups of the analysed classes were studied. We can understand well how the different classes within a group changed during the analysed periods.

Other information were integrated in order to get more detailed and related datasets, i.e. the ancillary information where the mainly demographic data became the most important correlator. Effectivity and limits of such combined analyses will be demonstrated by using examples. Especially in the mixed analyses, the problem to compare non-spatial data with spatial information was done using estimated factors to transfer these information into regional datasets.

5.1 Changes in artificial surface

Artificial surface is defined as the combination of industrial or business areas and residential surface. It combines the classes 1.* with exception of urban green, abandoned land and mineral extraction sites, finally, all the areas where human activities have changed the surface with constructive elements. This gives a good overview about strongest growth of the cities. The following image shows this changing situation.

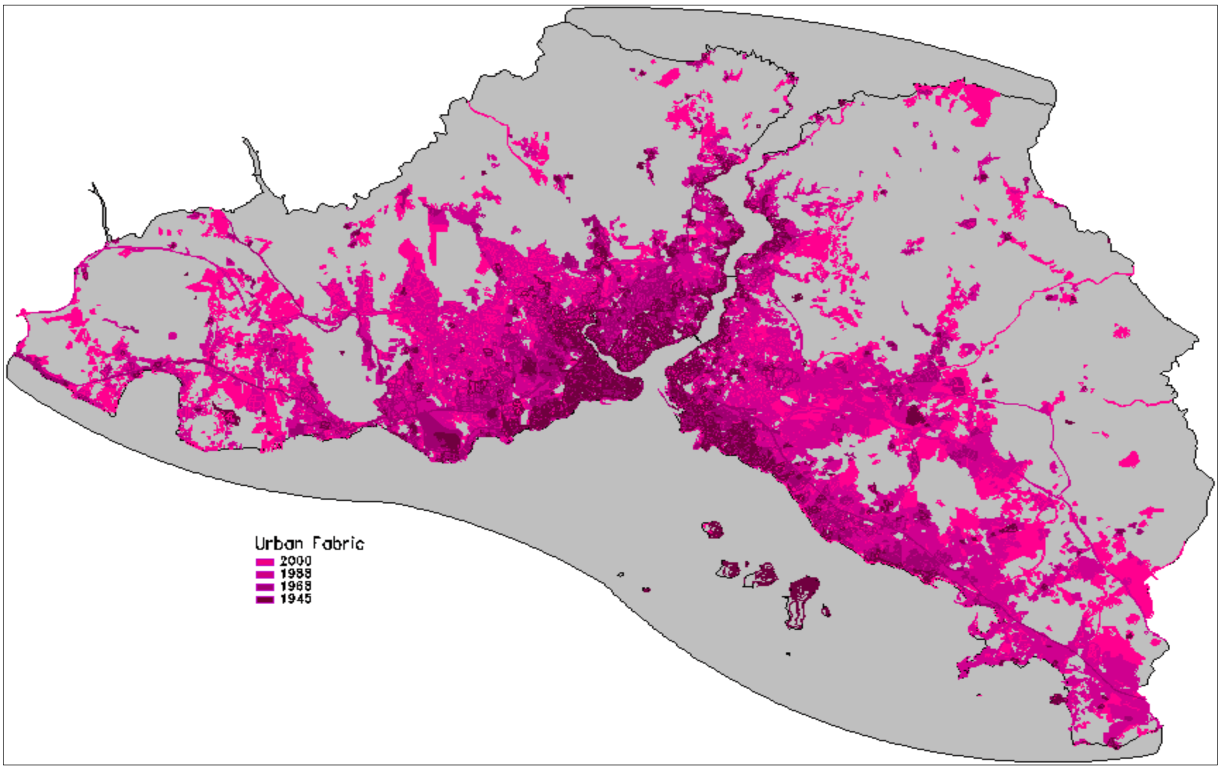


Figure 151: *Growth in artificial surface from 1945 to 2000*

Obviously, the development axes along the Marmara-sea are clearly visible. In 1945, more than 80% of Istanbul's artificial surface was situated on the European side. By constructing the first Bosporus Bridge, urbanisation crossed over to the Asian side and initiated a big growth in the artificial surface. The growth-rate between 1968 and 1988 was very high and reached more than 4% per year. This leads to the fact that the growth on the Asian side, is dramatically high.

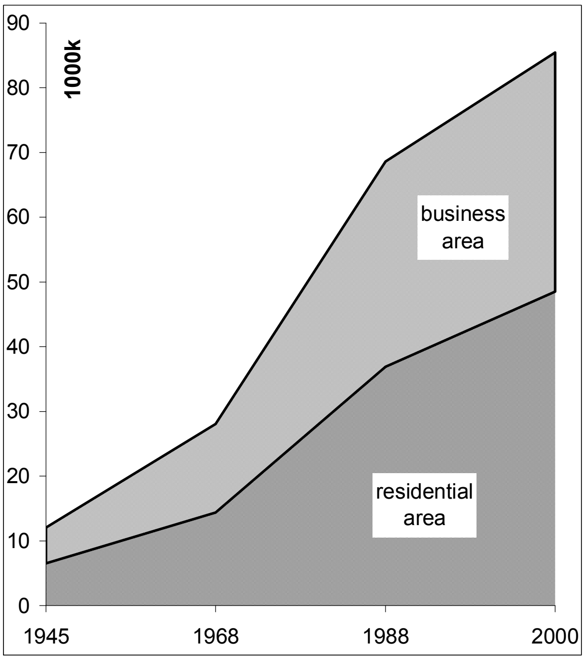


Figure 152: *urban sprawl of residential surface in relation to business ones*

The sprawl of residential and the business areas are similarly strong. The most severe changes happened between 1969 and 1988 because the first bridge was finalised and the second one was already been under construction. This effect was superimposed to the global urban growth in these times. Also in the period before, urban growth showed a high degree as figured out in table 40. After 1988, the urban growth-rate slowed down similar to other cities.

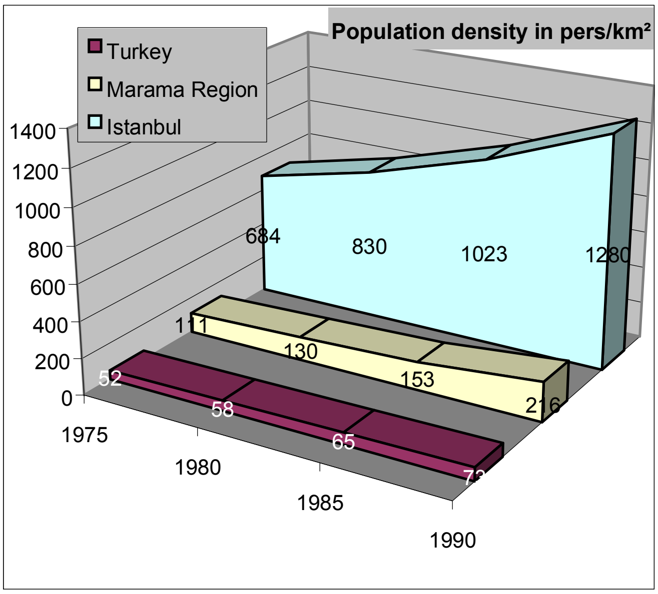
A problem in these analyses is in the unequal length of the periods; so far, the graphic shows different information. For this reason, also the annual urbanisation-rate was computed like as shown in the table below.

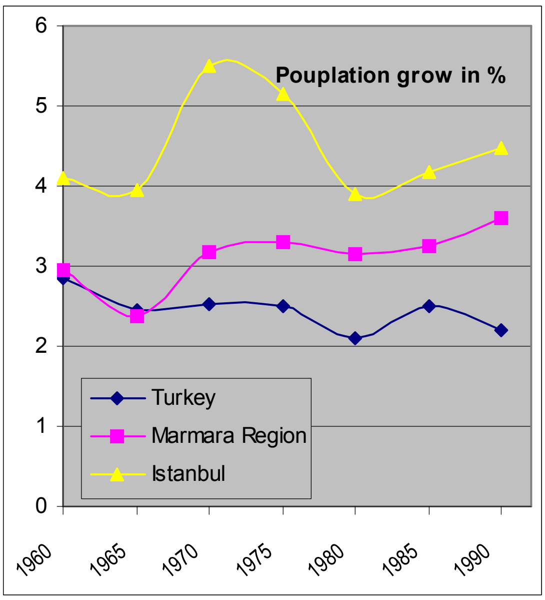
	1945-1968	1968-1988	1988-2000
Sprawl in residential areas	3.49 % per year	4.82 % per year	2.31 % per year
Sprawl in business areas	4.01 % per year	4.31 % per year	1.28 % per year

Table 40*:* *annual urban sprawl rate for the two groups*

5.1.1 Changes in residential areas

To get a more profound knowledge about the changes of urban surfaces, analyses of the residential areas by their different groups related to the demographic development has to be performed. The following figures show the development of the population density and the population growth of Istanbul related to the Marmara region and entire Turkey. Figure 153 shows a big impulse between 1965 and 1980, which caused the increase of residential structures. Density is about 6 times higher than in the Marmara region and more than 10 times higher than in Turkey. Density is growing on a high level.





Figures 153-154: *Statistics about the population growth and population density (State Institute 1998)*

However, this is a common statistic without a sharp definition of the study area (either Istanbul province or the city border) and its inhabitants. Population density is computed all over the area of different use. In Figure 154 the population growth rate between 1960 and 1990 is displayed. All trends are positive and relatively high related to Europe. While the trend for Turkey in total is negative (from 2.8 to 2.2), the Marmara Region is positive on a higher level and Istanbul with an positive trend on a very high level too. In the mid of the 60ies, many workers left Turkey to work in Western Europe; this fact might indicate the small depression in the curve around 1965. More emigrants from eastern Anatolia went directly to Europe especially to Germany and France instead to the Marmara Region and Istanbul. This trend changed at the beginning of the 70ies, while industrialisation and strong investment into the business areas took place and attracted workers to come to Istanbul again. In this period, many immigrants from abroad came to Istanbul. This can be seen from the growth of residential areas during this period. However, we have to be careful with absolute figures regarding the numbers of inhabitants and the population density. The statistics related are not properly defined and the sources differ. Figure 155 shows the sprawl of the residential areas during the periods first:

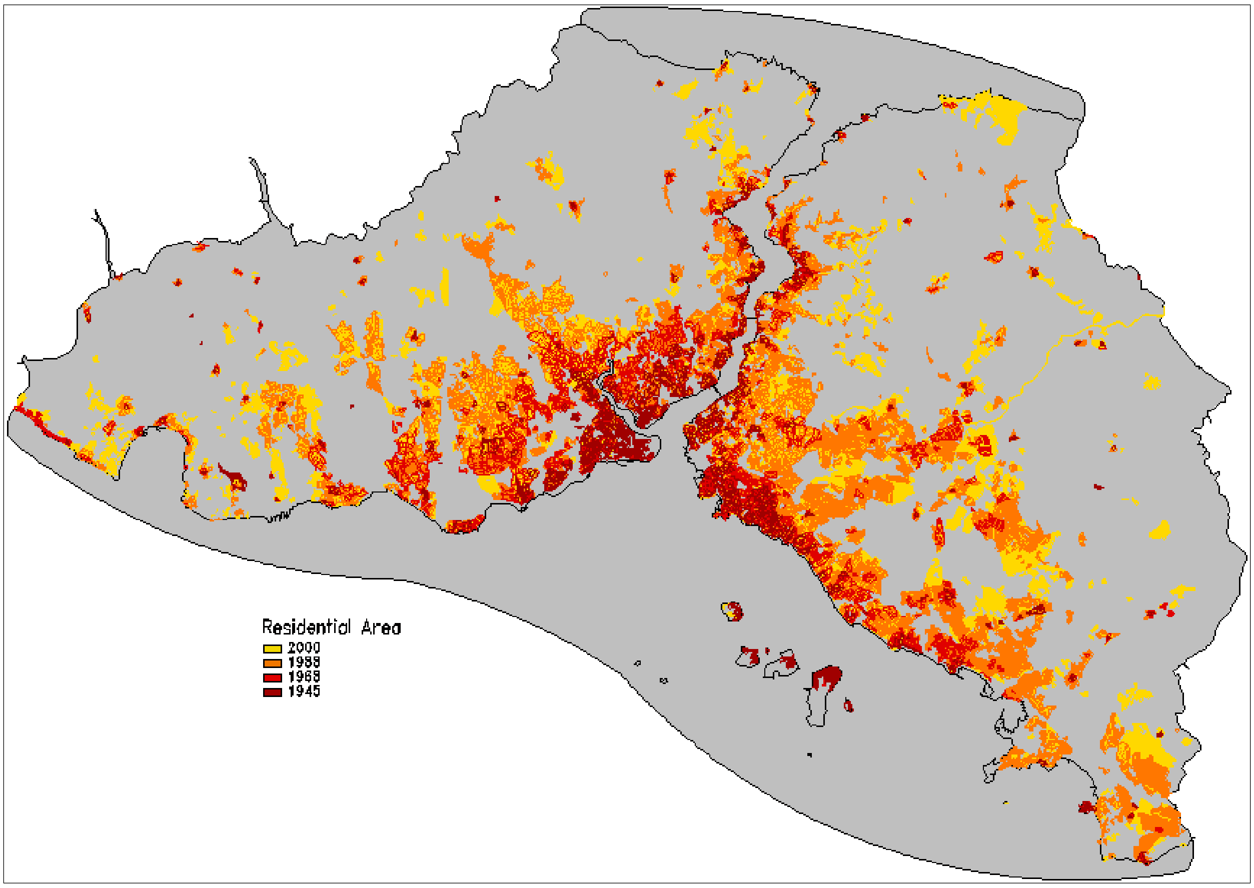
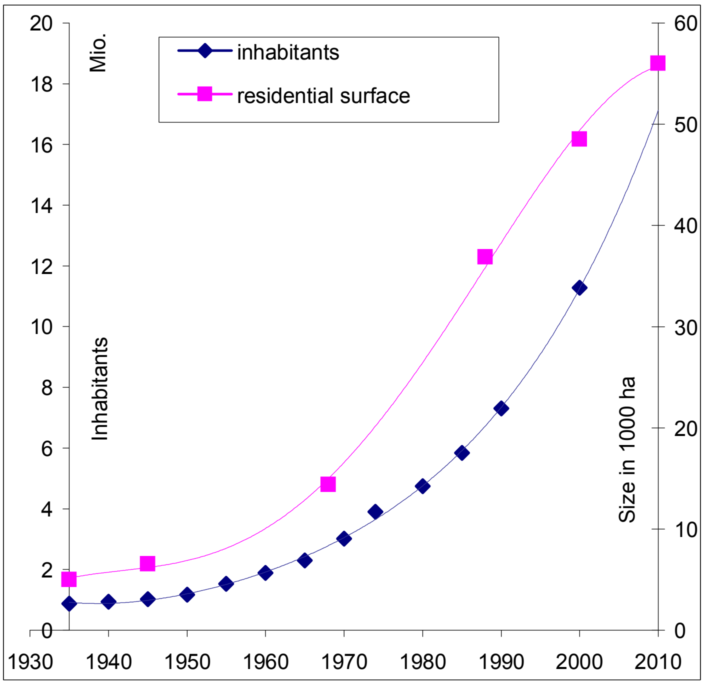


Figure 155: *Increase in residential fabric from 1945 to 2000*

In figure 155, the classes 1.1.1.1 to 1.1.2.4 are analysed jointly as residential. The increase in residential fabric is amazing. The development of the city on the Asian side seems stronger than on the European one. Especially when taking the size during the 40ies into account, the Asiatic side grew enormously. The strongest growth can be seen between 1968 and 1988, especially east of the Bosporus and along the coast of the Marmara-Sea, where completely new quarters of the city were founded. While the European side mainly grew between existing structures as a kind of "filling up existing axes", the Asian side grew more homogenously in large areas. This might be the result of competition between residential and business areas, which is on the European side stronger than on the Asian side. Further on, the terrain plays an important role due to its limitation for settlement. The northern part of Istanbul, which is mostly covered by forest, is mostly a very hilly terrain with big slopes that limits to build an infrastructure. The southern parts have a flatter relief, which in the past was used for agriculture.

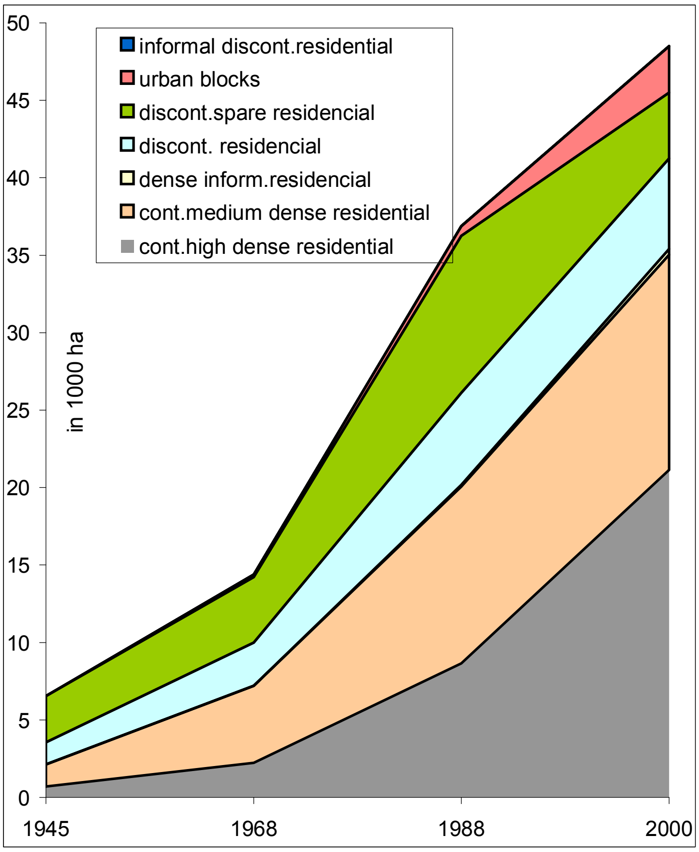
The Asian side is has larger areas that were changed into artificial fabric. This could be another indicator for the unequal development.



To compare the growth of the residential surface with the population of Istanbul, the following trend-analyses were done. In case that the census-data are not from the same year as the land-use data, the points represent the values and the line is computed as a polynomial trend by the 4th degree. Some points were computed by the growth-rate, documented in the different statistics of the State Statistic Institute. This kind of analysis enables us to point out the relation between both, surface structure of residences and growth of number of inhabitants.

Figure 156*: Relation between growth of inhabitants and increases in residential surface (own data and by state-institute 1998)*

The population grew similar to the artificial surface. Between 1945 and 1988, the increase of residential areas was stronger than the population growth. Since 1988 the population increase is stronger than the residential surface, this leads to a growth of the population density. This is the result of the strong population growth and the increase of illegal settlements with low density at the beginning of the 60ies. With their legalisation in the late 90ies, the Gecekondu areas changed to multi-storeyed buildings. The density in those areas increased dramatically. This is visible in the relation of the different residential classes.



Growth inside the residential surface was not homogenously. Strong growth can be seen in the high dense classes, especially after 1988. All the classes grew up to 1988, after then class 1.1.2.2 lost in size. This might be a result of former legalised Gecekondu areas, which then changed to high-density classes by rebuilding the surface. Strong growth started in the urban blocks after 1988, which can be the result of an upcoming planning. The informal settlement is not represented correctly for two reasons: it is difficult to detect them on the imagery and to separate them from other classes.

Figure 157: *The growth of residential surface of the different classes*

Secondly, they are usually legalised some years after and fit into other classes without change of the building structure. So far, Gecekondu areas are temporal surfaces, which mainly changed from 1.1.2.4 to the classes 1.1.2.2. It is important to keep the specifics of this class in mind, when discussing informal settlement. For extracting trends inside residential areas, it is suitable to do further trend-analyses by polynomial regressions.

These trends, however, are obviously oversized and point out what can be seen as the most important change. Growth of the class 1.1.1.1 (continuous high dense residential) is enormous and will continue. Not only the size increased, the growth-rate went in parallel. A reduction of the increase can be seen in class 1.1.1.2 (continuous medium dense residential). After 1988, an increase in urban blocks (1.1.2.3) took place. A decrease can be seen in the class 1.1.2.2. (discontinuous spare residential). In future those areas will be limited to villas of rich people. Also the class 1.1.2.1 (discontinuous residential) shows a decrease. Summarising the results, the trend goes to high dense urban fabric and therefore to higher population density in residential areas. This means that residential structures become denser and the number of flats is going to increase.

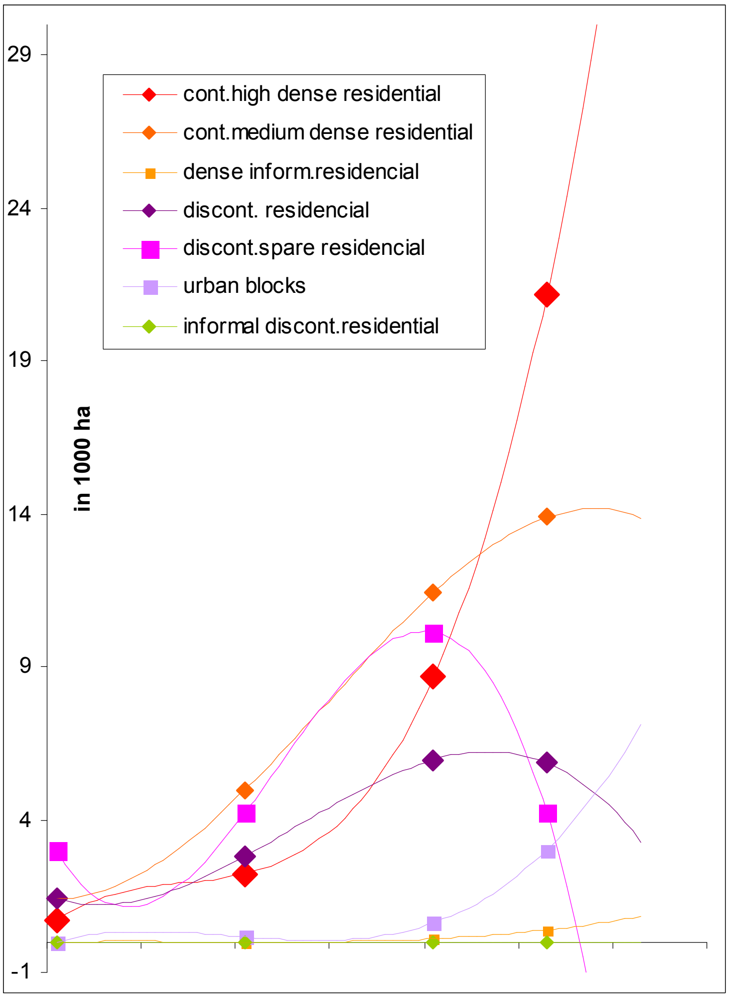


Figure 158: *Growth of residential surface by different classes as trend-analyses using polynomial 3rd degree regression between 1945 and extrapolated to 2010.*

In order to produce a map of the specific population density it is of special interest how the different residential areas relate to the number of inhabitants. Such kind of data are not available since the already described problem of combined temporal spatial data with demographic non-spatial sources exists here. Several steps of pre-processing and assumptions were done to enable the following analyses.

MOLAND Level 3	MOLAND Level 4	Weight
Continuous urban fabric (class 1.1.1.*)	Residential continuous dense urban fabric (class 1.1.1.1)	3.0
	Residential continuous medium dense urban fabric (class 1.1.1.2)	2.0
	Informal settlements (class 1.1.1.3)	0.8
Discontinuous urban fabric (class 1.1.2 .*)	Residential discontinuous urban fabric (class 1.1.2.1)	1.2
	Residential discontinuous sparse urban fabric (class 1.1.2.2)	0.9
	Residential urban blocks (class 1.1.2.3)	2.5
	Informal discontinuous residential structures (class 1.1.2.4)	0.5

Table 41*: the importance and resulting weighting-factor of inhabitants for the different residential areas*

It is assumed that specific classes of one year have equal distribution of inhabitants. Another assumption was done in that way that the different classes keep their relation during all periods. In this way, weights to each class were given which define the relation to each other. This was done by qualitative estimations based on local knowledge. The absolute value is not important; just the relation between them is of interest. Therefore these parameters are semi-quantitative. The applied weights are documented in table 41.

In a next step, the number of inhabitants for the analysed land-use data had to be detected. This can be computed by the growth-rate, which itself can be calculated out of different statistical data. Relevant data are available in the statistic handbook of Turkey and on the web-site of the Turkish Institute for Statistics.

Year	Turkey		Istanbul		Ratio Population Istanbul/Turkey [%]
	Population	Annual Growth Rate [%]	Population	Annual Growth Rate [%]	
1923	13,219,000		796,000		6.02
1927	13,648,000	0.80	822,000	0.81	6.02
1935	16,158,000	2.13	878,000	0.83	5.43
1940	17,821,000	1.98	941,000	1.40	5.28
1945	18,790,000	1.06	1,021,000	1.65	5.43
1950	20,947,188	2.20	1,166,477	2.70	5.57
1960	27,754,820	2.85	1,882,092	4.90	6.78
1970	35,605,176	2.52	3,019,032	4.84	8.48
1980	44,736,957	2.31	4,741,890	4.62	10.60
1990	56,473,035	2.36	7,309,190	4.42	12.94
2000	67,844,903	1.85	10,033,478	3.22	14.79

Table 42*: Population of Turkey and Istanbul and computed growth-rate (State-Institute for Statistics)*

Recalculating the weighted size of the different areas in combination with the number of inhabitants, the density for each land-use area digitised in the project was computed. By an iterative validation, the values of the weighting were re-observed in order to receive reliable and realistic values. Small changes in the weighting parameters did not change the result significantly. The result shows the density of the population for the different years as shown in the following maps.

At first sight, this map shows a similar distribution of the population density than the maps with the different residential classes because the weighting correlates them. In detail it might be visible, that the colours representing the density of population, differ throughout the years. This phenomenon was already visible during the validation of the weighting in relation to the size of the different residential land-use classes and the population. By changing the weight-values, the result of the calculation delivers modified number of people per flat during the years. In order not to stress these values too much, the result can be interpreted in semi-qualitative way.

The size of the denser residential fabric grew and the number of its population decreased with the change inside these classes. This effect is smaller than the principal increase of those dense classes; however, it shows the increasing space inside the residences needed by the inhabitants. The number of small families, single-households, and amount of second flats has grown during the last 20 years. Compared to well-developed western countries, this effect is smaller but in any case clearly detectable. This also corresponds with personal experiences due to the visits in Istanbul. It is a well known common social development and also described in literature. The multi-generation families disappear in Turkish cities while on the countryside they are still common. Istanbul as a modern city has nearly completely lost these structure. This means that Istanbul is influenced by two mechanisms of urban growth: the strong immigration to Istanbul and the need of more space for small and single households as well as double households. This initiates new settlements for weekends on the periphery of Istanbul, as already mentioned by the example of Büyükcekmece in chapter 4.2.7.

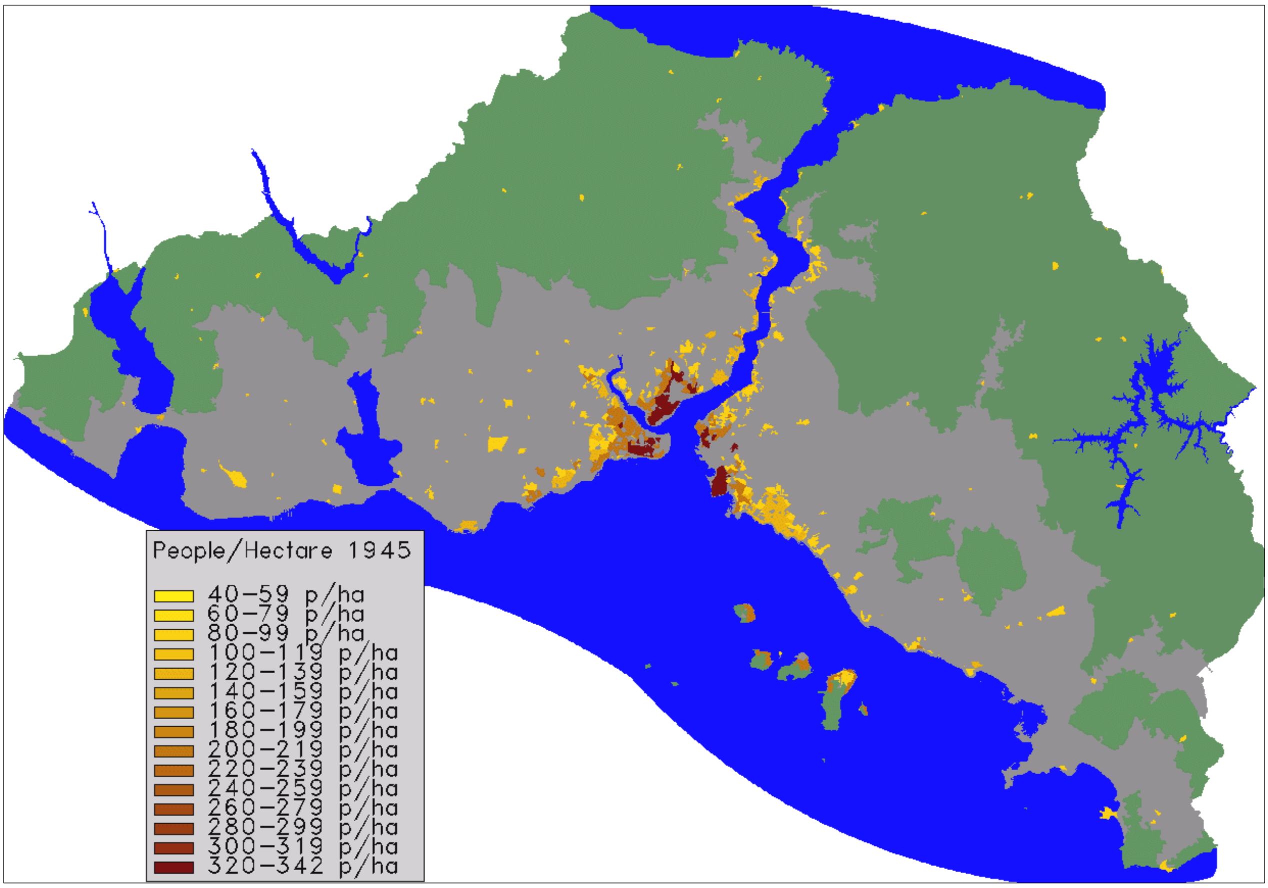


Figure 159: *Computed population density for the year 1945, based on statistics and assumptions.*

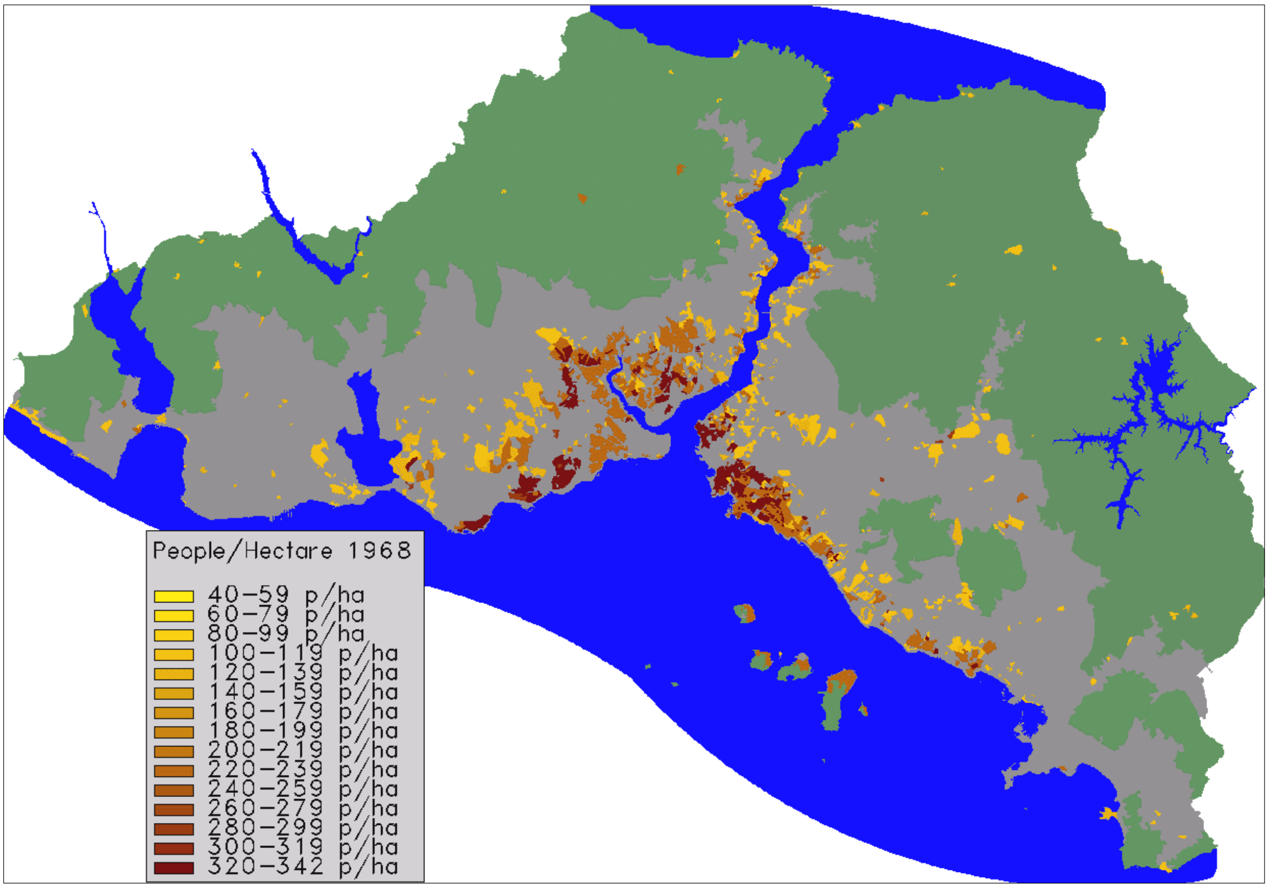


Figure 160: *Computed population density for the year 1968, based on statistics and assumptions.*

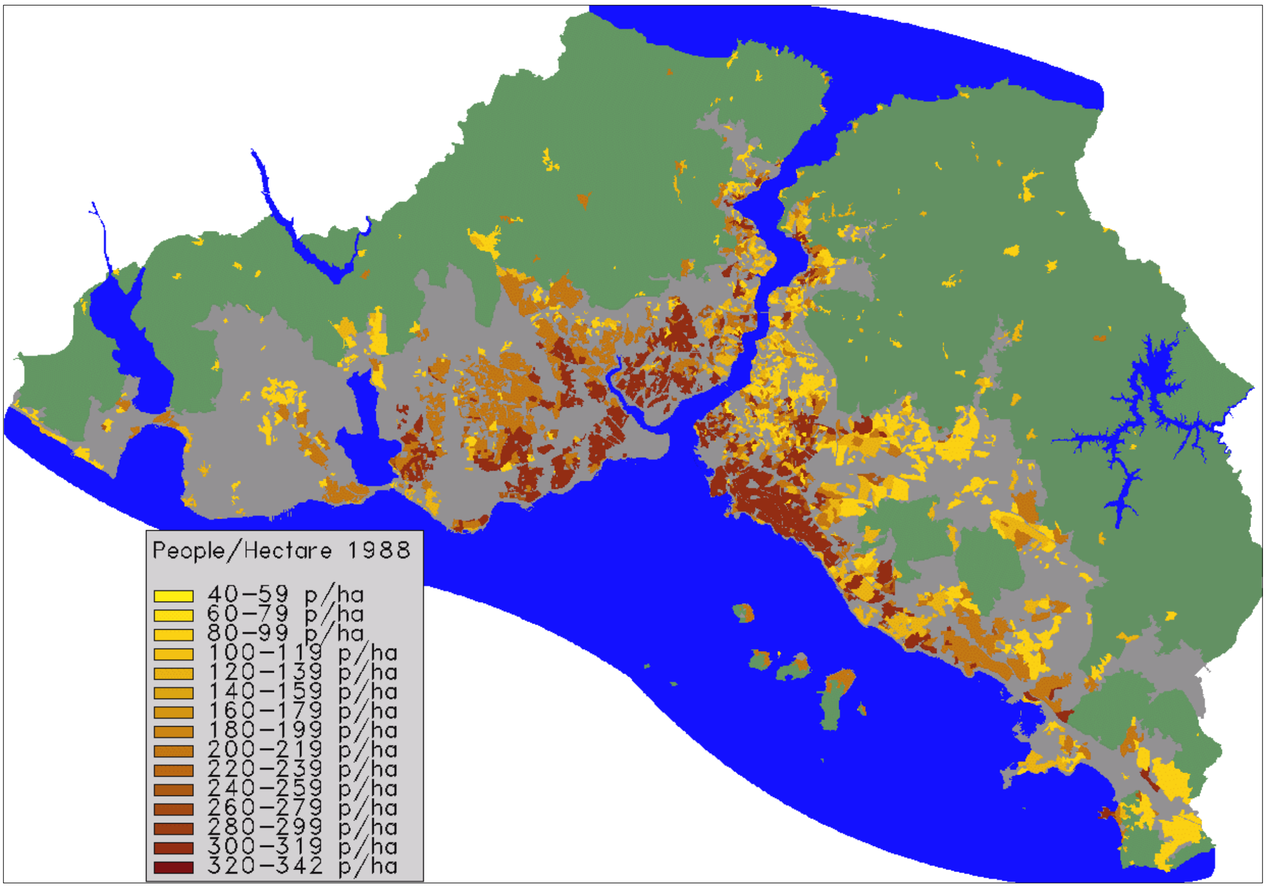


Figure 161: *Computed population density for the year 1988, based on statistics and assumptions.*

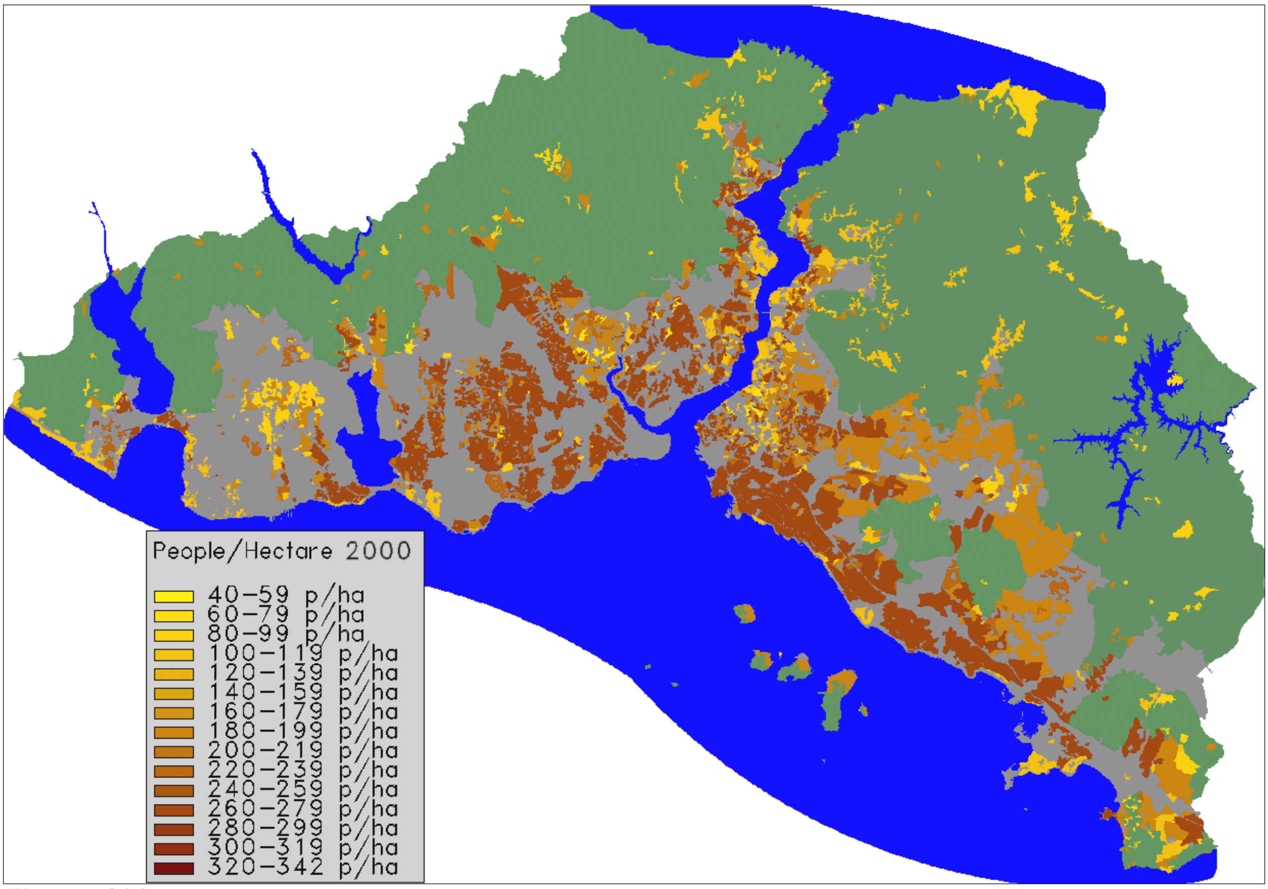


Figure 162: *Computed population density for the year 2000, based on statistics and assumptions.*

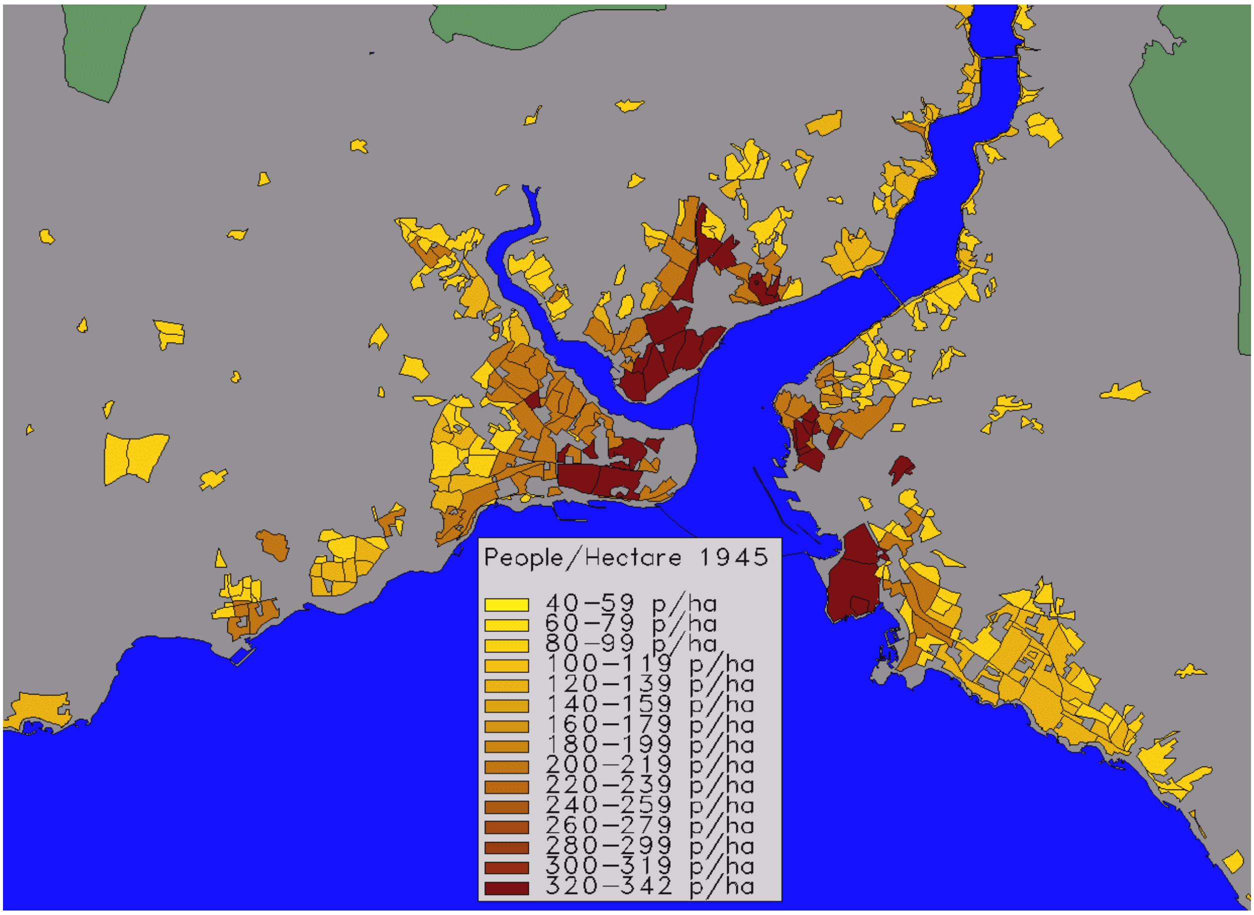


Figure 163: *detailed map of the population density of Istanbul's centre for the year 1945*

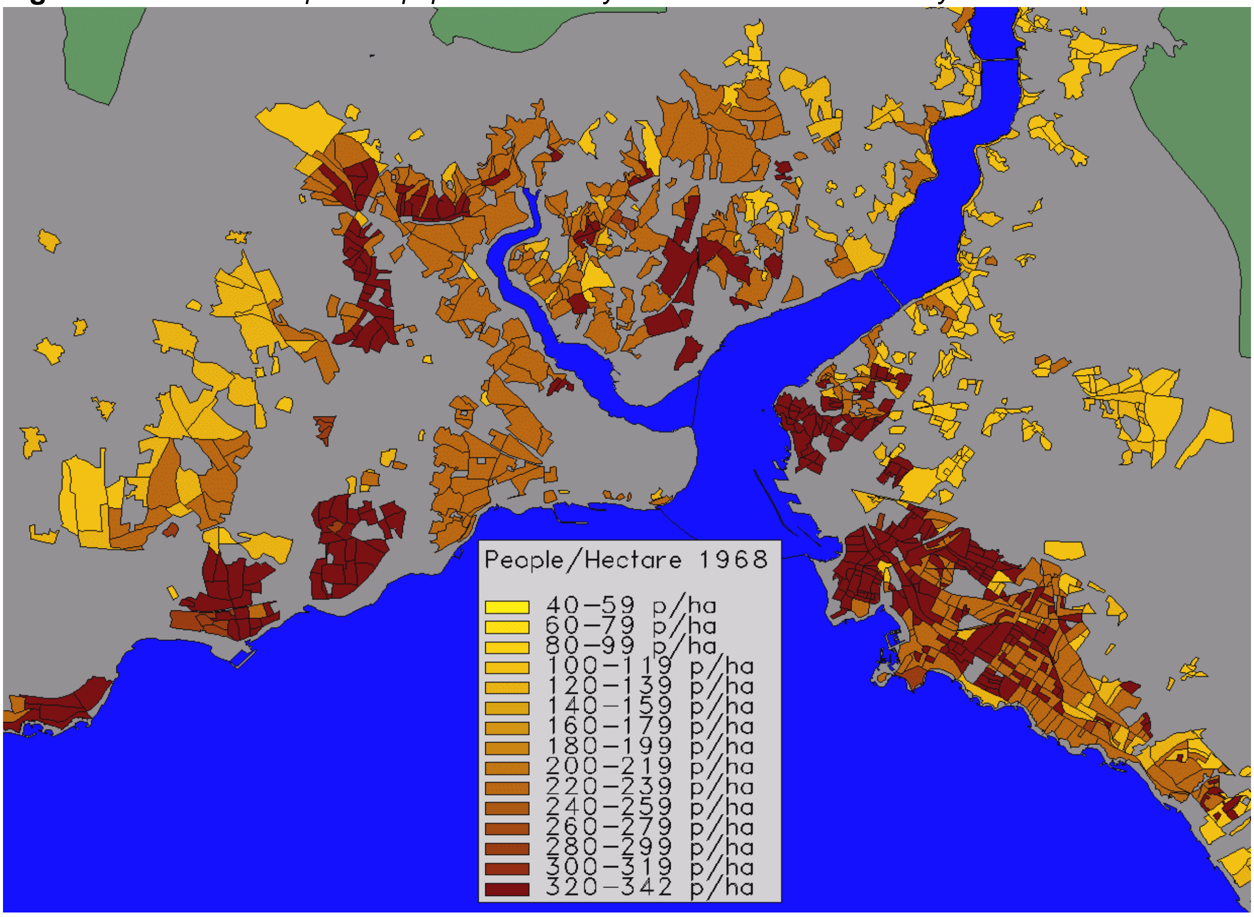


Figure 164: *detailed map of the population density of Istanbul's centre for the year 1968*

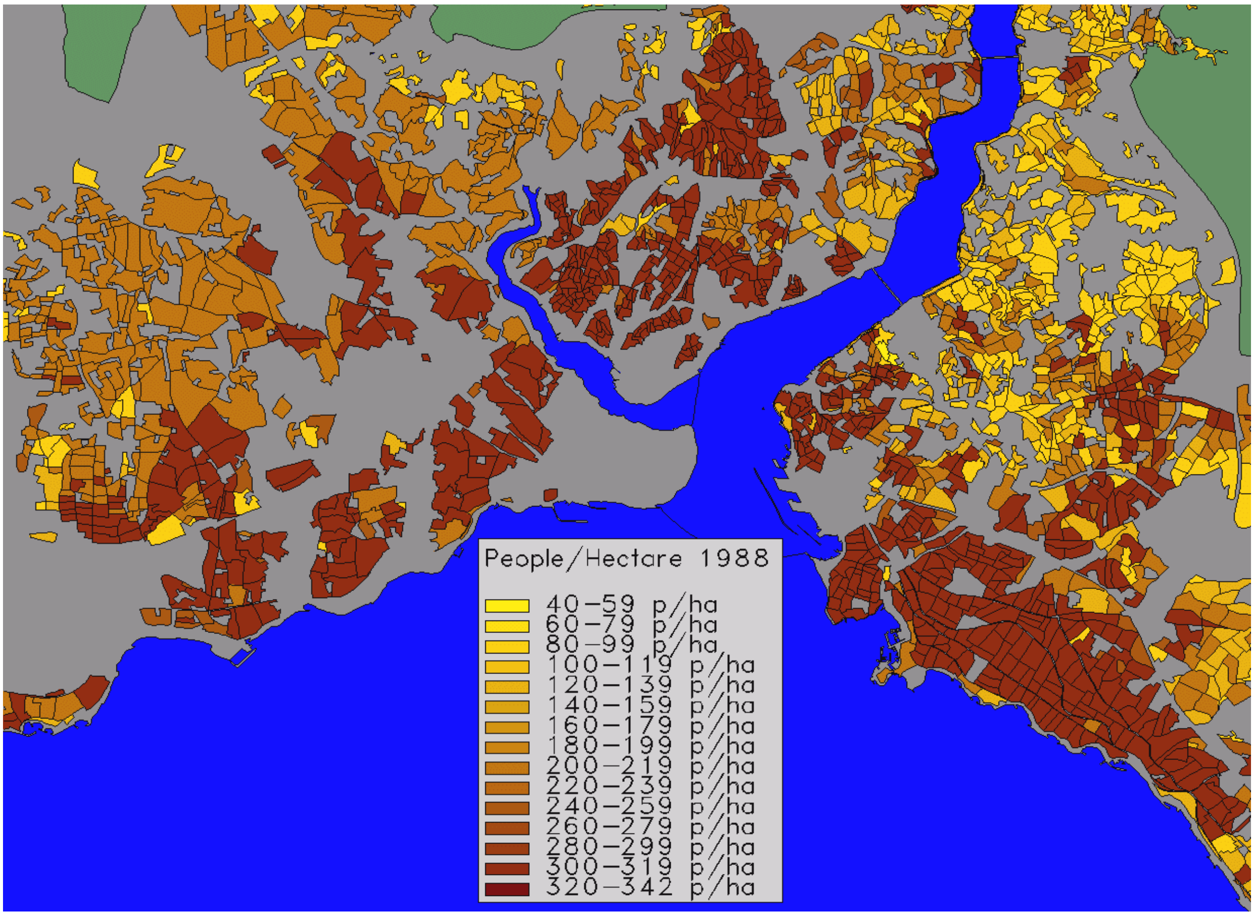


Figure 165: *Computed population density for the year 1988, based on statistics and assumptions.*

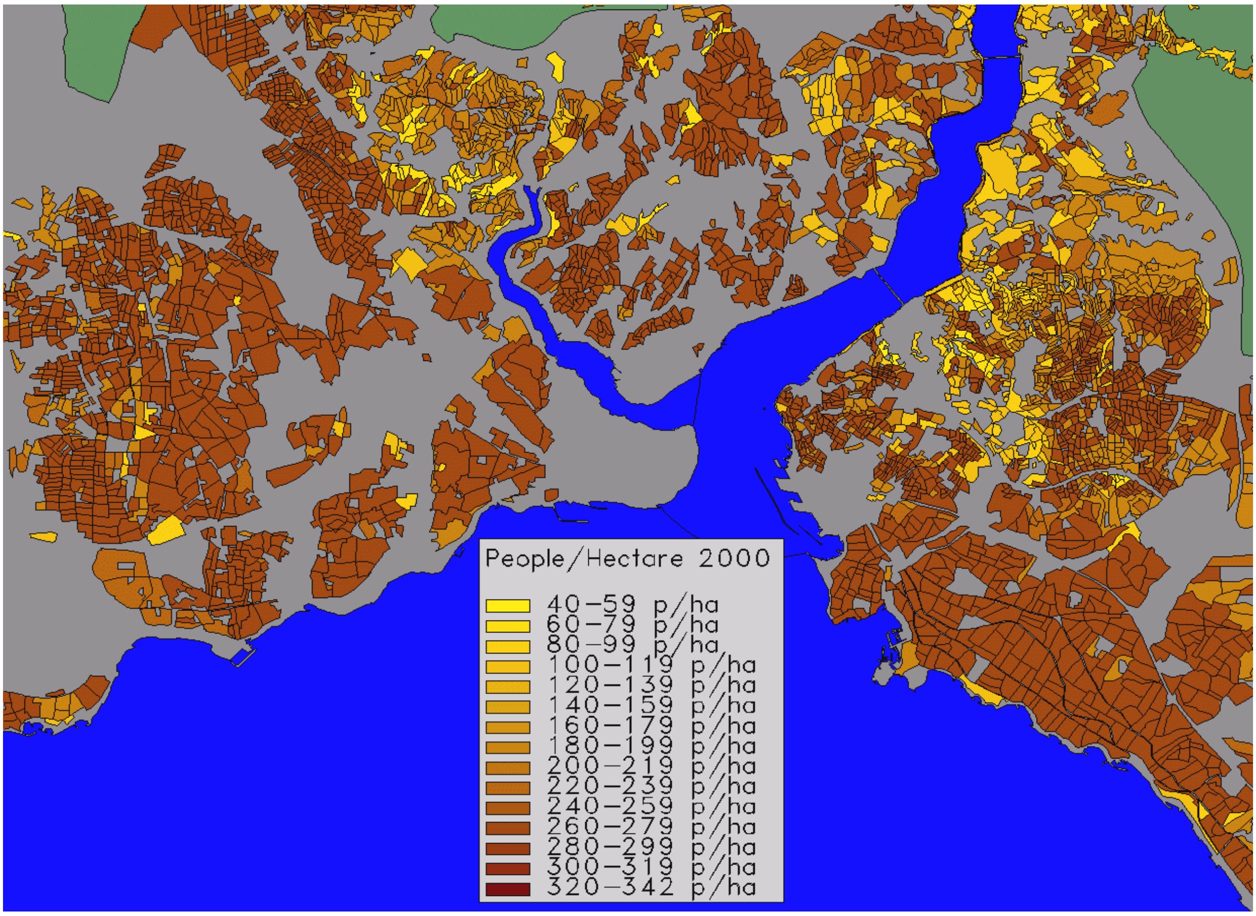


Figure 166: *detailed map of the population density of Istanbul's centre for the year 2000*

		1945			1968			1988			2000		
MOLAND Level	factor	total ha/class	Weight. result	inhab./ ha /class	total ha/class	weight. result	inhab./ ha/ class	total ha/class	weight. result	inhab/ ha/ class	total ha/ class	weight. result	inhab./ ha/ class
1.1.1.1	3.0	709	2,128	327	2,228	6,685	341	8,655	25,965	301	21,141	63,423	274
1.1.1.2	2.0	1,423	2,847	218	4,968	9,935	227	11,413	22,826	201	13,886	27,773	183
1.1.1.3	0.8	0	0	87	0	0	91	99	80	80	386	309	73
1.1.2.1	1.2	1,419	1,703	131	2,798	3,357	136	5,954	7,145	121	5,842	7,010	110
1.1.2.2	0.9	2,986	2,687	98	4,237	3,813	102	10,130	9,117	90	4,239	3,815	82
1.1.2.3	2.5	0	0	273	161	403	284	622	1,555	251	3,003	7,508	228
1.1.2.4	0.5	0	0	55	0	0	57	12	6	50	9	5	46
Total size of residential area		6,537			14,392			36,886			48,506		
total weighted area-ha			9,364			24,194			66,694			109,842	
Inhabitants			1,021 Mio			2,747 Mio			6,702 Mio			10,033 Mio	
Inhabitants /ha of residential			109			114			100			91	

Table 43*:* *Population and their distribution in Istanbul by statistical models*

The table above shows the basis of the maps previously created. The weighted factors for the classes and their computation can be seen. The most interesting point is the total amount of people living in residential structures by the above weighted residential space. This emphasises the latent change of living space during a denser period in the 1960ies (114) with a decrease since 1988 to an amount of 91 in 2000. As mentioned before, this shows the known effect of the social change in most countries to smaller and single households. Only by means of land-use detection, this effect cannot be visualised.

On the other hand, smaller households and sometimes also families or people with more than one flat can be found. This affects the rapid growth, which does not correlate exactly with the increase of inhabitants. Nevertheless, there are changes in the built-up areas to denser buildings where not as many people live as there is place for. In total there is still a densification in people per ha.

Finally, there is a superposition of the effects in the residential sprawl in Istanbul. First of all, there is the ongoing migration to Istanbul that is mainly based on the emigration from eastern Anatolia. A smaller effect is seen in the immigration from foreign countries. Main motivations to migrate are to economic reasons. The step to leave the native home became easier because the first generation of relatives already have lived in Istanbul for several years. In many areas people of similar origin live together. That is the reason why Istanbul is described as the “biggest Kurdish city” outside Kurdistan.

In addition, life in Istanbul is easier due to the environmental conditions. Whereas the climatic situation in eastern Anatolia with very cold winters and hot and dry summers is very difficult, Istanbul and the Marmara Region have mild winters and warm summers. In addition, the terrain is not as mountainous as in the eastern sites. The infrastructure e.g. roads, electricity, telecommunication, drinking water,…, is much better than in the rural areas of east Turkey. The idea to start farming around Istanbul, which on the first view seems to be easier and more profitable than in eastern Anatolia, might have influenced the migration. However, the agricultural land is in competition with the urban sprawl.

5.1.2 Changes in business classes

Istanbul can still be seen as a victim of an unsystematic urban development (Görgülü: 2002). The process of sub-urbanization was not only implemented by the illegal Gecekondu settlements and the construction of residential areas, but also by the increased settlement of industrial areas as well as the formation of satellite towns like Ikitelli or Mahmutbey and the agglomeration of industrial estates along the Londra Asfalti.

Istanbul is growing rapidly in both dimensions, in space and in density. The above-described urban sprawl is the visible result of striking and permanent structural alterations. Two of the main factors making it hard to control this process, are internal migration and globalisation. Another factor is the frequent paradigmatic shift in Istanbul's economic and development policy, which increases the pressure for change and prevents sustainable development (Görgülü, 2002). An example for the ambiguous and alternating policy in Istanbul is the decentralization program to thin out the city centre. The forced resettlement of enterprises from the city centre to Beylikdüzu, Iketelli and Mahmutbay is contradictory to the rather careless regulatory policy handling the Gecekondu settlements.

In this chapter, business areas and transportation areas (lines with a width more than 20 m) are combined. Istanbul as the economic heart of Turkey has changed and grown strongly during the times analysed. As shown in Table 40, business areas have grown stronger than the residential surface during the first period, similarly during the second period similar and less during the last one. This shows the changes inside these areas.

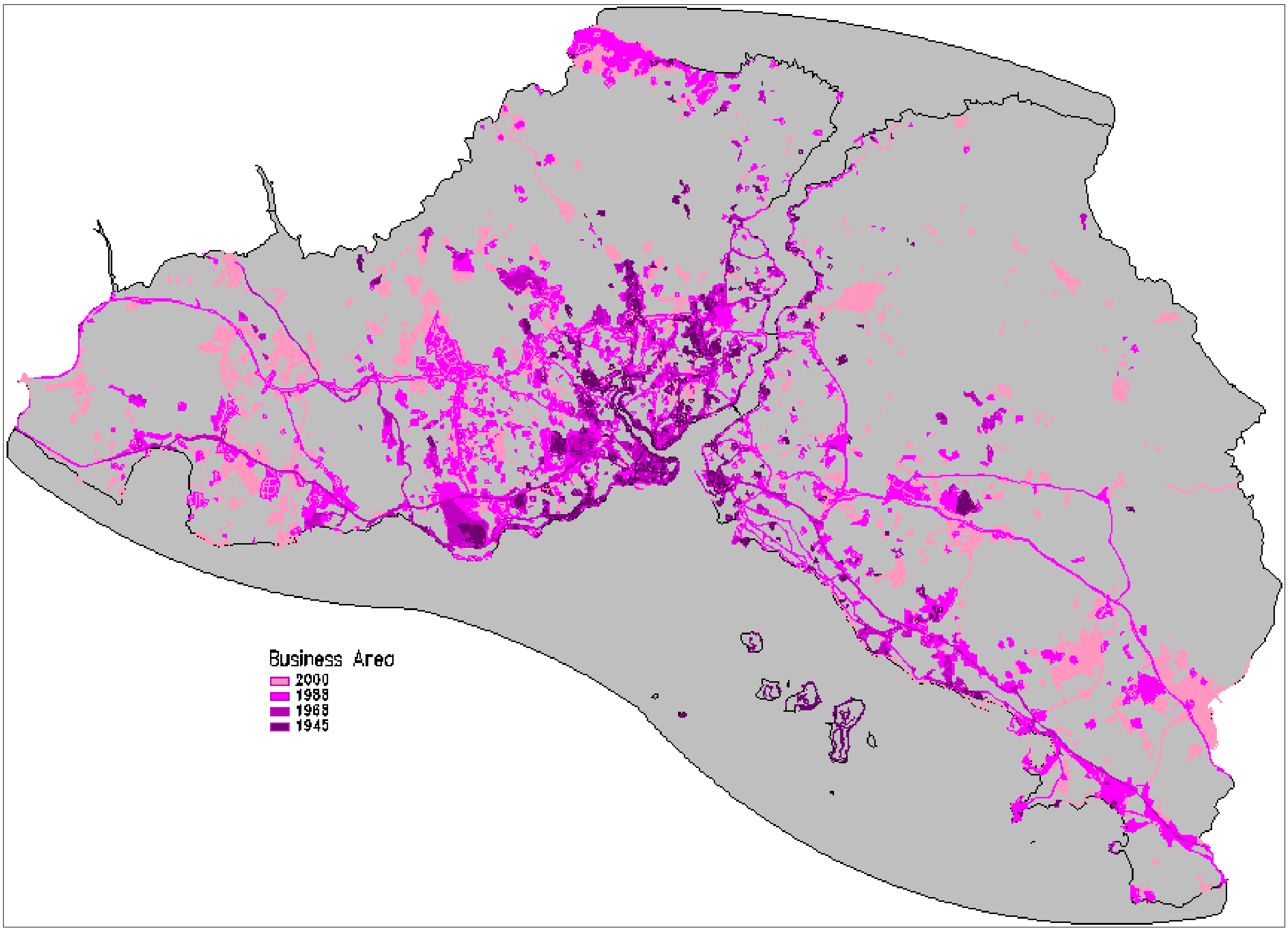


Figure 167: *Increase of business areas from 1945 to 2000*

Istanbul is Turkey's largest port and the hub of its industry. Textiles, flour milling, tobacco processing, cement, and glass are the city's principal manufactures. Tourism is a growing source of income for Istanbul.

The classes 1.2.1.1-1.2.1.4, 1.2.1.8-1.2.1.10, the entire group 1.2.2 and 1.2.3 and classes 1.3.1-1.3.3 were selected and combined for the overview in Figure 167. The main business centre is on the European side. During all the periods, this part of Istanbul hosts the industrial and trade areas with the biggest increase in total. Nevertheless, some areas are also developing on the Asian side mainly orientated to newly build transportation features.

Those linear features on the east variate clearly to the block structure on the European side, especially visible at the area surrounding the Atatürk-Airport. A strong industrialised fabric is detected west of the centre and along the coast of the Marmara Sea.

As a strategy of the city planners, industrial production was shifted from the centre of Istanbul to the frame of the city. During the last 2 periods, many companies were removed from the inner part of Istanbul to its fringe. The main idea of this political impact was to strengthen the industry, to create space for further development, to improve the infrastructure and to reduce air- and water pollution in the inner city. These ideas were successfull, in fact, the industry grew strong and became more effective, air pollution is better controlled and the air-quality improved in the centre.

The free spaces in the centre where filled by residential areas, but mainly with complex structures including shops, trade, smaller companies, commercial areas and others. Some of these parts changed to modern CBDs (central business districts), some other were filled with poorly organised small industrial workshops.

The effect of the replacement of the larger industry also influenced the residential growth around these new industrial parks. As result, the industry is surrounded by residential areas and today back inside the urban agglomeration. Also here, the evolution from Gececondo, smaller residential areas to residential blocks took place. Indeed, this development finally increased the urban sprawl, which was surely not the intention of the city planners and decision-makers.

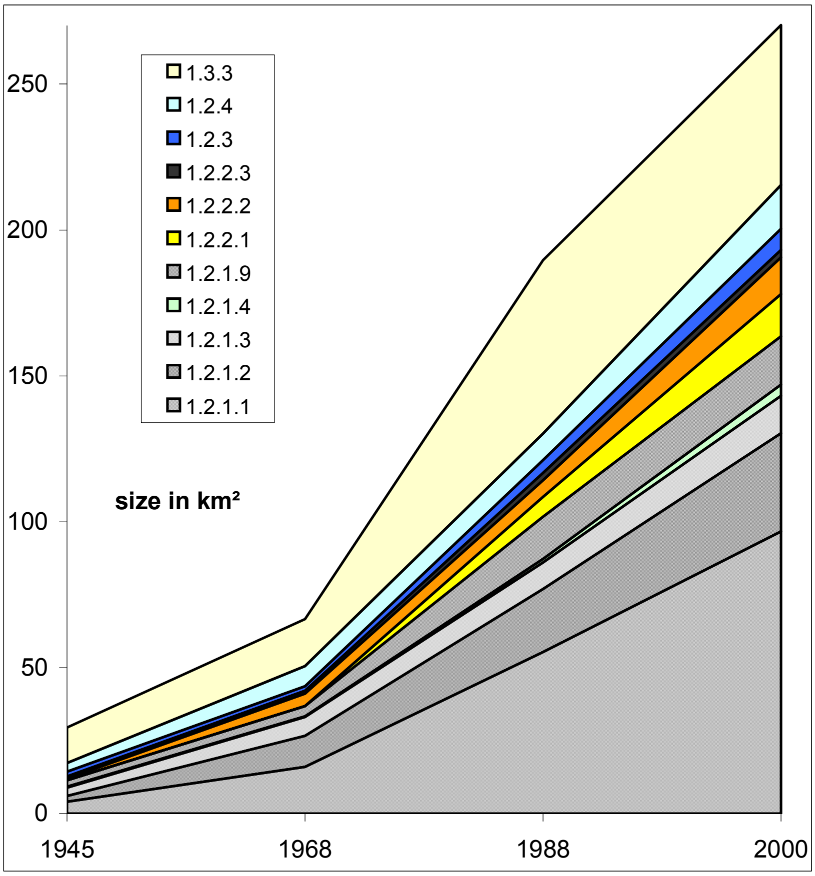


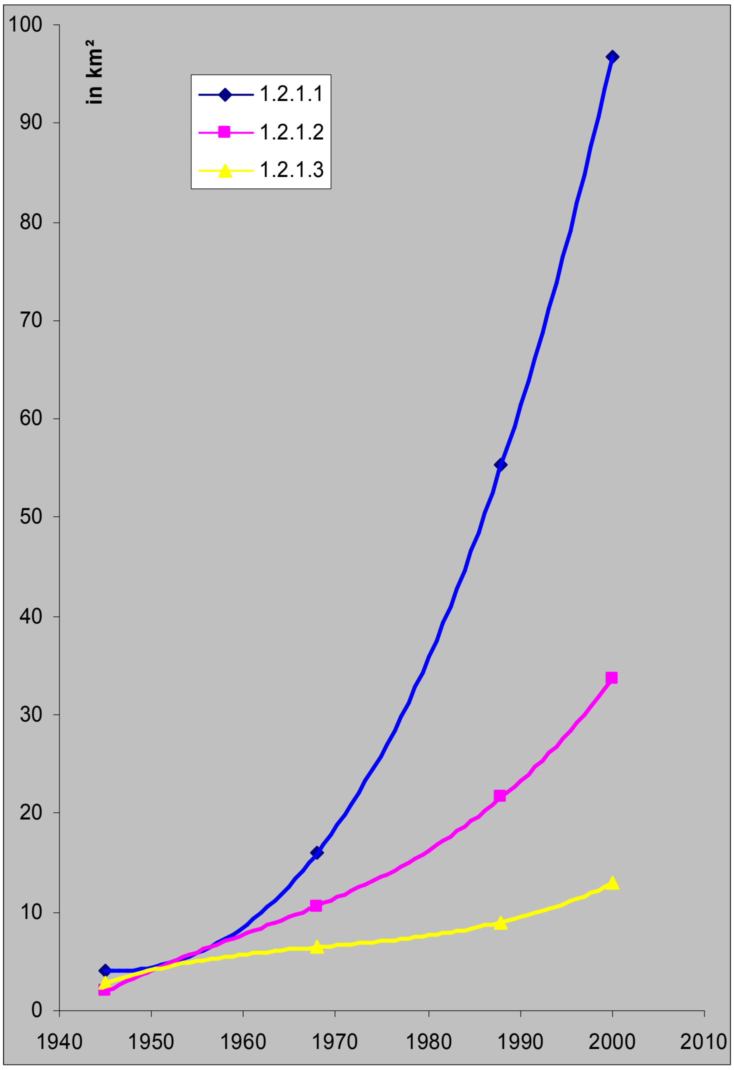
Figure 168: *Increase in different business areas*

The strongest increase can be seen in the industrial sector, followed by the commercial sector. This classification is difficult since in many residential areas also shops, workshops and others co-exist. A relatively high increase can be also found in class 1.2.1.9, restricted access areas. The reason lies in public power-management and areas for similar purposes. The increase in classes 1.2.2.1 and 1.2.2.2 (highway and roads) is therefore consequent. These constructions initiated an accelerated growth of the population as well as of the urban fabric. Amazing is the big growth and size of areas under construction. On the one hand, it shows the dynamics in the urbanisation, on the other it shows the fact that always and everywhere something is going to be changed, added, renewed or “never be finished”. The construction often continues when the financial situation is positive. This represents the difficult economic situation of Turkey.

In the meantime, nearly any kind of industry can be found in Istanbul. The original ones, textile industry and machine construction are still strong, but nowadays many other goods are produced in Istanbul. The primary industries are machine-construction, textile, glass industry and services around transport and trade. Petrol and chemical industry became powerful during the last 20 years. Secondary industries like telecommunication, electronics, and others find in Istanbul the most important trade-place and the market for end-users. The market for investment is in Istanbul bigger than anywhere else in Turkey. National and international banks, international foundations and cooperation offices have their main branches in Istanbul. Although Ankara is the capital and the administration of Turkey, big state investment and subvention goes to Istanbul as Turkey’s central market and production place.

Foreign foundations of companies are typical in the area of Istanbul, most fairs and exhibitions related to industry and trade take place here. All these facts accelerate the economic growth, which is still on a high level. This trend is shown in the following figure.

Figure 169: *Trend-analysis of industrial commercial and services by polynomial 3rd degree*



The trends show the big increase in industrial areas (1.2.1.1) as well as in commercial ones (1.2.1.2). Public and private services, stored in class 1.2.1.3, are growing on a relatively small level. This shows a big difference to the high-developed cities, for example, in Western Europe, where this service is growing strongly and industry shows small increase or stagnation. Istanbul has always been an industrial city and due to low cost production, western companies established here factories for production. In future, Istanbul has to compete with other production places. This should result in strategies for a sustainable development. The industrial growth is based on the super-position of the primary and secondary sector. If the primary one changes its growth, the secondary one reacts in same direction. This builds a high risk for an economic collapse. The economic situation of the construction industry is known as an indicator for economic growth or stagnation. In year 2000, the trend was still positive.

5.2 Loss of agricultural land

The area around Istanbul and the Marmara Region is traditionally an excellent land for agricultural activities. The climate with sufficient amount of rain, warm summers and mild winters allows farming of a wide range of plants for food production. Wide plains and smooth hills provide a suitable terrain for those activities. Only the mountains with bigger slopes are covered with forest, which persist more or less during all periods. Since centuries, this region was densely populated due its environmental conditions and its strategic position. During history different farming, technologies and crop-systems were used, which can still be detected today. Gardens with vineyards demonstrate Greek influence in the history, also the order of field and the used irrigation systems reflect the importance for very different nations, occupying this land during the last 2000 years. Food-production with focus to the city as a market place lead to a specific relationship between Istanbul and its surrounding. This dependence, similar to other cities in history, was persisted for many centuries.

The smooth terrain also suits for urban construction. The ownership of the agricultural land is partly administrative and partly private. During the centuries, the ownership of the land often changed and the parcels variated in size and form. While in forest the ownership is relatively clear, for agricultural land, it is complex. This makes the illegal construction of buildings much easier and faster. Nearly all the Gececondu areas were founded on former agricultural land.

Agricultural land as a source for urban sprawl is a typical phenomenon of all mega cities also in Europe. So far this change from rural farmland to urban fabric meets the expectation.

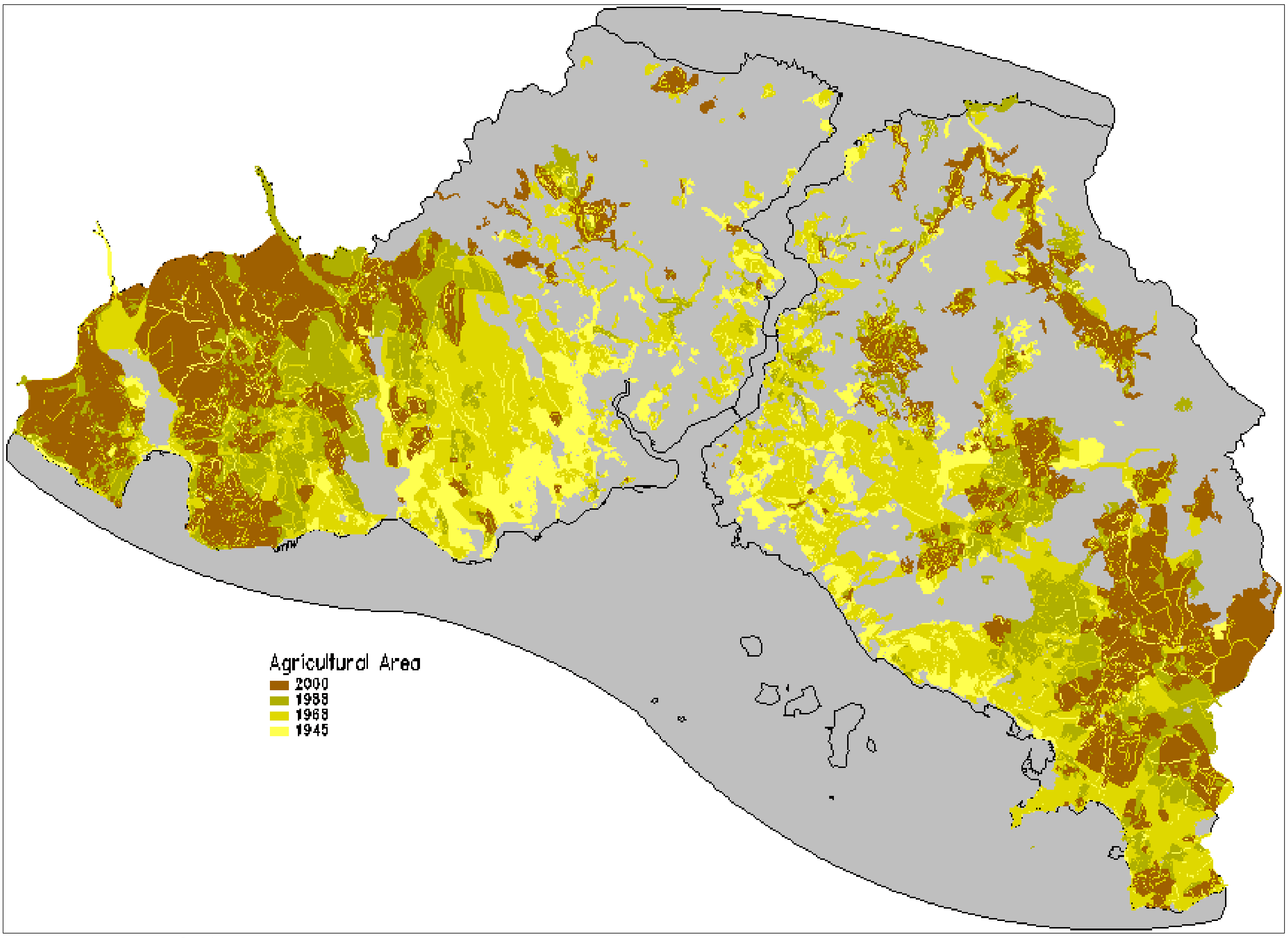


Figure 170: *The loss of agricultural areas from 1945 to 2000*

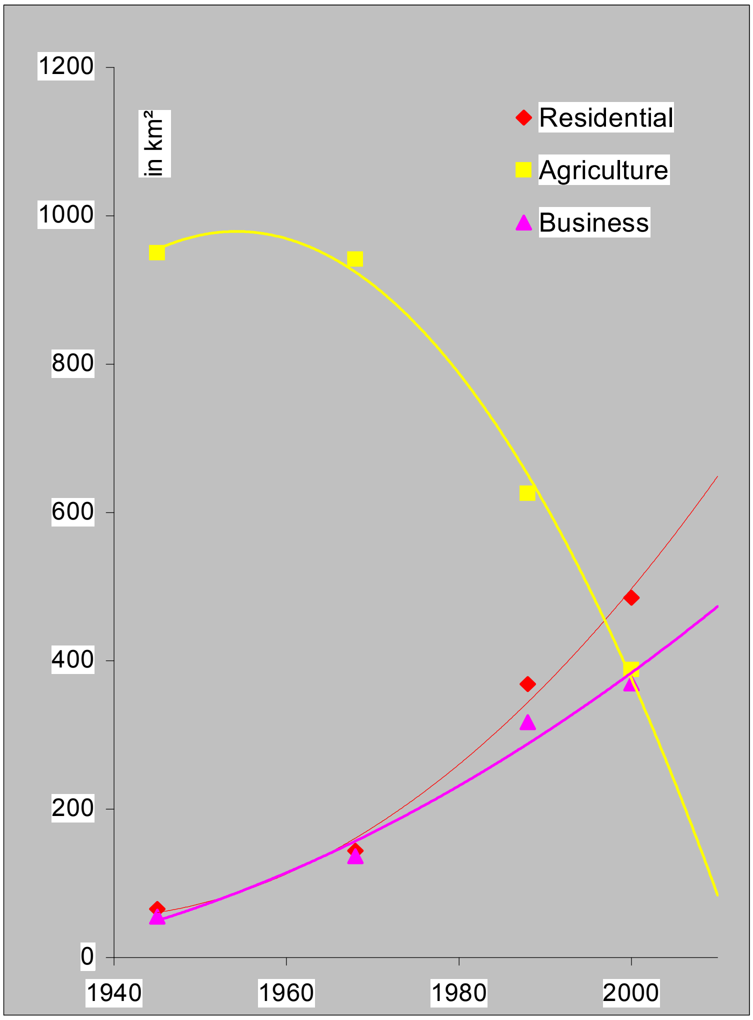


Figure 171: *Trend-analysis of agricultural land in relation to urban fabric*

The big growth of residential and business area caused loss in other types of surfaces. This was mainly in agricultural land, where the decrease was as strong as the increase of residential fabric and business surface. In this case, Istanbul reacts similarly to all big agglomerations worldwide. If we do trend-analyses up to 2010, nearly the entire area of agricultural land will be used for urban fabric. Alternatively, forest areas can be used for urban growth. But we must be aware of the fact that forest is better protectable than agricultural land. Forest is mostly state owned and due to ecological reasons not as endangered to be destroyed by urban growth as agricultural land.

Production of food is not as important as it was in the past. Irrigation and fertilisation enabled farming even under poor conditions. The amount of agicultural goods produced per ha increased strongly as described in the first chapters. Strong efforts of the Ministry of Agriculture are responsible for this change in food production. Dams for irrigation, training of the farmers, and development of new methods in fertilisation and farming have made this progress possible. In combination with modern transportation technologies like fridge-lorries and inert-gas protection, fresh goods like fruit and vegetables can be shipped across Turkey.

This development reduces the need of agricultural food production near Istanbul. It opens the market for real estate and ground speculations, which are responsible for the ongoing urbanisation in the agricultural areas.

Figure 172 shows, where agricultural land has been lost since 1945 and replaced by residential or business surfaces. A big amount of new urban fabric was established west of Istanbul's centre. Especially around the airport and west of the Kücük-Cekmece Lake, agricultural land was lost. On the Asian side, mostly along the Marmara Sea coast, huge loss of agricultural land is visible. There are two mountains west of the centre, which are covered by forest. The urban structure grew around and has meanwhile surrounded them entirely.

The change into industrial fabric happened very fast while the change into residential fabric often went via different density levels. However, as shown by various examples, also planned new residential areas made the change in one single step possible. On figure 172, the difference between the European side, with a more closed block structure, and the Asiatic side, with a stretched linear structure, is visible.

The urban sprawl, based on the use of agricultural land, continues to the southeast and west along the cost of the Marmara Sea.

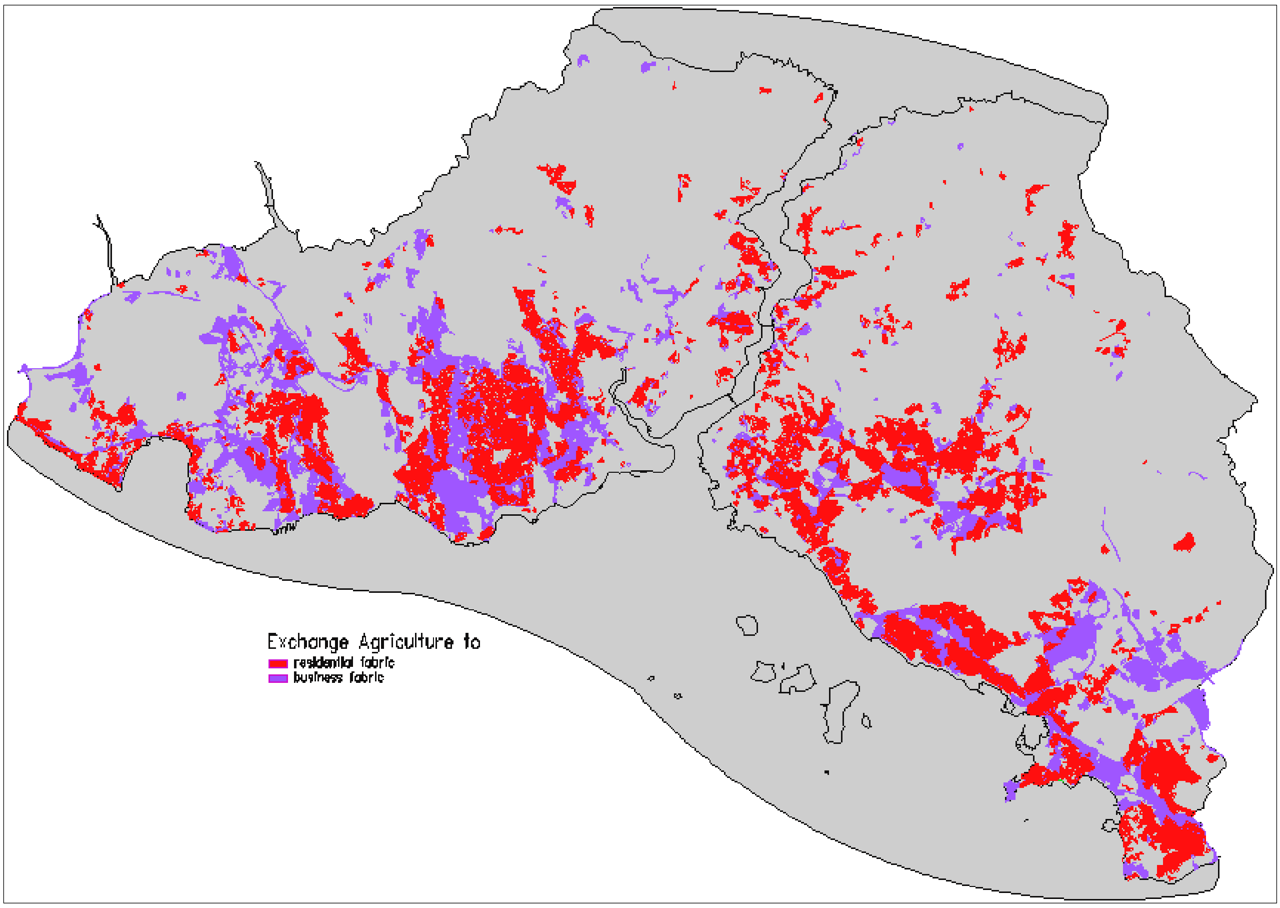


Figure 172: *The exchange of agricultural land to residential and business areas*

5.3 Increase in the transportation network

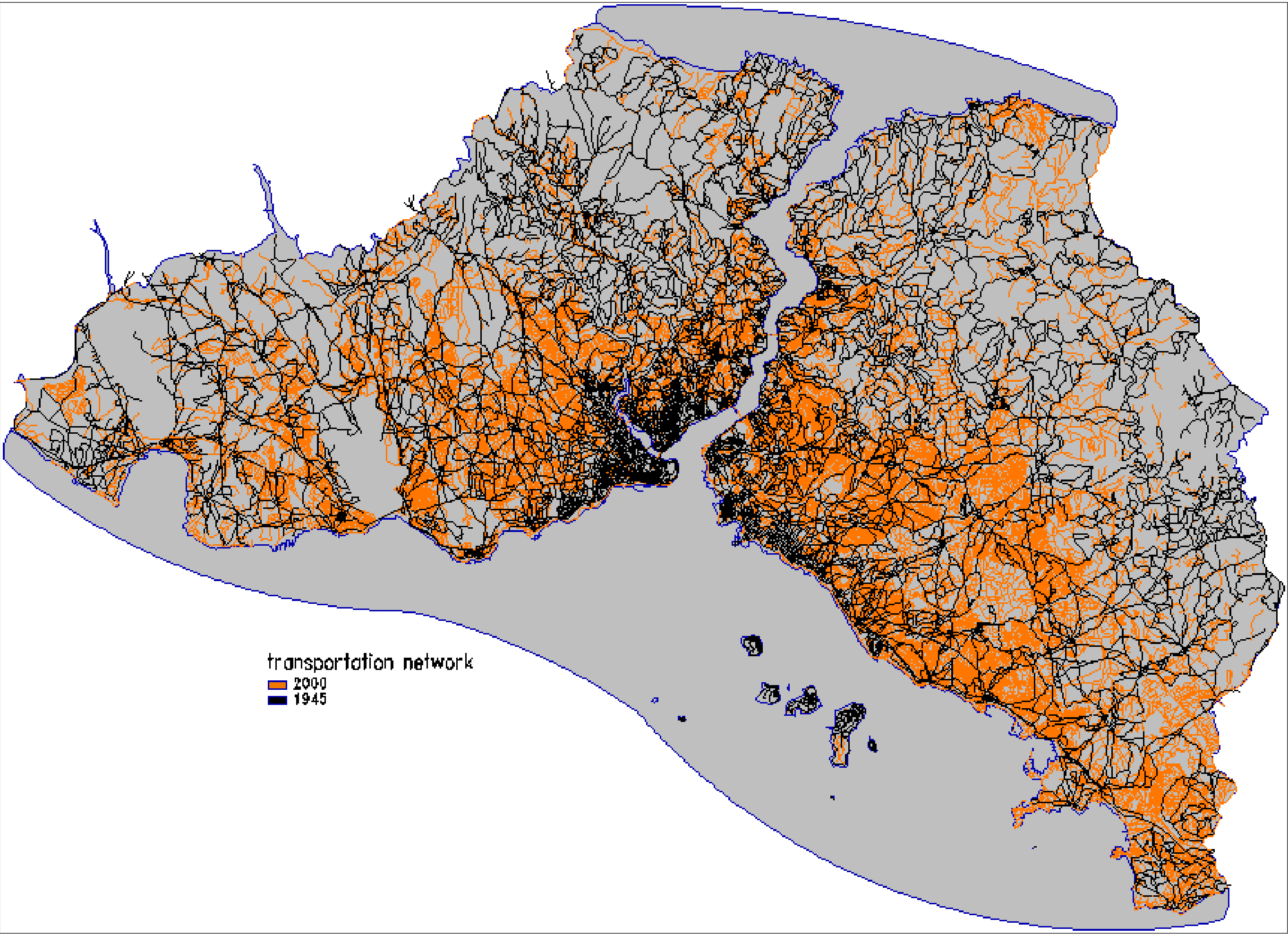


Figure 173: *Change of the transportation network between 1945 (black) and 2000 (orange)*

Changes in the Transportation Network reflect the urban sprawl. The density, length and the type of transportation line represent the quality and quantity of the urban development. In this study no analyses about the frequency of their use were done, so far density and total length do not represent the real traffic in Istanbul. Nevertheless, this transportation network indicates the dramatic change. The main group contains roads with a total of 7,000 km in 1945 and 16,000 km in 2000. Further their quality was not taken into account. While in the 1940ies roads without asphalt were common, nowadays most roads are sealed with asphalt or concrete.

YEAR	Highway Europe	Roads Europe	Railway Europe	Tram Europe	**Europe Total**	Highway Asia	Roads Asia	Railway Asia	**Asia Total**
	in km	*in km*	*in km*	*in km*	*in km*	*in km*	*in km*	*in km*	*in km*
1945	0	3,532	52	0	**3,583**	0	3,394	49	**3,443**
1968	0	3,904	51	0	**3,955**	0	5,808	51	**5,859**
1988	78	5,314	55	3	**5,451**	48	8,929	50	**9,028**
2000	167	6,246	56	13	**6,481**	112	9,697	51	**9,860**

Table 44: *The transportation network in numbers*

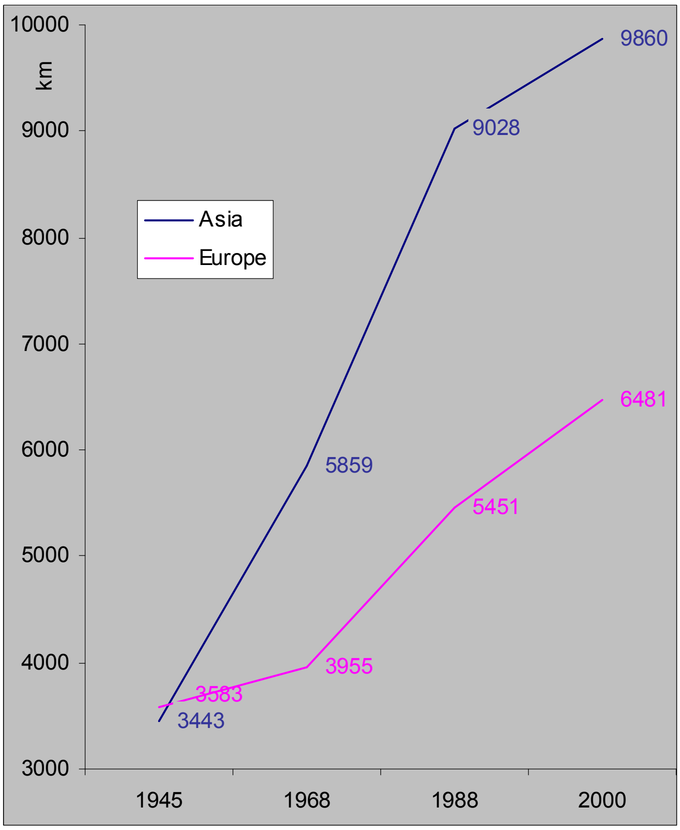


Figure 174: *The increase in transportation network (roads and railway) divided by the continents.*

Figure 174 shows the enormous increase of roads (1.2.2.2) on the Asian side of Istanbul. The urban area of the Asian part is just 10% bigger than the European one while its shape is much longer and less compact than on the European side. This is one of the main reasons for the unequal growth of transportation lines as well as due to the fact that the urban structure is not as dense as on the European one. In 1945, both sides started on similar levels. Until 2000, the European side grew 2 times while the Asian side grew 3 times. The actual size is amazingly large in contrast to public transportation network as rail and tram. But it must be stated that a high number of busses are important for solving public transportation needs as well as the private busses, the Dolmusch, that have a big importance in public transport too. The mapped bus-stations of the public bus-services (from municipality or contracted companies) show a high figure. A number of 1360 stations on the European side cause an average distance of 4.7 km between them. This is a relatively high density. The Asian side counts 1346 stations with an averaged distance of 7.32 km between them. This difference reflects the smaller density of the urban structure eastside the Bosporus.

Private busses, so-called Minibuses, manage today an important part of the public transport, in former times they were known as Dolmush. These busses grew from the typical Ford Transit vans before the 1980ies to the bigger minibusses with a capacity of 10-20 persons, a specially designed bus for Turkey. Due to the frequent use of these busses, the individual traffic has not yet collapsed. They run frequently and adapt to the actual need. Being privately owned, they react on economic conditions, thus, they are able to change even during day the number of transports, the directions…. These Minibuses are used by all social groups of the population and are accepted by the local authorities. They might be the main pillars of the public transportation system.

In addition, also the water-taxies and ferries manage the connection across the Bosporus and along the city. These ferries and ships are relatively cheap and go very frequently. As far as they are free from rush hours and traffic-jams, they can usually follow their timetable precisely.

Transportation by train and tram is not very important in total. Along the few operational lines, they are strongly used, especially in the historical part of Istanbul where cars are partly restricted. As a special system, the old- historical tram from Taxim-square to the old Tünnel-subway at the end of the Istiklal Caddesi has to be mentioned. It is a very special mixture between real public transport and a historical tram-ride with a touristic background. However, this tram (finally two of them, which meet as a shuttle service in the middle) is usually crowded. The named Tünnel is a historical subway, leading from Karaköy to the Istiklal Caddesi, also as a shuttle lifting the people from the Bosporus to the Taksim 200 m up. This subway is one of the oldest in the world and still frequently used. It demonstrates the early efforts to solve public transportation problem in former times. Nevertheless, related to their short length in total, both lines are unimportant for entire transportation network. Too long no additional efforts have been undertaken and today they cannot keep pace with the urban development at all.

Unfortunately, statistics of the transported number of people have not been discovered to give a real weighting to the different systems. One problem might be that they belong to different organisations and they are not really coordinated by the municipality. In case of financial problems in Turkey during the last 20 years, when the economic situation often changed, external sponsors had to be integrated into the running projects. This is mainly the new subway from Taxim to Levent, which connect the main business areas. However, the construction is due to big technical problems caused by the hilly terrain very slow. Efforts in a rail-based public transport exist only on the European side of Istanbul, where the main trade and business areas are. This attracts the interest of sponsors. A chance for additional transport lines exists since a new airport on the Asian side, the Sabiha Gökcen Havalimani was built.

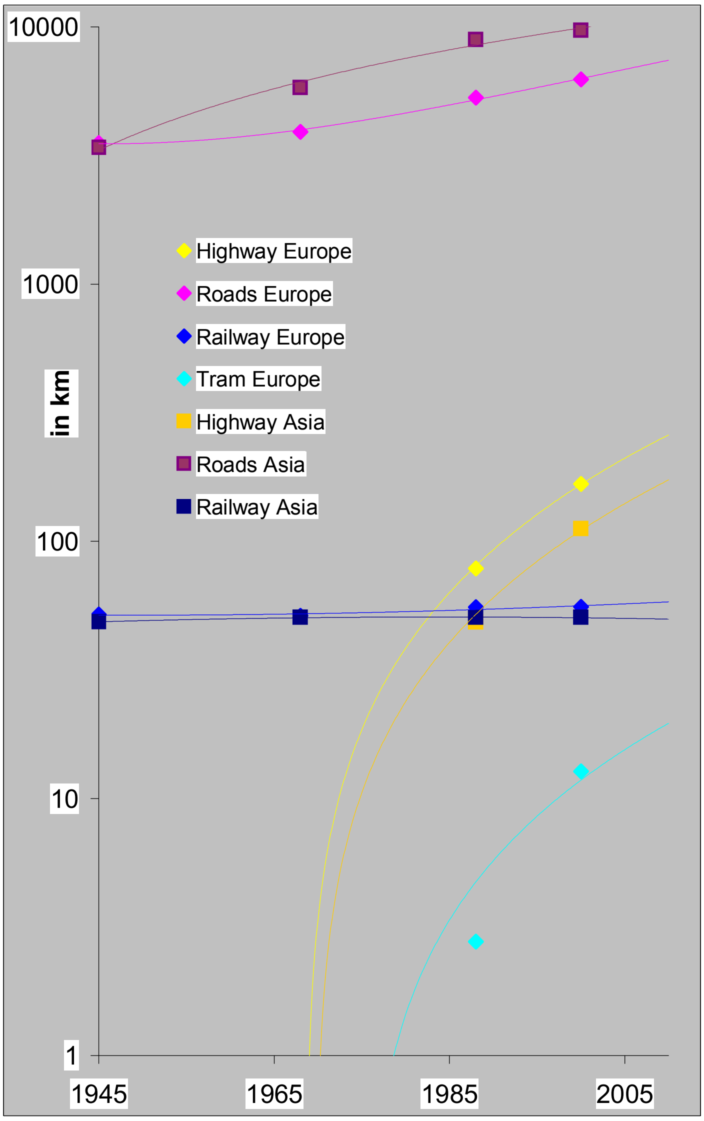


Figure 175: *Trends of the transportation network*

This figure shows trends for the different transportation classes in Istanbul for each sides of the Bosporus. The y-axis is designed logarithmic show the various dimensions. Further, it highlights the related trends. The increase of roads (1.2.2.2) accelerates on the European side while on the Asian side the growth-rate gets slower. The growth-rate of the highways (1.2.2.1) is very similar for both sides since they build the main connections via the two bridges. They depend on each other; the increase is slow. The railroads have not changed since 1945. Nothing was done to support the public transport. Only on the European side, a tramline in the historical city of Istanbul was built. It has about 13 km of total length, which is nearly nothing compared to the length of the roads.

As a future trend, the increase of roads will continue, perhaps on a smaller level. The increase of highways will continue, and hopefully also the tram. Not included, because not visible is the newly built subway, but also this one only covers a few kilometres.

Referring to figure 40 on page 100, the increase in individual cars in Istanbul is surprising in relation to the Marmara region and Turkey. Usually, in developed countries the trend is diferently. Because of the lack of public transport, the number of cars / inhabitant in rural areas is higher than in cities. Here it is inverse; a clear signal for what has to be done in the future.

5.4 Differences between the Asian an the European Side

Concerning the urban sprawl in space, analysed on the classified areas, the change of Istanbul as a whole was monitored. If we analyse the European and Asian part of Istanbul separately, we are able to compare them and detect differences. This was already done with the transportation network on its linear features. The development is at first sight similar, but in detail, there are some interesting differences. As already mentioned, the quantitative analyses in literature clearly define the European part as the main business area. The Asian side is usually described as a residential one with lower density than the residential areas in western Istanbul. What can be expected is an influence due to the connection of both parts of Istanbul by the bridges built across the Bosporus. In order to keep the overview, the classes have been aggregated into groups.

As the group of residential areas the classes 1.1.1.1 up to 1.2.1.4 have been combined, which cover all the residential structures even those that are partly business but mainly residential areas.

As the group of business areas, the classes 1.2.1.1 up to 1.2.2.7 have been combined which cover industrial, trade, services, and the wider transportation features.

As agriculture all the classes 2.1 up to 2.4.4 had been grouped, this includes also extensive and intensive agricultural production

As natural green all the areas of class 3.2 up to 3.3.4.1 had been selected. These can be open spaces in forestry as well as spare vegetated areas on rocks.

Classes 3.1 up to 3.1.3.4 have been grouped as forestry. Young forests or bushes as well as harvested areas are included too.

As water-bodies all areas of class 5 with the exception of the sea-spaces like the Bosporus are grouped.

As other bodies have been grouped e.g. the sea-spaces and areas not clearly to be integrated into the groups mentioned above.

Table 45: *The land-use groups separated by the continents in ha*

	1945	1968	1988	2000
Residential Europe	3,577	7,863	15,978	20,301
Residential Asia	2,961	6,529	20,907	28,205
Business Europe	1,324	4,050	8,338	12,834
Business Asia	653	1,492	5,384	9,573
Agriculture Europe	50,315	46,792	34,163	20,904
Agriculture Asia	44,676	47,341	28,417	17,906
Natural Green Europe	16,183	9,990	5,515	11,783
Natural Green Asia	18,190	9,288	4,965	6,025
Forest Europe	27,386	27,391	24,808	25,112
Forest Asia	49,430	49,090	47,725	46,798
Water-bodies Europe	3,214	3,353	4,772	5,630
Water-bodies Asia	190	130	2,190	2,254
Others Europe	2,896	5,528	10,900	9,128
Others Asia	1,384	3,570	8,306	7,464

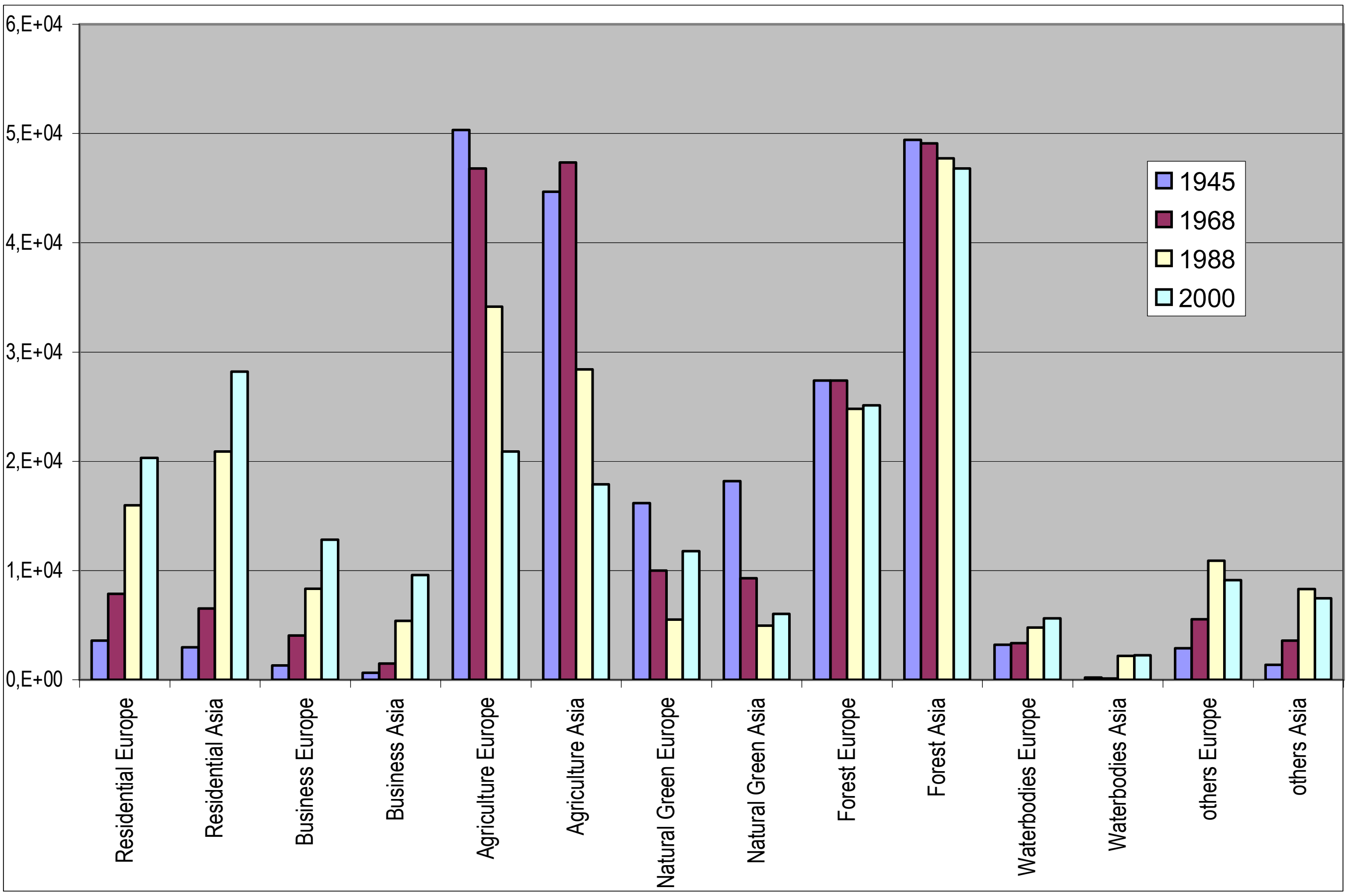


Figure 176: *Land-use change differed by the continental location of Istanbul (ha)*

The residential surface on the European side grew more or less continuously with an acceleration between 1968 and 1988 and slowed down after 1988. The acceleration in the increase of residential surface on the Asian side started before 1968 on a much smaller level, but between 1968 and 88, the growth of the residential surface was enormous. While in western Istanbul the space was doubled in this time, the Asian side grew 3 times as fast. After 1988, the growth is stronger but also the growth rate also slowed down. This is the result of the building of the bridges in 1972 and 1988. The size of residencial areas became bigger than on the European side, their density, however, is lower. On the Asian side 144 people live per ha, 298 people on the European. This reflects the double inhabitant density of the European side compared to the Asian one.

Comparing the business areas, the Asian side grew stronger, but the total size is still smaller than in the western part. Growth on the European side is more homogeneous than on the Asian side, nevertheless, the “bridge function” can be detected as a trigger too.

The increase in this urban fabric was compensated, so that the results of the loss of agricultural land between 1945 and 1968 were low. On the Asian side, some growth can be detected, which might be a compensation of the loss on the European side. It could be speculated that some farmers shifted in this period. The natural green areas strongly decreased in this time. This demonstrates that in this early period those obviously extensive or non-used parcels were used to build up urban fabric. The “Gecekondu” phenomena might has profited from that because the risk to be discovered as illeagal on such land is smaller than on the agricultural surface.

Also interesting is the continuing loss of agriculture during the last 12 years, even the increase in the urban fabric slows down meanwhile. It was partly compensated by natural green, which is quite surprising. An extinction or a total abandon of farming on some fields was detected. It has been already discussed that subvention and irrigation activities in other parts of Turkey influenced the need for farmland near Istanbul in a negative way.

The size of forest seems quite stabile and is well protected. Mainly in the north, where hilly terrain limits agriculture and urban growth, the size of forest areas is stabile. The loss of forest areas is significantly smaller than discussions with forest men in Istanbul might indicate. The area NNE of Istanbul is a protected area for water-resources and in any case due to the roughness of terrain unsuitable for agriculture and urban development. The urban growth usually surrounds the forest.

In some cases, urban sprawl started to affect forest areas, via either Gecekondu constructions or even as planned build up of business or residential areas. This effect is relatively small and happens only in direct neighbourhood of densely urbanised areas and forestry. There is a slight tendency that this phenomenon is stronger on the European side, but cannot be quantified in this study.

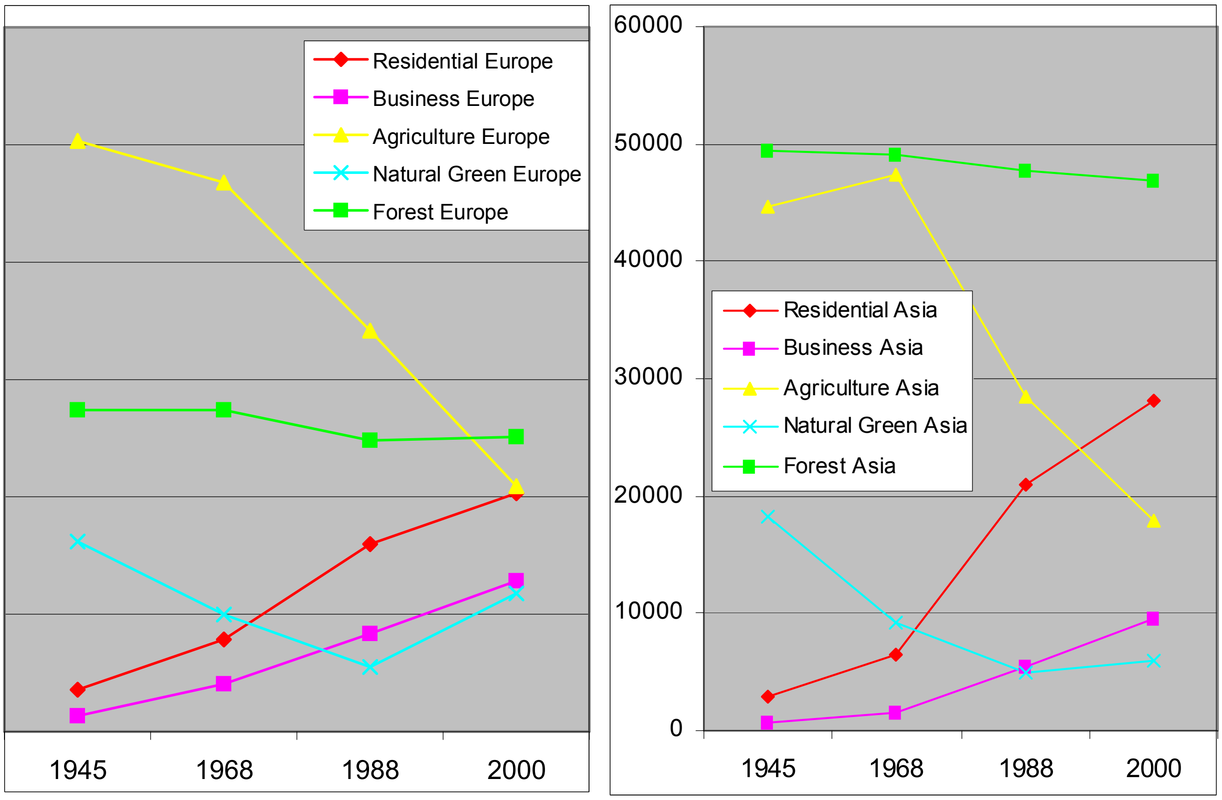


Figure 177 - 178: *Comparisons of growth in the main groups on the Asian and European [in ha] side of Istanbul.*

Surprising is the increase of natural green, especially on the European side of Istanbul during the last period. We have found out that in the former periods these new areas had been analysed as agricultural land that means, that the fields became wasteland and finally natural green. It reflects again the change in the agricultural production in Turkey commonly and the loss of areas to do profitable farming in the area of Istanbul.

Some demographic statistics with trend analyses were made by ISKI, which is the main service company for supplying fresh water. Indeed, there is an urgent need for the estimation of the development in order to build resources for the water production. Detailed master plans and reliable statistics were available and have been used for this interpretation.

The number of inhabitants is based on the official statistics and represents the official census data. The real count of inhabitants might be higher. The values are not continuously available for both sides; so far not all the growth-rates could be computed.

Year	Asian Side		European Side		Total Population (1000)	Growth Rate (%p.a)
	Population (x1000)	% of Total Population	Population (x1000)	% of Total Population		
1990	2,699	36.11	4.776	63.89	7.475	4.56
2000	4,075	40.31	6.035	59.69	10.11	3.07
2010	5,455	43.35	7.129	56.65	12.584	2.21
2020	6,659	45.35	8.024	54.64	14.683	1.56
2030	7,489	46.46	8.631	53.54	16.12	0.94
2040	7,986	47.08	8.977	52.92	16.963	0.51

Table 46: *The population growth estimated by the water-management institute (ISKI 1999)*

	1945	1968	1988	1990	2000	2010	2020	2030	2040
Residential area Asia in ha	2,961	6,529	20,907		28,205				
Residential area Europe in ha	3,577	7,863	15,978		20,301				
Growth population Asia in % / a					4.21	2.96	2.01	1.18	0.64
Growth residential areas Asia in % / a		3.50	5.99		2.53				
Growth population Europe in % / a					2.37	1.68	1.19	0.73	0.39
Growth residential areas Europe in % / a		3.48	3.61		2.02				
Density pers/ha Asia			119		144				
Density pers/ha Europe			285		298				

Table 47: *Further analyses on the ISKI-data in combination with the MOLAND-Data*

These analyses show the trend in the different parts of Istanbul. The Asian side develops more strongly than the European side. Growth in space and by inhabitants is much bigger than on the European side. The change west of the Bosporus happens inside of existing structures, the population growth is smaller as well as the urban sprawl. Therefore, the density in 2000 is still twice compared to the Asian side.

The Asian side grows strongly in space and in number of inhabitants and will meet in year 2060 similar number of inhabitants as the European side will have. The residential surface already became the stronger of both parts since 1988, however, the density of inhabitants per ha in the year 2000 is still half than one of European side.

As a final interpretation, it can be said that even in the future the Asian side will not meet the dense residential structure of the European side. Even the growth in population and space is bigger the structure will be different. The reasons are based on the continuing difficult traffic across the Bosporus to the working places in Europe and a fact, which has not been mentioned up to now, the bigger risk for earthquakes and Tsunamis along the cost of the Marmara Sea. Some residential areas are built on risky ground, which has already suppressed the price for flats. The fear against earthquakes and floods has influenced the development since the last big earthquake of Izmit in 1999. This initiated a trend for searching flats rather in the north of Istanbul, which, on the other hand conflicts with low availability for suitable space there. A risk for social selection is give in this way that poor people will live in more risky areas than rich ones, who have the financial possibilities to move.

5.5 Trends and Axes of the Development

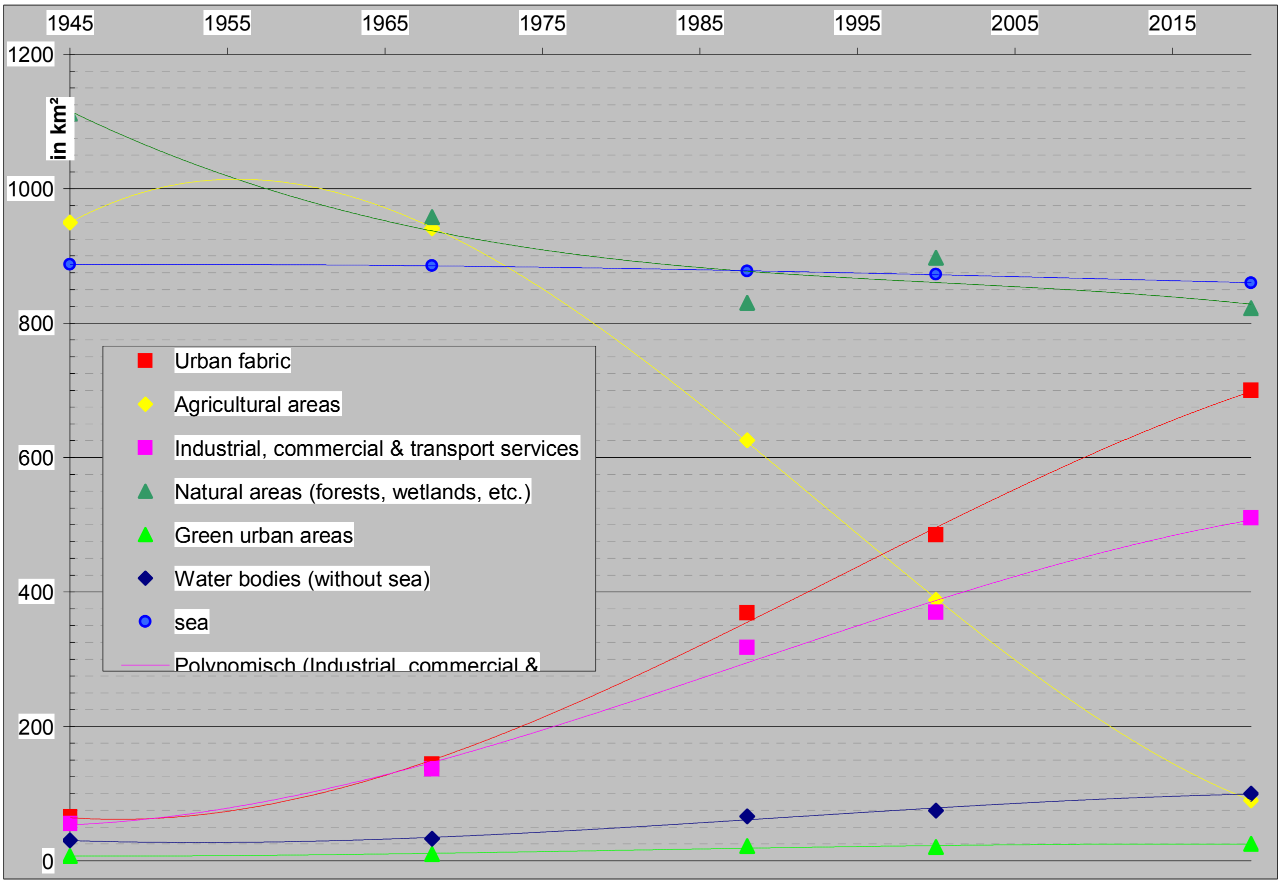
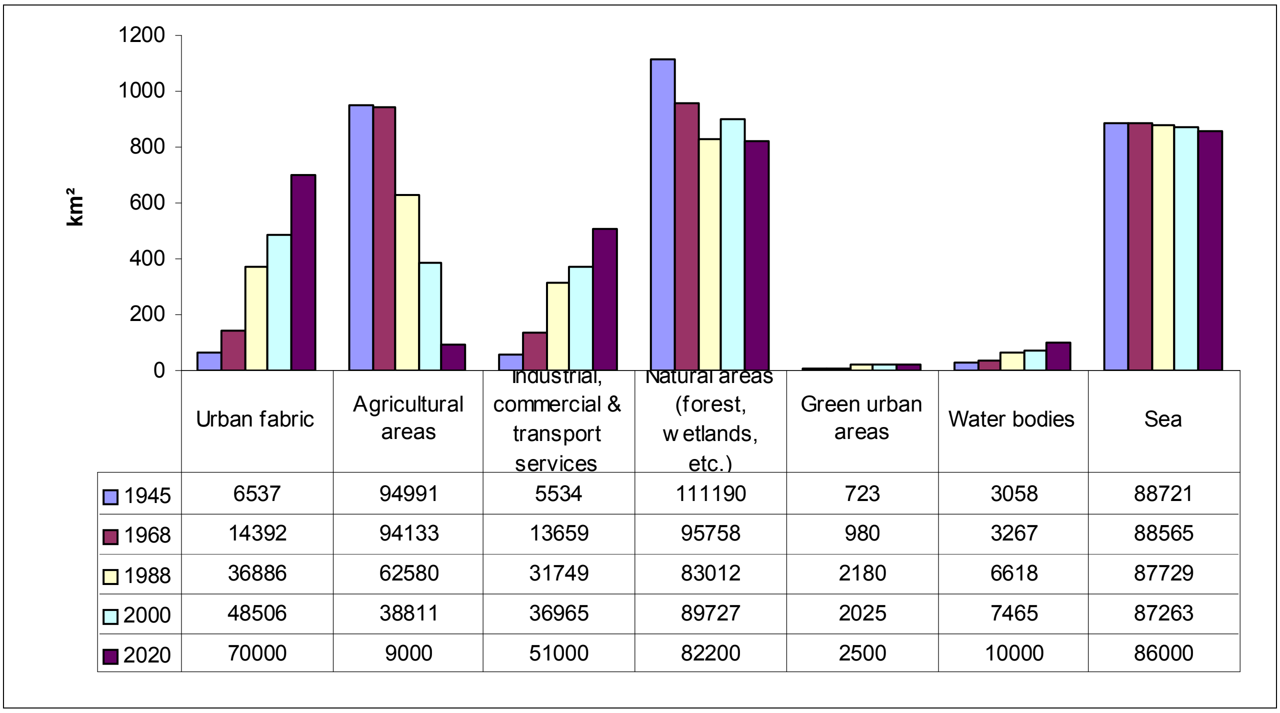


Figure 179: *Estimated development up to the year 2020 by combined polynomial and linear regressions using smoothing and balancing to the total size*

The trend analyses shown up to the year 2020 are based on a combination of a polynomial regression and a linear regression. As already analysed in the previous chapters, the development did not go linearly of the three most dynamic groups, agricultural land, residential and business surface. The calculated values have been related to the size of the project area and to the linear groups like forestry and water bodies. The trend, however, is a speculation and shows the future of Istanbul quite impressively. This also fits to the estimated trends of published statistics for the population growth. 14.5 Mio inhabitants have been estimated by the water management Institute (ISKI) these are about 45% more than in the year 2000. This was already presented in Table 46. Following the further estimations of ISKI, the growth rate slows down contineously and meets the one of other European cities.

Figure 179 shows a linear x-axe, with the exception of the last points in 2020, they are measured values out of the dataset.

Comparing the population growth of 45.2% from 2000 to 2020, the growth of urban fabric is with a rate of 44.3% similar. However, if we take the increase of the population density into account, it should be less. Growth of business areas count for 38%, which is a realistic figure. Estimating where the development goes to, table 47 clearly indicates that the Asian side will have a higher increase than the European one. These facts have already been analysed in the previous chapters.



	Urban fabric	Agricultural areas	Industrial, commercial & transport services	Natural areas (forest, wetlands, etc.)	Green urban areas	Water bodies	Sea
1945	6537	94991	5534	111190	723	3058	88721
1968	14392	94133	13659	95758	980	3267	88565
1988	36886	62580	31749	83012	2180	6618	87729
2000	48506	38811	36965	89727	2025	7465	87263
2020	70000	9000	51000	82200	2500	10000	86000

Figure 180: *Development up to the year 2020 out of the trend analysis*

Using city planning strategies, it will be a huge job to deal with this development in order to take pace with the urban sprawl to get it controlled. Which directions of the urban sprawl can be detected are the favourite ones? Using the GIS based data allows to extract axes, mainly along the southern coastlines of Istanbul. This, however, is just a semi-quantitative analysis.

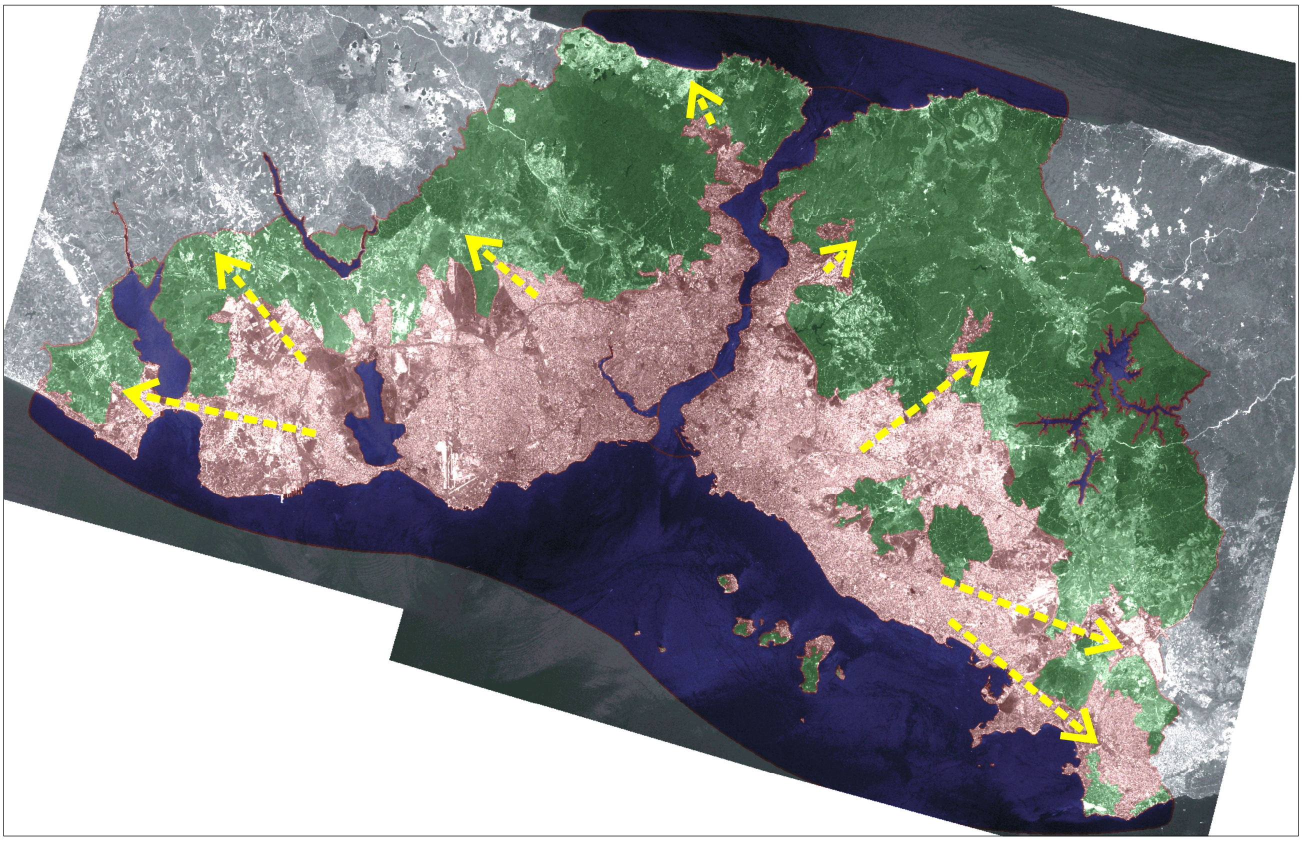


Figure 181*: The directions, where the increase might be orientated. The length of the arrows shows the intensity*

6 Istanbul compared with other Agglomerations

In the following chapter, the results on Istanbul will be placed in a wider context. Comparing Istanbul and its development to the biggest agglomerations in the world is of various interest. Such comparison is fixed on published data only while the comparison on MOLAND-Cities enable spatial analyses on land-use classes with more than 20 cities. In addition, the comparison of Istanbul to other national or neighboured mega-cities helps to understand the context of Istanbul's development to widen the focus of this study.

6.1 Istanbul and the world biggest urban areas

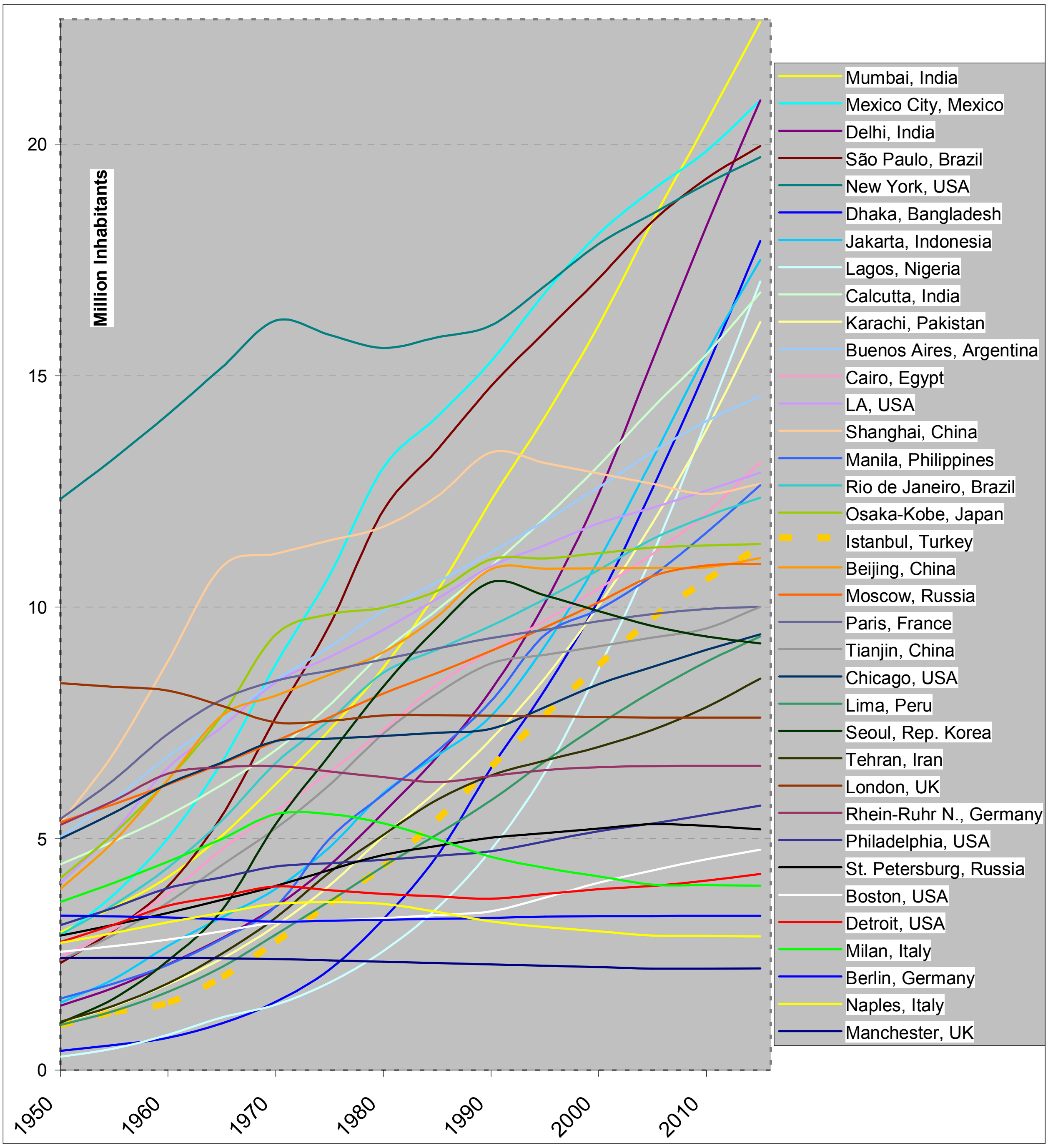


Figure 182*: Population growth in the 25 biggest cities (except Tokyo) or agglomerations in the world with included trend-analyses. (Data from UN 2004 in: UN - World Urbanization Prospects)*

The data in figure 182 are based on the World Urbanisation Prospect of the United Nations. They include real data from the year 2003 and estimate the population for the year 2005. The years 2010 and 2015 are calculated using the population growth index. To keep the overview in the graphic, Tokyo was excluded from this graphic due to its extremely high number of inhabitants of more than 36 million people. The remaining top 25 agglomerations are listed in this figure while the other cities mentioned in a previous period have been one of these top 25.

One difficulty concerning such data is the fact that the areas of the demographic data are not precicely defined. In some cases the city is taken into account, in other cases a wider region is used for the analyses. In some cases, net of big cities included in one study object was used as basis. On the other side, we find Istanbul relatively small to the data used in the previous chapter. In the graphic only the city is analysed, not the Istanbul district. As already discussed, the urban area of Istanbul crosses the district border but does not fill the entire administrative district in the north and west. Due to such administrative divergences, especially between different countries, absolute values have to be interpreted carefully. Nevertheless, the change of the population highlights the dynamic of cities in developed, underdeveloped and threshold countries.

Analysed on such a base, Turkey is not a developed country neither an underdeveloped one. Compared to other cities of threshold countries, Istanbul has an continuing growth, which represents the lack of administrative activities. Such impact from the administrative side can be seen in the curve of Chinas cities. To extract the population growth, the annual population growth rate was extracted from the data shown in figure 182.

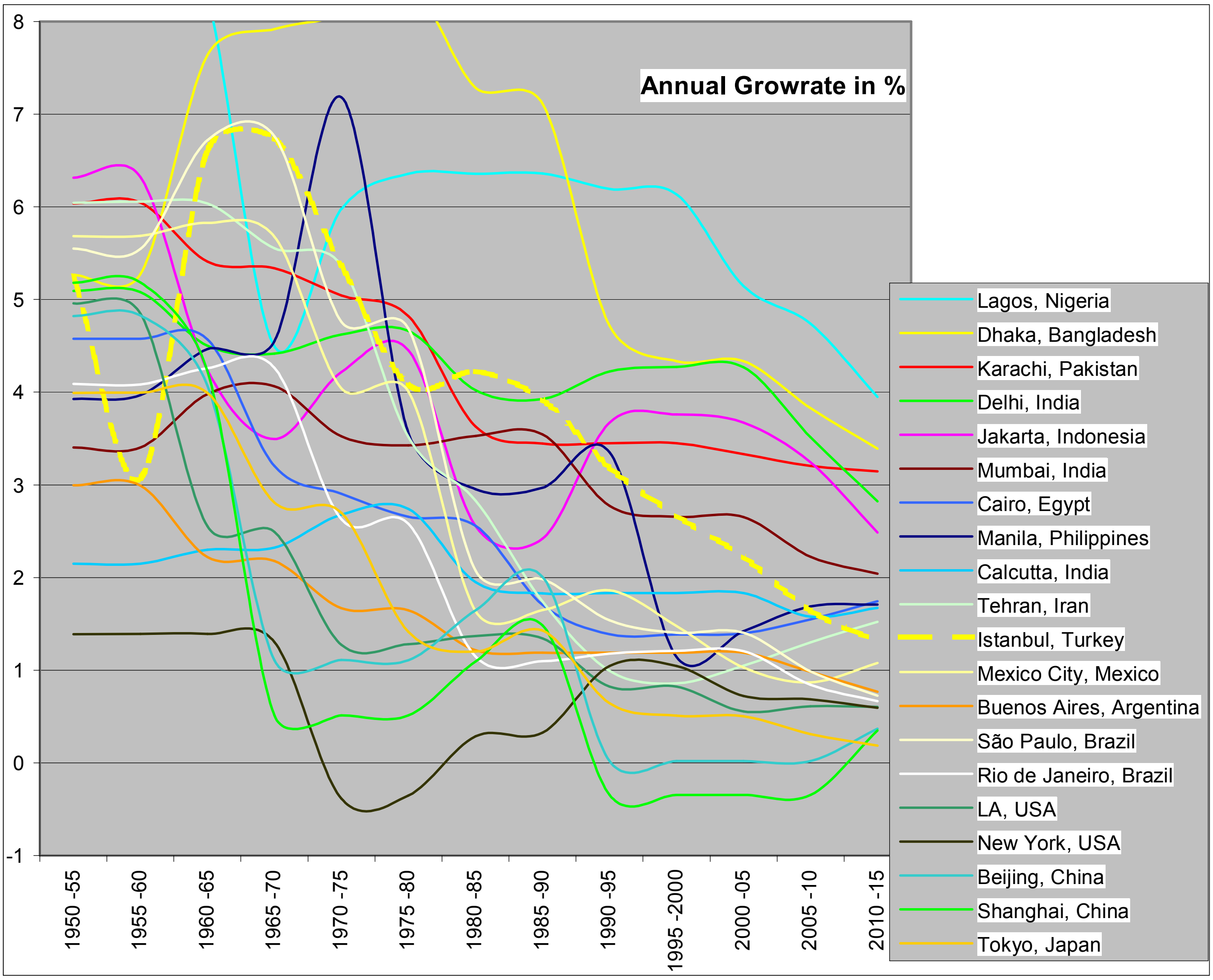
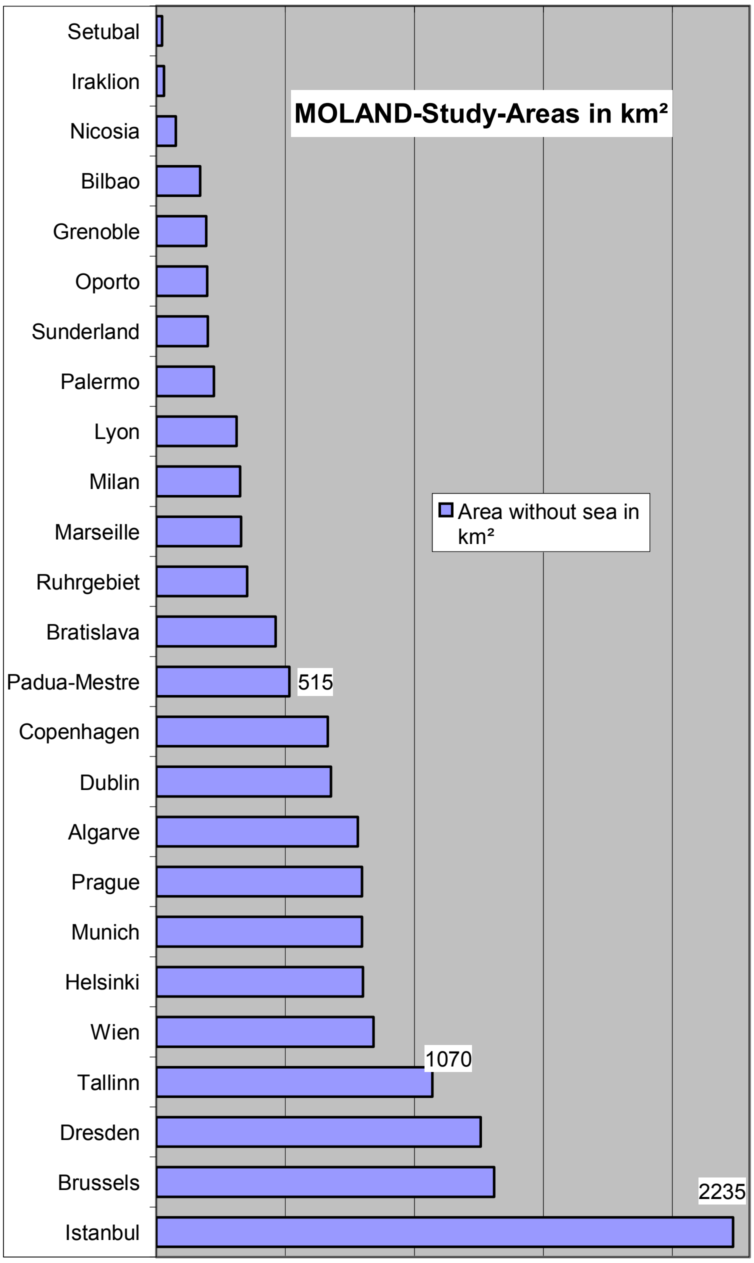


Figure 183*: The population growth rate of the biggest and strongest growing agglomerations. (Data from UN 2004 in: UN - World Urbanization Prospects)*

The main intention is to compare the trends. Analyses of the absolute values is difficult due to different methods and their related data. Even in summarised analyses of the world's mega-cities development, bigger agglomerations are placed beside single cities. This makes absolute evaluation of those sources impossible.

Figure 183 shows the relation of Istanbul to other rapid growing cities using the annual growth-rate. If, what is done often by demographic studies, the growth-rate is related to the degree of development, Istanbul is similar to South American agglomerations and the cities of Teheran, Calcutta, Cairo and Manila. This might be a mirror image of the city as a socio-economic object. Istanbul is able to compete by economic means with South American cities. Of course, it is difficult to balance this precicely; many other facts influence growth too. Istanbul is definitely a threshold-city by demographic means with a good step forward to become a developed one. As already seen in the chapters before, there are many strong economic developments in Istanbul, but there is still a lack of administrative management to do the final step.

6.2 Istanbul and the MOLAND-Cities



As mentioned before, the study on Istanbul was part of a wider project of the European Commission, named MURBANDY – Monitoring Urban Dynamics in a first phase and as MOLAND – Monitoring Land-Use Dynamics. In this chapter, a comparison on the statistical data of Istanbul in relation to these 24 other cities is presented. These data should not be regarded absolutely because they are related to the availability of the source data; the time period analysed can differ between the cities. Nevertheless all the cities have reached their highest growth-rate within the last hundred years during the study period. The chosen study areas differ extremely as shown in figure 184. The selection of the study area was already discussed but it must be mentioned, that the actual urbanised area and the buffer relate to the size selected. The absolute size is not the most important one, therefore in the following chapter the relational values are taken into comparison.

Figure 184*: Absolute size of the “MOLAND”-Cities study areas, already cleaned from Sea-Areas*

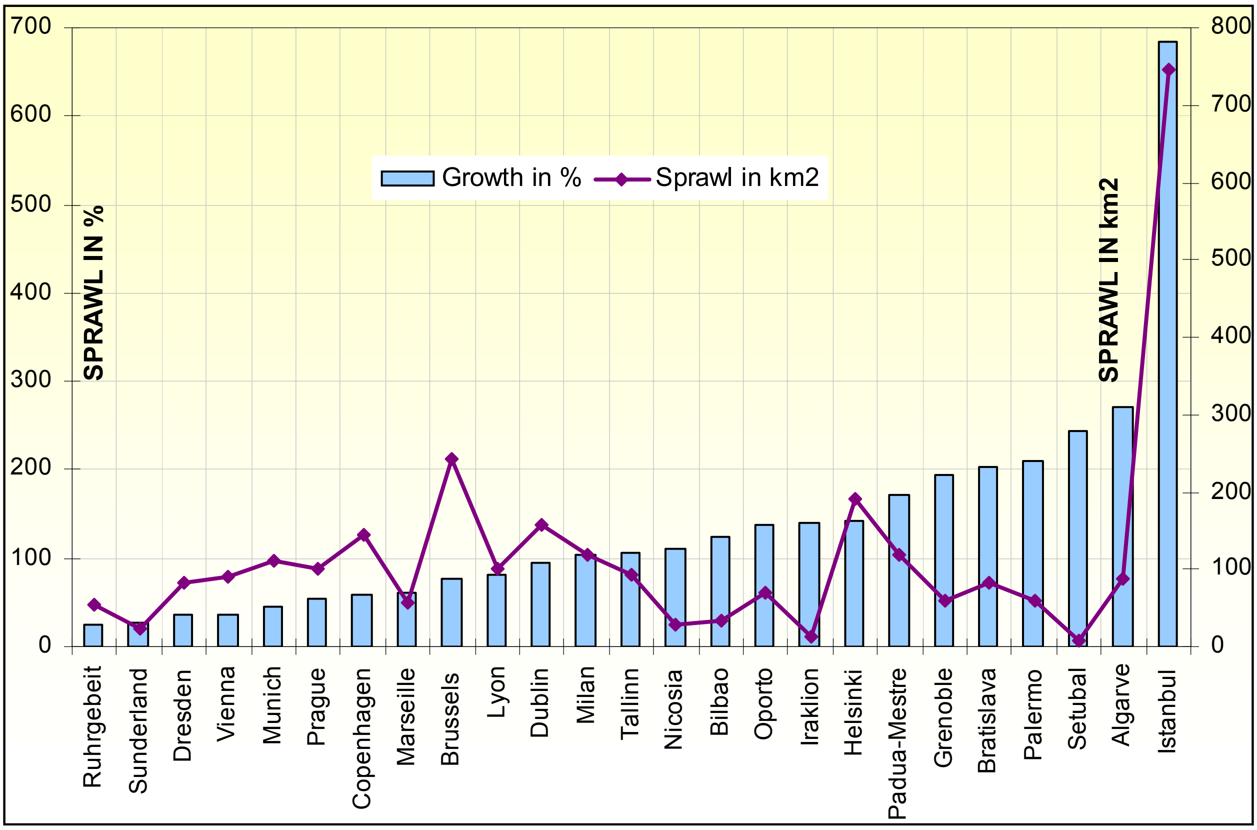


Figure 185*: urban sprawl of "MOLAND"-Cities within the last 50 years.*

Figure 185 clearly points out how Istanbul's growth relates to these cities. The difference is enormous. The relative growth shown in figure 185 by bars, are measured on the urban surface between the youngest and oldest year. With a sprawl of 680% and the biggest growth in absolute space, Istanbul is the "number one" of all MOLAND-cities.

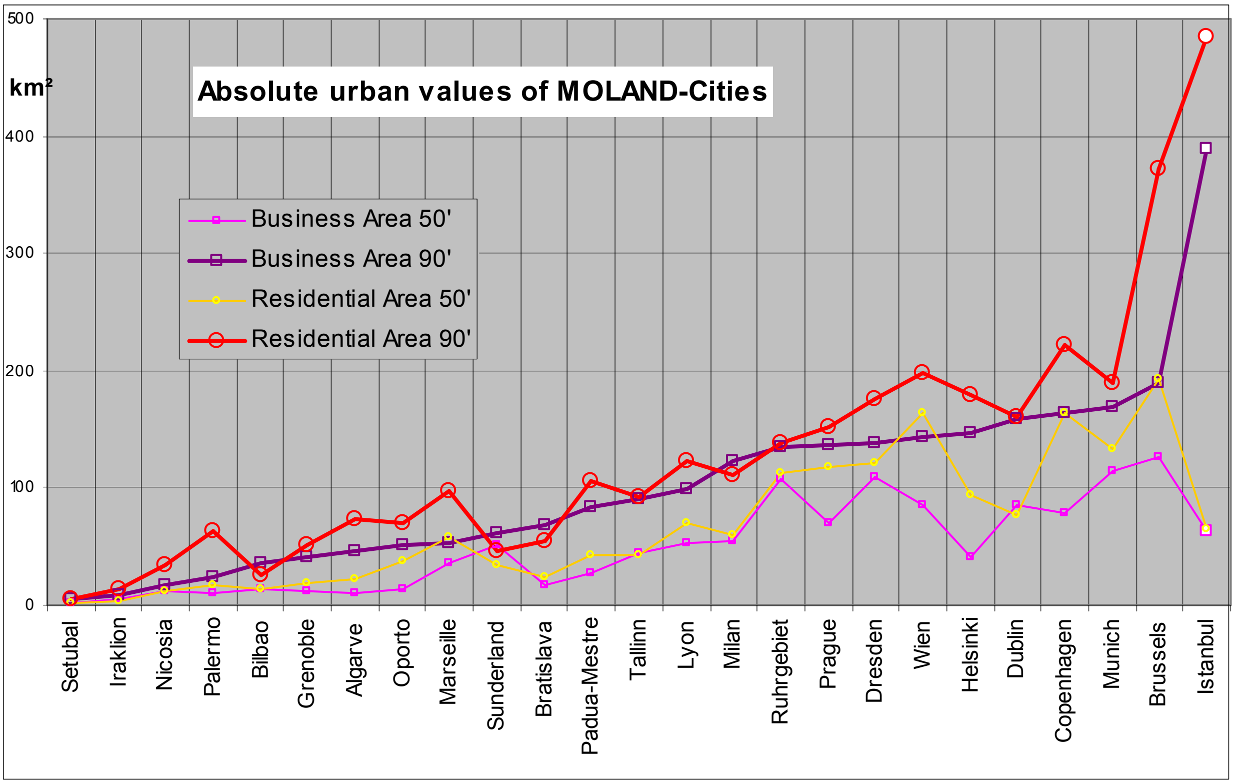


Figure 186*: absolute values on "MOLAND"-Cities within the last 50 years.*

The reasons for Istanbul's growth have already been discussed. All the other cities are placed in a well-developed environment and do not profit as much from the countryside as Istanbul does. The contrast of a country placed at the threshold of development is one of the important reasons for its development in comparison to the others. So far, Istanbul should be compared to other cities with a similar situation, but only for the MOLAND-cities the data are comparable with this method.

Finally, we should try to compare the absolute and relative changes among the cities' developments more detailed. In figure 186, the absolute values are shown with the sorting done by the business areas. So far, Istanbul seems to be the busiest city in the MOLAND context. Indeed, this interpretation is only based on the area used but gives an idea of the financial power of such an area. Seen from the values for the 50ies the change is also of interest. Brussels was in this period number one and Istanbul on the 9th place. The residential surface of Istanbul is highest in the 90ies meanwhile in the 50ies Istanbul is ranking on place 11. Regarding the change and the trend visible in the figure, Istanbul is not so much different from other cities, only the absolute change is at a higher level.

Based on this fact,it is important to compare the changes of the cities relative to the urbanised areas in the years analysed to point out the internal structure of them.

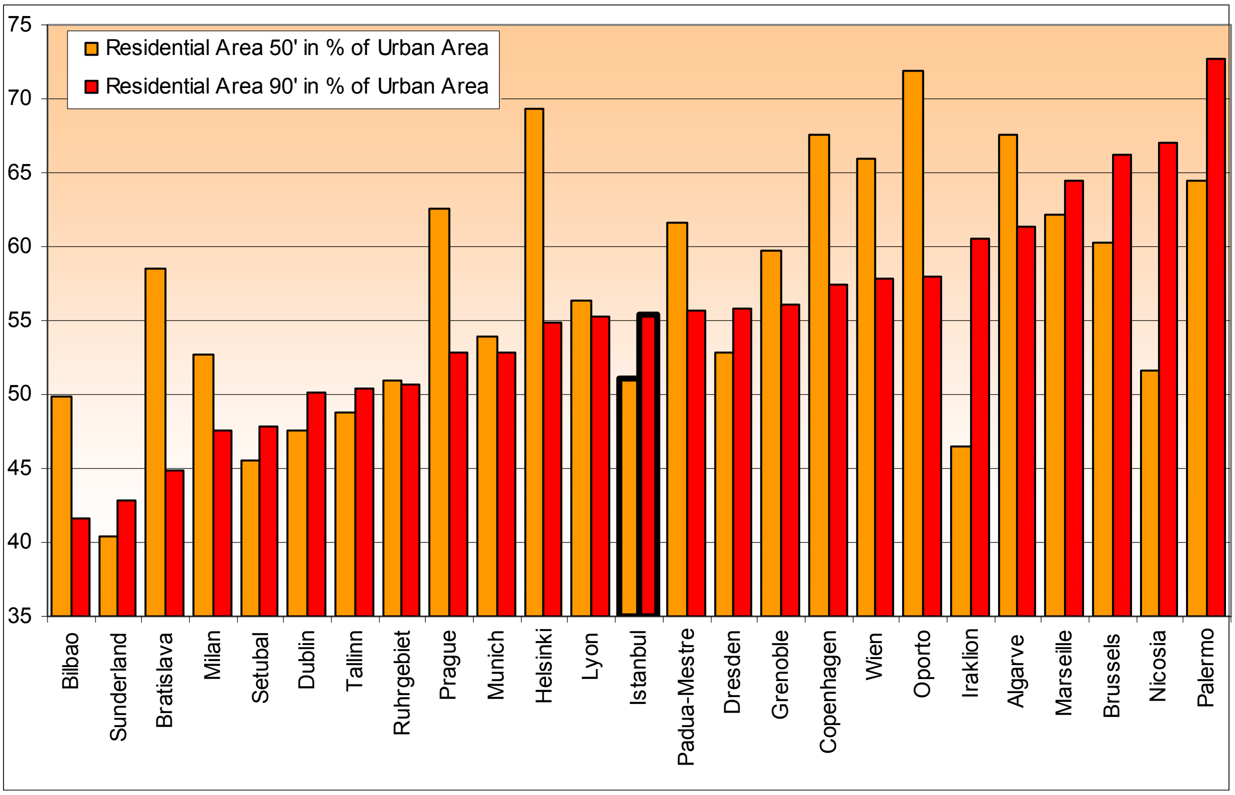


Figure 187*: values on "MOLAND"-Cities for residential areas relating to the urbanised area.*

Figure 187 shows interesting facts concerning the internal structures of the MOLAND-cities. 14 cities changed residential surface for business areas or infrastructure while 11 have a growth in residences – means a change more to a living city. Istanbul is ranking in the middle and can be compared by its structural dynamic and the relative values to Dresden – on different absolute level of course. The smallest residential percentage can be detected at Bilbao with an ongoing trend to less residential areas. On opposite Palermo is covered by residential area on high level with an ongoing increasing trend. The most extreme changing cities towards to more residential are Nicosia and Iraklion, in case of loosing residential percentages it is Bilbao, Bratislava, Prague Helsinki and Oporto. I am not able to analyse here the details in such an overview, there is of course the trend to suburban growth in residences and the use of cities for business.

The logical consequence of this is, with the exception of infrastructural space, an inverted trend of the industrialised areas. This is shown in figure 188, which is more or less an inverted result of figure 187.

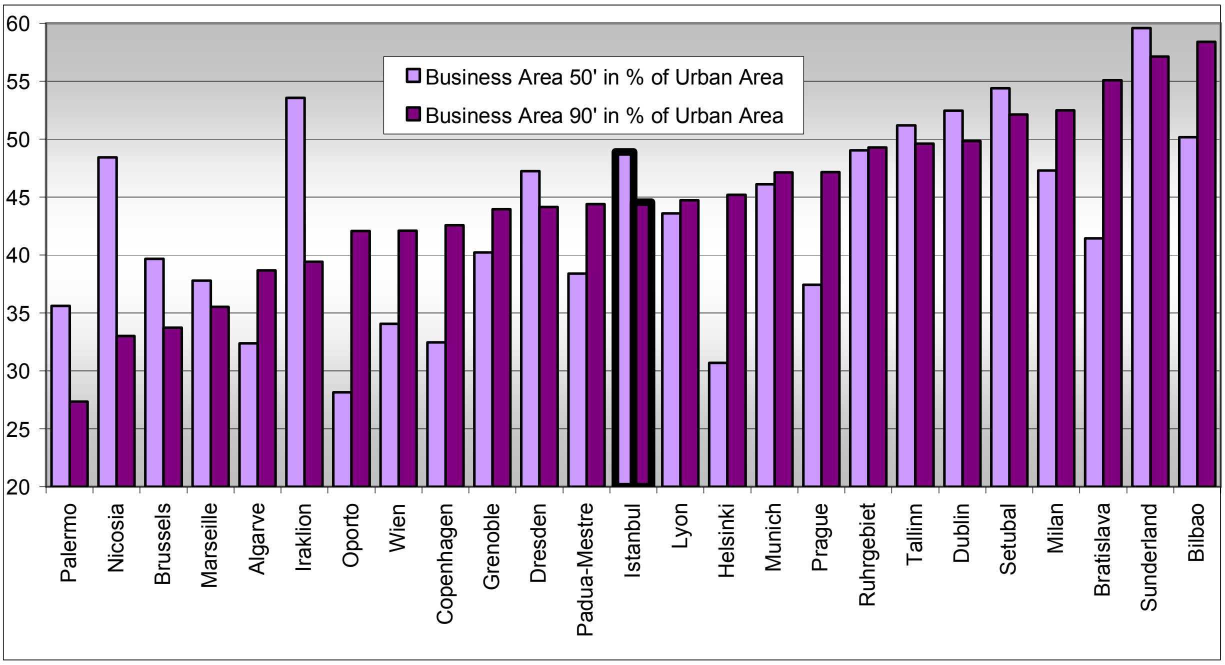


Figure 188: *values on "MOLAND"-Cities for business areas relateing to the urbanised area.*

Concerning the business values, Istanbul is again ranking in the middle of the MOLAND-cities with a small negative trend. As mentioned above, these trends are inverted to the residential values and show the direct connection.

As a common interpretation of figure 187 and 188, Istanbul seems to change its internal structure in a sliding way, not as dramatically as other cities. Might be the high developed electronic industry with smaller spatial needs replace other industrial sectors. This covers the trend. The income due to tourism does not reflected in the growth of industrial space. Moreover, the trend in structural change seems reliable for a sustainable development.

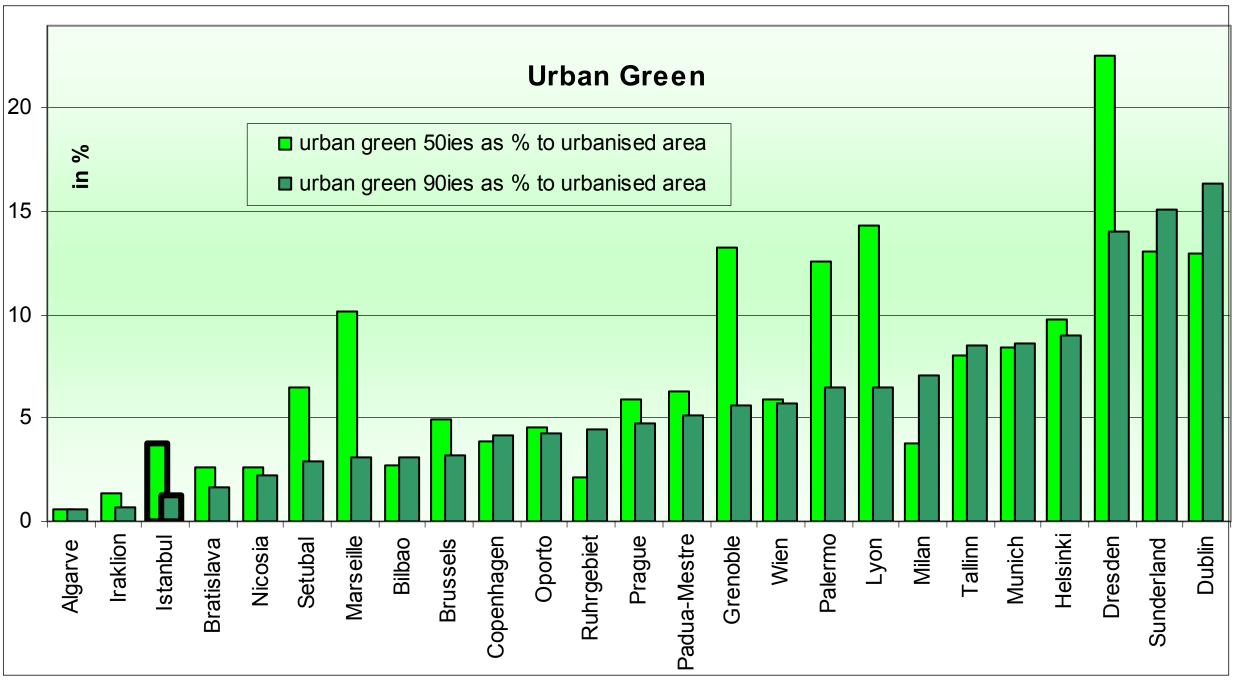


Figure 189: *relative amount on urban green in "MOLAND"-Cities relating to the urbanised area.*

Comparing the urban green areas in figure 189, Istanbul shows a rather poor result. The loss of this type of area is related to the small absolute amount of such urban green. Urban green is an important element for a healthy urban environment. By that, Dublin has the best environmental conditions. The average of all the cities is about 5% while Istanbul only counts 1.2% of the total urban area. In fact, this is a relative value. In absolute figures using the size in ha it grew in Istanbul. However, the increase of urban green could not compete with the sprawl of the built-up area. This points out the lack of planning.

The increase of urban green should be an important part of the city planning policy; meanwhile in most cases it is defined as lost space and continuously running costs for maintenance. So far, urban green mostly depends on the efforts of the local authorities. As an example, Milan and the Ruhrgebiet have made big efforts to improve the urban conditions by increasing the urban green. This is visible in figure 189. Finally, the environmental conditions in Istanbul are still resilience enough to build up a strategy for more urban green. There are environmental facts (e.g. water, climate, soil) that are convenient to support the increase of urban green. Other cities (e.g. Iraklion and Nicosia) have worse conditions. Indeed there has to be established a management for the maintenance of parks and other green spaces which needs manpower and financial resources.

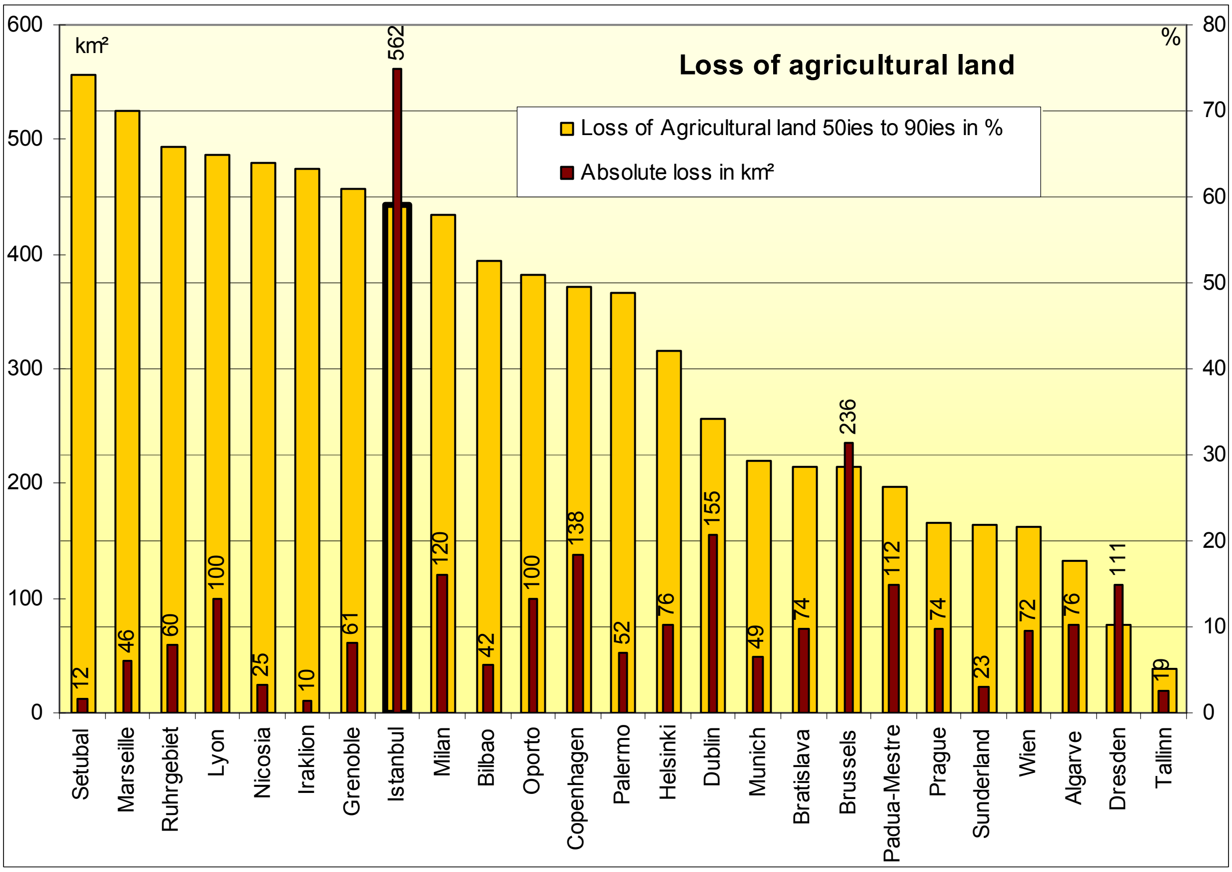


Figure 190: *loss of agricultural land in "MOLAND"-cities based on class 2.* related to their original size and as absolute values of lost area*

Regarding urban growth, we have to compare the lost areas, which in most cases concern from agricultural land. An overview is given in figure 190, which points out Istanbul on a high level of loss in agricultural land. The percentage is computed by the lost area in relation to the size of agricultural land in the 50ies. So far, the absolute size in the oldest period is an important fact for this result. Agricultural areas and the size of the study area influence these results. Regarding the absolute values, Istanbul has an averaged loss of 562 ha which is 5 times higher than other megacities show. The loss was also compensated by using "natural" areas, depending on the availability for urban development in the analysed region. In figure 192, a combined analysis is given to point out the natural, agricultural, and urban development.

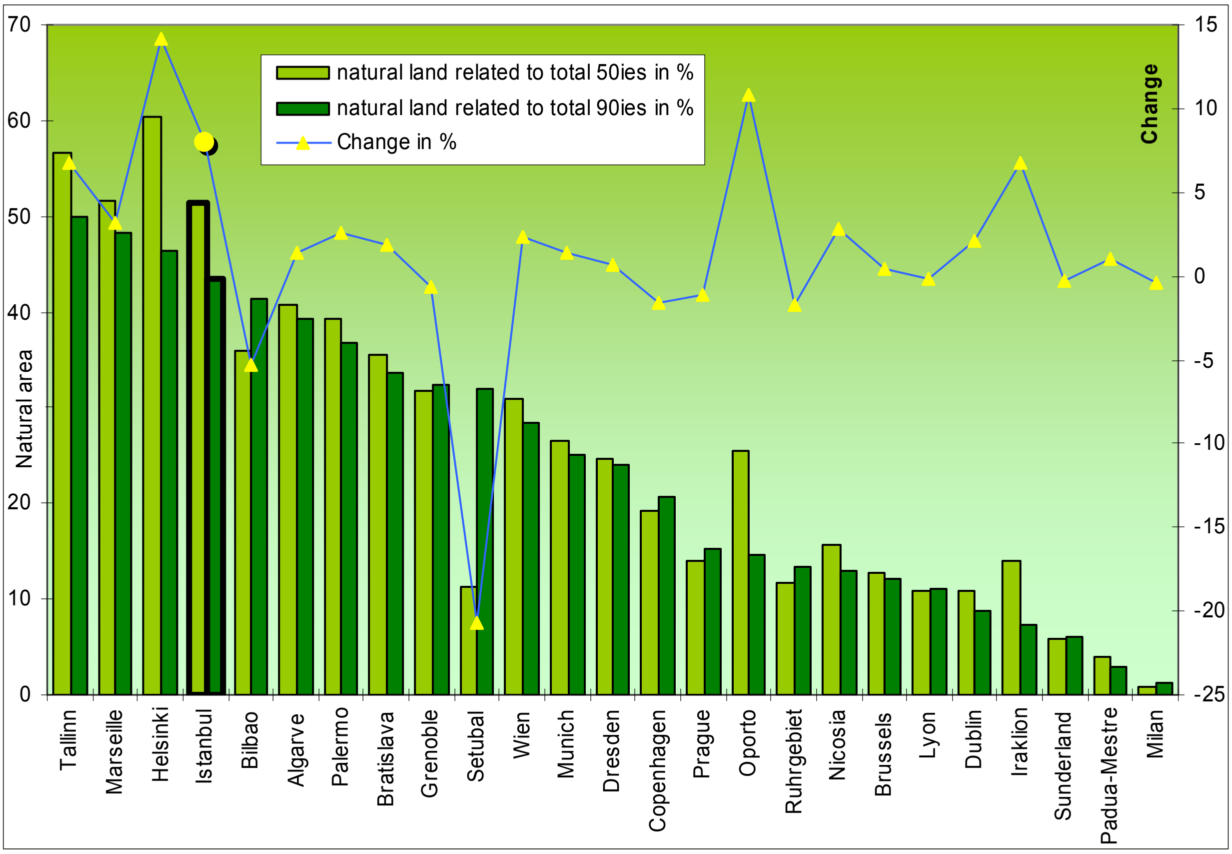


Figure 191: *relative loss of natural land in "MOLAND"-cities computed by the classes 3, 4, and 5 with exception of water bodies related to the total size in the 50ies and the change rate.*

Figure 191 shows the loss of "natural" areas, which contains forests, pastures, open grassland and all the other non-agricultural and non-urban areas except the water-bodies. It is computed in relation to the size of the study area to compare beside the loss also the environmental trend of the cities. Istanbul shows a relatively high level of natural areas that is based on the big amount of forests, which have not been really affected by urban sprawl, and open grass land, that became partly urban area. In fact, there is a loss of 8% of such areas, which moves Istanbul to the third place in the statistics. Istanbul has lost 170 km² of natural land while in agriculture area 562 km² have been lost. In the absolute amount of km², Istanbul has the highest loss of natural space due to urban sprawl of all the cities. Some of the MOLAND-cities show an increase in natural area based on a transformation from agricultural land to natural classes. The urban sprawl needs of available land; this must not be agricultural one at all.

Comparing figure 190 with 191, there can bee seen a correlation between agricultural loss and the conservation of natural areas – not so Istanbul. Istanbul is ranking in both on a medium to high level. To analyse the details of land-use transformation, figure 192 aims to combine both. The total area sizes are displayed inside the bar while the three groups urban area, agricultural land and natural spaces together build the 100% level.

Figure 192 points out more clearly where the urban area was placed. In nearly all the cases agricultural land was the main source for the urbanisation. There are only a few exceptions like Setubal, that spread its urban structures into agriculture land and parallel to that changed nature land to agriculture. May be farming in this areas were stopped by economic means due to small parcel sizes. This reason might be responsible for the immense loss of agricultural land in other cases too. Lyon as an example based its urbanisation on agricultural land totally. Urbanisation only based on natural area cannot be seen anywhere. There is not any city, where agriculture was not influenced.

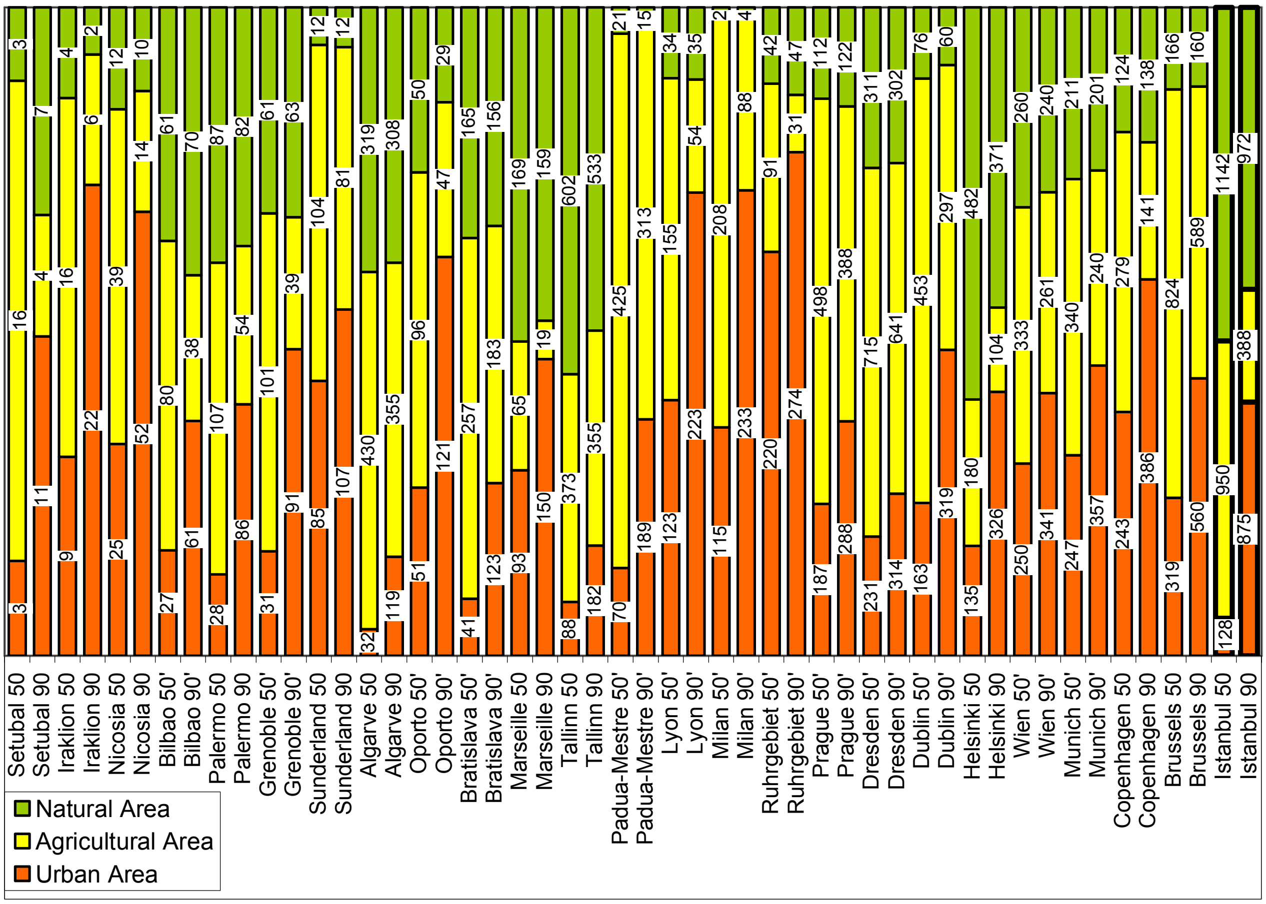


Figure 192: *land-use transformation in "MOLAND"-cities*

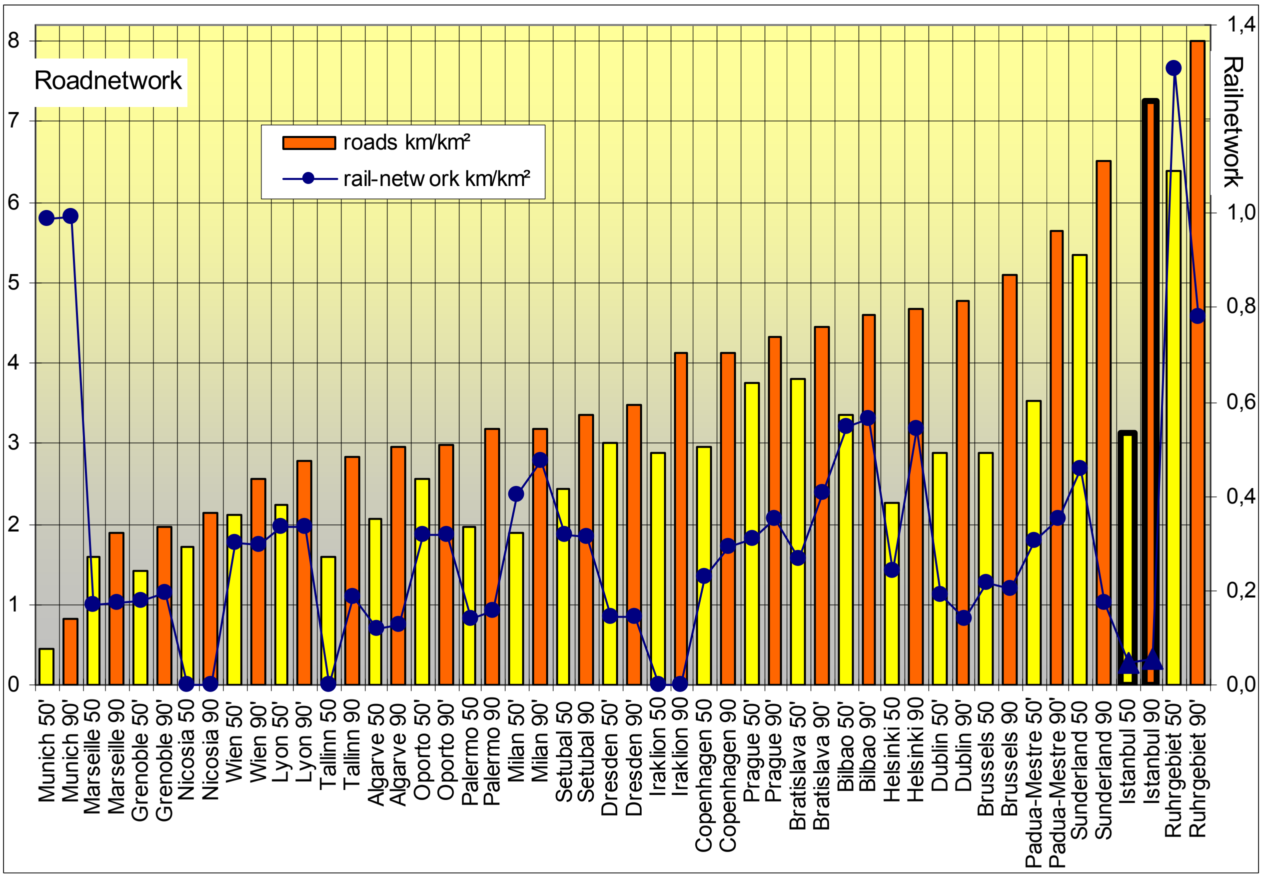


Figure 193: *change of the transportation network in "MOLAND"-cities*

Figure 193 highlights Istanbul as the second highly developed city concerning the road-network, just behind the Ruhrgebiet. In the 50ies, Istanbul was ranking on place 6. The growth-rate is the highest of all the cities, in a relative view only Helsinki has a stronger growth in the road network. As discussed before, Istanbul's transportation is mainly based on cars and busses. This corresponds with the interpretations.

On the other hand, the rail network in Istanbul is on a very low level concerning its distribution. It has not been significantly increased within the last 50 years. Only Nicosia and Iraklion, which have not any Tram or Railway System, are behind Istanbul. Munich, with a strong rail network and a relatively small road network, shows the advantage of public transportation. In some big European cities this kind of transportation is solved efficiently. Many MOLAND-cities have increased their rail network, not so the Ruhrgebiet where mostly industrial rail tracks were redesigned for public transport. This shows the urgent needs for working on this thematic in order to keep pace with other European transportation strategies. However, the bus-system in Istanbul is well developed and helps to minimize the daily traffic jams. In some cases, due to discussions between city developers on international conferences, the "bus-model" of Istanbul has been discussed as a solution for other cities with similar difficulties like Istanbul has.

6.3 Istanbul in relation to Turkish and neighbouring cities

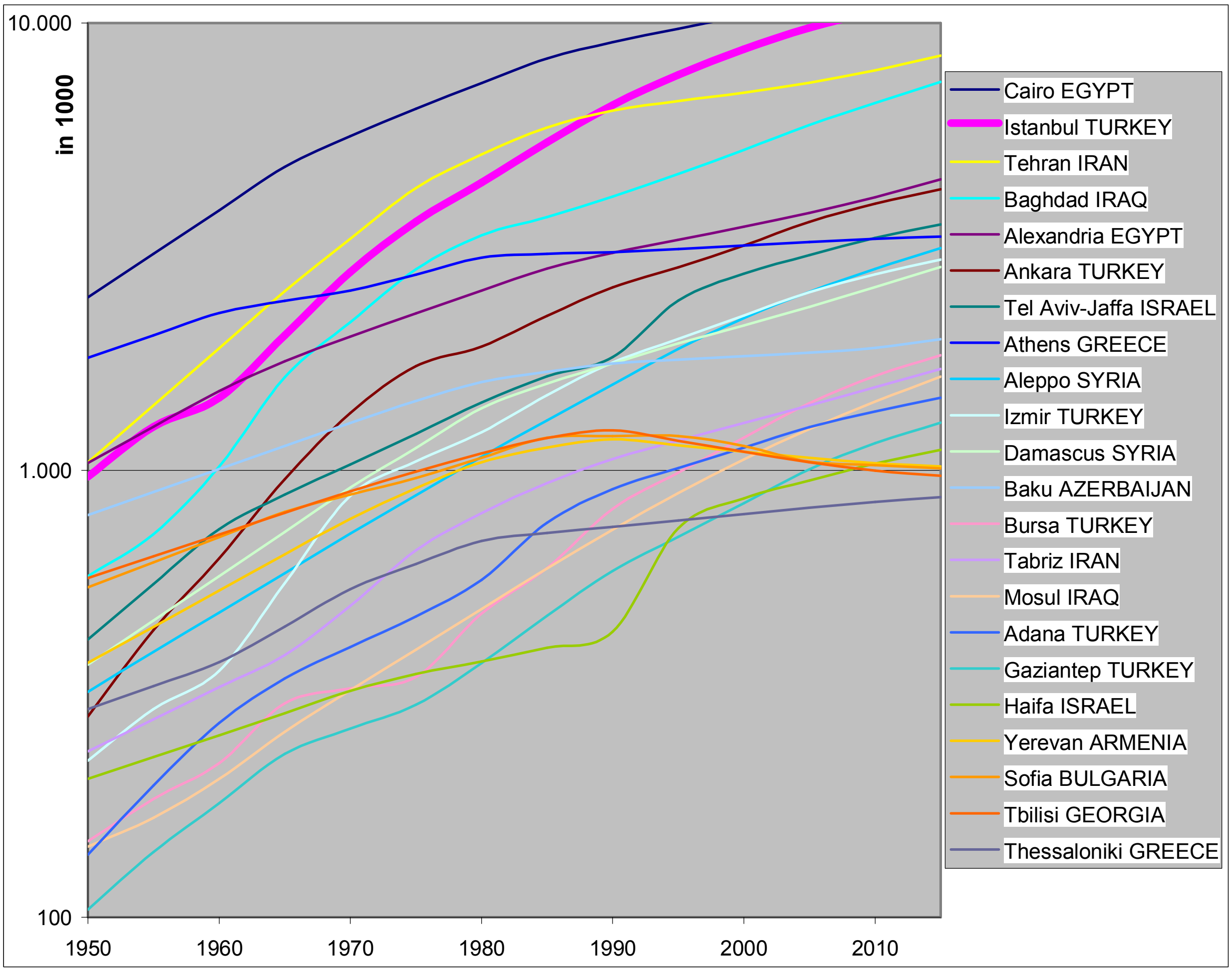


Figure 194: *Growth of inhabitants of neighbouring agglomerations on logarithmic scale, based on Data of the World Urbanisation Prospects - Revision 2003*

Many of the selected cities have a similar growth; especially Istanbul and Cairo correlate on their absolute level. Athens stopped its growth at the end of the 70ies while Thessaloniki decelerates the population growth at the same time. Yerevan, Sofia, Baku and Tbilisi show the collapse of socialism in their countries since end of 80ies as a negative trend due to a re-privatisation of agricultural lands and a escape from the cities. The cities in Israel stopped their internal growth at the end of the 80ies, but they profit from the break down of Socialism in the former Soviet-Union and received a new impulse of immigrants, clearly to be seen in the graphic. Therefore, these cities are excluded from further analyses. Grouping the cities related of the state of development would result in the statement that many of these cities can be seen as indicator for a threshold country. However, a look at the growth-rates of these cities should be done first to compare the results independent from their absolute size.

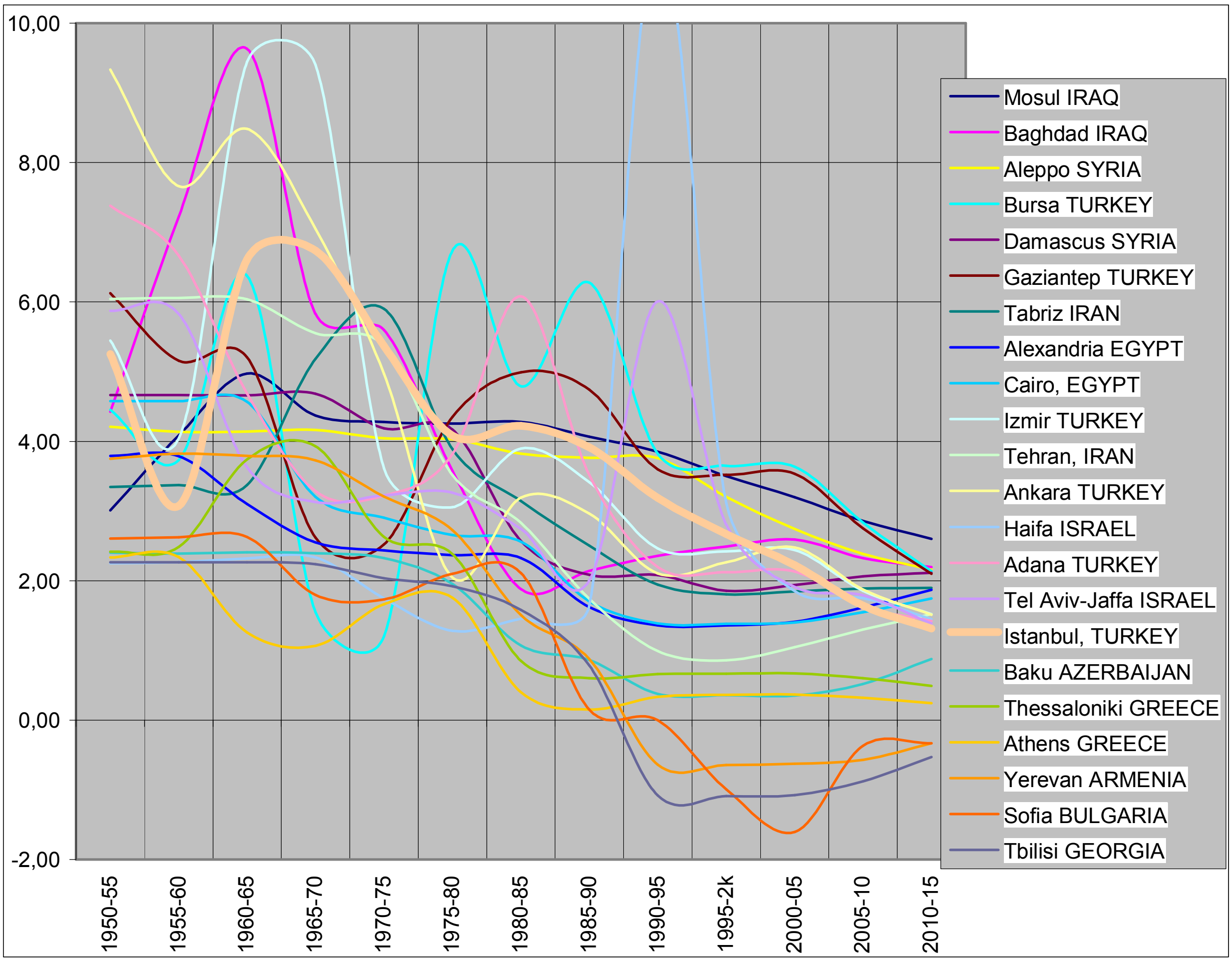


Figure 195: *Annual growth-rates of the neighboured agglomerations, based on Data of the World Urbanisation Prospects - Revision 2003*

This graphic shows the actual growth-rates per year. Istanbul with a annual rate of 1.32 in 2015 moves closer to the level of Greece cities while all the other Turkish cities are still growing. This will be analysed separately. Since the 1980ies, Istanbul has a relatively constant development, which documents a sustainable change. Compared to the international Mega-cities' growth, (see Figure 182 and 183), the annual growth-rate is smaller in average.

Strong changes in the growth-rate can be found for nearly every city initiated by political or social impacts, which cannot discussed in detail in this study. For Istanbul, it will be done in the Turkish context, for some others it was mentioned already. Surprising, however, is the growth of Mosul/Iraq, with a homogeneous rate-change in the last decades and the highest-level forcasted for 2015. For Egypt-cities and for former Soviet-Union cities an increase in the annual rate is expected.

It can be said that in the prognosis, all the cities observed will become more similar with an average annual growth-rate of about 2%. Exceptions are Tbilisi, Sofia, Yerevan, Athens, Thessaloniki and Baku. Except for the two cities in Israel that grow by ongoing immigration, all analysed cities are part of the Islamic world in the near east and developing towards to become industrialised and well developed.

What is the situation like in Turkey itself and Istanbul as its business centre? Figure 196 shows, based on the data of the World's urbanisation Prospect 2003, the 6 biggest cities in Turkey. Referring to figure 9 and 10 of the introduction of this study, these cities belong to the most densely populated regions in Turkey. They are centres for immigration of the hinterland, mainly of the eastern and northern Anatolian region. While Istanbul, Bursa and Izmir in the western part of Turkey are relatively close to each other, Adana and Gaziantep are neighbours in the southern Part of the Mediterranean Turkey. Ankara is placed in the western part of the central Anatolian plateau.

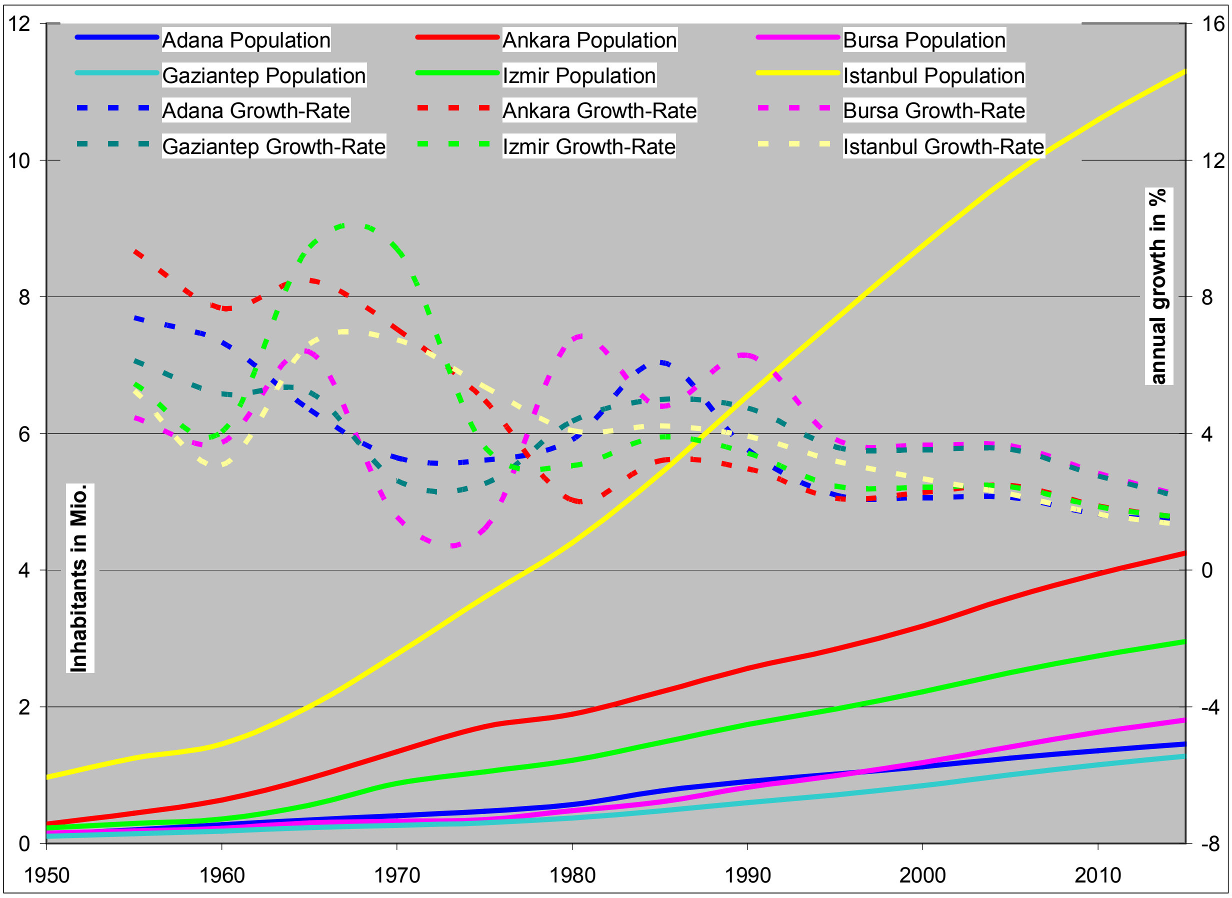


Figure 196: *Annual growth-rates of Turkish agglomerations, based on Data of the World Urbanisation Prospects - Revision 2003*

During the last 50 years, Istanbul's growth-rate was on similar level as all cities are and this seems to continue in future. Between 1960 and 1975, strong changes in the annual growth-rate of all the cities can be detected. The industrialisation in Izmir was strong and lead to a high growth-rate around 1965. Istanbul and Bursa had a similar increase in this time. The first economical problems around 1975 stopped this effect, after 1980, it started again. Bursa benefits most from the second step of industrialisation with two impulses in 1980 and 1990. Close to Istanbul, Bursa is in a kind of competition due to foreign investments. There is a kind of changing trends to one of the cities and vice versa.

Adana, as a strong developing industrial but more touristic region, has been profiting from foreign investments since 1980. Gaziantep however does not show such extreme changes; this city develops with small industry and agricultural production on irrigated land, supported by state water management with dams. Ankara as the most Turkish administrative city profits only indirectly from industrialisation and shows the trends in a smoothed way.

The strongest growing city, prognosticated for the future, is Bursa. Since 1995, it has been the fourth biggest city in Turkey. Of all the analysed six cities, Istanbul will have the smallest annual growth in the year 2015.

7 Summarised Interpretation

Istanbul has left the years of strongest increase behind; nevertheless, demographic trends have shown that Istanbul is still a strong growing Mega-city relating to others in the world. While Istanbul, based on the number of inhabitants, was not among the top 30 until 1980, since 1990 Istanbul climbs up the ranking slowly and aims to reach place 19 in 2015. However, more interesting is the annual growth-rate that shows Istanbul was the eighth strongest growing city in the 50ies, increasing the rate to place 3 at the beginning of the eighties and dropped back to place 7 in 2000. This refelcts what can be seen in the urban sprawl too: Istanbul's strongest increase in population and urbanised area was in the period between 1968 and 1988. The population growth rate decreased constantly and demonstrates the socio-economic state of Istanbul as a kind of threshold city.

Comparing with the six biggest Turkish cities, Istanbul has meanwhile the lowest annual growth rate. However, it has to be mentioned that all cities profit from the industrialisation in the southern or western part of Anatolia. The Migration from the east and the north into those areas still persisting. Comparing the development of the growth-rates to neighbour big cities, Istanbul has similarity to many cities in the near east and is ranking on a lower level. With the exception of cities in Israel and Greece, Istanbul seems to be the best-developed city in this observed area with a trend towards European standards, but still far away from European standards in many aspects.

This was proved by comparisons among different MOLAND-cities. Istanbul relatively and absolutely is the most sprawling city in the past and today. With a sprawl of nearly 800% Istanbul stands more than 6 times above the average of the MOLAND-cities. Focusing on some details, like the amount and change in business and residential areas in the analysed periods, Istanbul is more averaged. Regarding the loss of agricultural areas, Istanbul is number one in absolute values but similar by relative analysis to other cities. The loss of natural areas is small and persists on a relatively high percentage relating to the study area. Amazing is the increase of the road-density of Istanbul. With the highest increase, Istanbul is behind the Ruhrgebiet on the second place using the computed raod density. Istanbuls railway network is poor. Here the main traffic problem of Istanbul with a lack of public transport like tram or railway is to be found. Public transport is nearly completely managed by busses. Green urban area is also something, where Istanbul shows a big deficit comparing to European cities. Decreasing even this few areas shows lack of planning and political willingness. However, Iraklion and Algarve are still behind Istanbul.

Analysing Istanbul's land-use change in detail, as already done by using the MOLAND data, the strongest change between 1968 and 1988 can be detected, which corresponds to the previously analysed growth-rates and also the change within other MOLAND-cities. Nevertheless, two phenomena can be detected. First there is a strong increase in both, residential and business area by the total size, and second a change within the residential areas from less dense structure to high dense constructions. This means that Istanbul grows in four dimensions, in space, in height and in density. Residential area in some cases was replaced by business area, especially in the shopping areas or tourist regions, where shops, offices, and very different types of agencies repressed residential use. Multiple use in the buildings can still be found frequently. Such urban sprawl was mainly based on former agricultural areas. The well-protected forest did not lose important parts and other natural areas survive on a high level. The trends, both urban types, residential and business areas show a decrease in their annual spatial growth rate. The trend to more dense residential areas seems to go on.

Focusing on the differences between the European side and Asian side, it can be said that the main business area is placed west of the Bosporus while the Anatolian side is commonly of residencial use. The urban growth however, did not go homogeneously on both sides. The European side was the most urbanised of both in the first two periods analysed. The eastern part started to grow rapidly with the construction of the bridges; finally, the development crossed the Bosporus by using this connection. Indeed these infrastructural lines encouraged people to build their homes on the Asian side where the real estate value is much lower than on the

European one. This was the reason for an enormous sprawl after the 1980ies that finally equalized the size of both parts of Istanbul. The urbanisation follows the flat terrain along the Marmara Sea, which was mainly used for agriculture at beginning. The corridor Istanbul-Izmit-Ankara, defined by the axis of the highway on the Asian side, shows that in the last decade a growth of industry on both sides of this corridor took place. A new airport offering international and domestic flights was built there. The main business centre, however, is still on the European side where in the meantime also skyscrapers of international companies and banks represent the modern Istanbul. This part is also the most frequently visited one for business or touristic matter.

Combining population growth and urban sprawl, changes in the population to a higher dense level can be detected. This does not consider the residential structure. Using the combination of demographic non-spatial data and land-use data for detailed classes, a simple model was implemented to estimate the population density based on weighted factors. In total, there is an increase of the population density due to the increase of the high dense residential areas. More details can be assumed in that way, that the number of people living in flat decreases and more single households are established. The result is amazing but after all not surprising. This is amplified by the trend, having aweekend flat like in Büyükcekmece, and a flat for the daily business in the city. By that, the increase of the city is disproportionately high, surely a lack of planning and political willingness.

Beside the poor activities of the local authorities, there is still the existing problem of the Gecécondu areas. These areas are difficult to detect without deeper knowledge. These areas are only of temporary character due to the post-legalisation of the political authorities during election periods. Beside some radical single actions, this problem is still unsolved. In the meantime most Gececondus look like normal houses and not anymore as poor as in former times. These areas still reflect the ongoing migration to Istanbul, not as strong as in the previous decades, but still on a high level. In some cases, also “rich” Gececondu areas were bilt as a kind of non-legalised villas in protected areas. Local authorities have stopped such activities in most cases.

Focusing on the increase of the transportation network, the number of roads is on a very high level and competes with the urban sprawl, more than that; the new residential areas are strongly cut by roads. This reflects the common use of private cars in those area. The Asian side grew stronger than the European side, while specific structures persist in the older parts of Istanbul. On the other hand, the rail-network did not increase significantly and remains on a very low level. Due to this fact, the public transport by train, tram or subway is without greater importance for Istanbul. Busses, minibuses, taxis, water-taxis, and ferries manage public transport with a limited capacity. The digitised map of the bus-stops show the wideness of this bus-net, which is managed by the municipality.

Regarding the future trends of Istanbul, growth slows down and the most agricultural fields in the study area will be changed to other use. The forest areas are well protected by state forest organisations and in some parts by the army. There is a slight change inside the urban area from business to residential structures, but on small level. Heavy industry was reorganised by moving to the suburbs and smaller industry and services entered the inner city. Industry will remain as the backbone of income of Istanbul’s population in future.

8 Data-Utilisation

In this study and during the entire MOLAND-Project, a big amount of data has been collected and others generated in order to fulfil the needs of the project requirements and to provide this study with the basics presented. These data are of different scale, resolution, accuracy and content, some of them are images or rasters; others are vectors and a third group are non-spatial data like demographic statistics and others. There is a big and various data pool to develop new studies, projects and real strategic planning. The interest in these data is different and due to its variability not easy to manage and to provide in a suitable form. Nevertheless, there is a huge number of possibilities to use these data and to create new projects based on them.

8.1 Future of the MOLAND-project

A common strategy of all MOLAND and MURBANDY cities is the more detailed comparison of the cities to exchange specific trends and mechanisms in order to provide European wide scenarios. The JRC itself has changed its internal organizing structure during the project, the former SAI (Space Application Institute) was reorganized and the support for MOLAND belongs to the Land-Management Unit in the Institute for Environment and Sustainability .

The European Commission, however, does not finance the MOLAND-Project anymore, new projects and additional analyses are managed by regional authorities with support of the JRC and are financed by pools of national or international organisations. Based on this fact only few new areas, mainly corridors and wider agglomerations, have been added to the cities already mentioned. Such are the corridor “Prague-Dresden”, the regions “Northern Ireland and Border Countries”, “Friuli-Venezia-Giulia”, “Tallin-Harjumaa-Via Baltica” and the inner alpine corridor “France-Italy”.

This Land-Management Unit, namely Carlo Lavalle, understands itself as an interface between end-users, service-providers, scientific institutions and as management service with validation capabilities. They are open to support any study and project concerning urban development. Also for Istanbul, contacts and further cooperation have been discussed to find a possibility to utilize the data and results for planning purposes. This is mentioned in chapter 8.3 and 8.4.

Furthermore, the JRC supports the CORINE 2000 project, a European wide updating of the Land-cover by the new CORINE database, which covers the MOLAND-Legendary. The launch of the CORINE–project for Turkey that will also cover the study area on a smaller scale (1:50k) is under preparation as well.

New projects have been launched to meet the actual problems of potential end-users. Like this, the TRIDENT project is one of the separetly-funded projects. TRIDENT (Three-Dimensional Restitution via Internet of Digital Elevation Networks in Towns) Project is a shared cost action under the IST Programme (Theme 1.1.2) of DG Information Society (ex-DG XIII). The aim of TRIDENT is to develop a prototype system for 3D urban cartography, for three European cities.

The dramatic events in Europe during the floods in the summer of 2002 have triggered several initiatives to improve preparedness and response to extreme weather conditions. It has become clear that, while continuing the discussions on the effectiveness of measures apt to limiting the anthropogenic contributions to climate change in the long term, concrete actions should be initiated to cope with the impacts of extreme events in the short- and medium term. The European Commission has responded by setting up financial and aid programmes in the frame of EU regional development and environmental policies. In parallel, DG-JRC has established a framework of activities relating to weather driven natural hazards to contribute to the reduction and better control of their catastrophic impacts, in collaboration with research organisations and national authorities. MOLAND contributes to the JRC Action on Weather Driven Natural Hazards - Prediction and Mitigation with a newly set-up research activity, aiming to evaluate spatial planning options in the context of adaptation to extreme weather events and sustainable development in urban areas. This research work is based on the combination of hydrological and land-use modelling and aims at two main objectives:

- to assess the effectiveness of mitigation and adaptation measures in the context of wider regional development policies;
- to define spatial planning options for the adaptation to weather driven natural hazards.

The work focuses on two interlinked elements for the adaptation to climate change impacts:

- the catchment based hydrological rainfall-runoff model LISFLOOD adapted to scenario modelling, flood forecasting and flood plain inundation modelling;
- the MOLAND land use forecast model for urban and regional growth, to evaluate spatial planning policies and measuring reduction of natural risks.

The scientific network of the JRC is amazing and will support many scientific institutions with their data and methods to analyse urban dynamics on a model-based program. Such strategies, which will finally produce the scenarios mentioned, are treated in the following chapter.

8.2 Scientific use of the data

There are many possibilities for using these data by different scientific aspects, first of all from the JRC that is the owner of most of the here presented data sources and the extracted results. There are different groups with various strategies that are interested to continue on the MOLAND-Istanbul. There also possible further researches to be proposed to different foundations, i.e. the German BMBF with the Mega-Cities Program, launched in 2004 and a similar program, set up in 2005 by the DFG.

8.2.1 Modelling of Future Urban and Regional Land Use Development

As mentioned before, further Scenarios are created in the JRC (Joint Research Centre) of the European Commission across all analysed areas by using models. Such scenarios can only estimate the further development, but help to make the decision makers sensitive and aware of the upcoming tasks and resulting problems. One scenario, created by the JRC in cooperation with RISK (Research Institute for Knowledge Systems, Ltd.) for the Netherlands, is shown in figure 197.

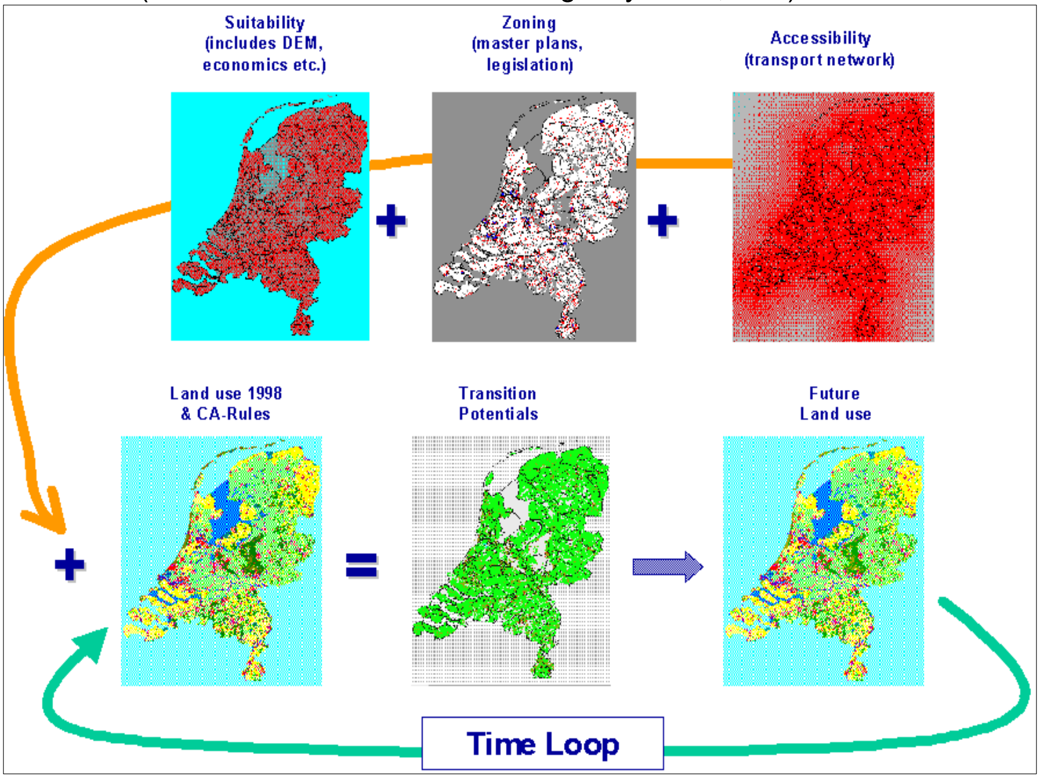


Figure 197: *Scheme of a Time-Loop Scenario for the planning impact (Lavalle, C., Kemper, G., et al 2003)*

One of the most useful components of the MOLAND Project, concerning spatial planning, is the use of a spatial dynamics model for to simulate future urban and regional growth. Urban modelling is of particular interest to urban and regional planners, since the future impact of actions and policies are important, but usually quite difficult to simulate.

The MOLAND urban growth modelling tool was developed by the company RIKS, under contract with the MOLAND Project. The model, which is based on dynamic spatial systems called "cellular automata", takes different types of spatially referenced digital data as input:

- Land use maps, showing the distribution of land use types in the area of interest. These maps are derived from the MOLAND reference and historical land use databases.
- Suitability maps, showing the inherent suitability of the area of interest for different land use types. These maps are created using an overlay analysis of maps of various physical, environmental, and institutional factors.
- Zoning maps, showing the zoning status (i.e. legal constraints) for various land uses of the area of interest. These maps are derived from available planning maps (e.g. master

plans, zoning plans, designated areas, protected areas, historic sites, natural reserves, land ownership).

- Accessibility maps, showing the accessibility to transportation networks for the area of interest. These maps are computed from the MOLAND land use and transportation network databases, based on the importance of access to transport networks for the various land use.
- Socio-economic data for the main administrative regions of the area of interest, comprising demographic statistics (i.e. population and income), and data on production and employment for the four main economic sectors (i.e. agriculture, industry, commerce, and services).

The output from the MOLAND urban model are maps showing the evolution of land use in the area of interest predicted, for the next twenty years. Varying the inputs into the MOLAND urban model (e.g. zoning status, transport networks), the model can be used as a powerful planning tool to explore the future urban and regional development of the area of interest in a realistic way, under alternative spatial planning and policy scenarios (including the scenario of no-planning). The MOLAND urban growth model is based on a spatial dynamic system called "cellular automation". The main components of the model are:

- A two-dimensional grid or cell space, each grid-cell having its own unique set of attributes (i.e. land use, suitability, zoning, accessibility, socio-economic);
- A cell neighbourhood, consisting of a circular area of radius eight pixels around each cell;
- A set of discrete cell states (i.e. 24 MOLAND land use classes);
- Transition rules (describe the effect of neighbouring cells on central cell).

The twenty-four land use classes used in the MOLAND urban growth model comprise nine active functions, eight passive functions, one transitional state, and six fixed features. The active functions are the urban land use that changes in direct response to urban growth. The passive functions participate in the land use dynamics, but change in response to land taken or abandoned by the active functions. The transitional state (i.e. construction site) represents a transition between two functions. The fixed features do not change, but affect the dynamics of the active land uses. All the twenty-four land use classes used by the MOLAND model are listed below:

Nine active functions

- Residential continuous dense urban fabric
- Residential continuous medium-dense urban fabric
- Residential discontinuous urban fabric
- Residential discontinuous sparse urban fabric
- Industrial areas
- Commercial units
- Public and private services
- Port areas
- Abandoned land

Eight passive functions

- Arable land
- Permanent crops
- Pastures
- Heterogeneous agricultural areas
- Forests
- Shrub
- Sparsely vegetated areas
- Wetlands

One transitional state

- Construction site

Six fixed features

- Road and rail network
- Airport
- Mineral extraction sites
- Dump sites
- Artificial non-agricultural vegetated areas
- Water bodies

In the MOLAND urban growth model, the central concept that drives the spatial dynamics of an area of interest is that the land use of a point or cell at any time is directly influenced by the neighbouring land uses. This neighbourhood effect represents the attraction and repulsion effects of neighbouring land uses on the central cell. In the MOLAND model each land use function has a set of transition rules, which quantify to which degree it is affected by neighbours of the other land use functions, for example, the two transition rules that describe the effect on MOLAND class "Residential discontinuous sparse urban fabric" of neighbouring cells of (a) the same land use type, and (b) of Industrial areas,
Currently the MOLAND urban model is being tested and calibrated for a Europe-wide network of cities and regions, using the MOLAND land use and transport databases and ancillary data acquired from the local authorities. A new, more powerful version of the MOLAND urban growth model, which incorporates socio-economic information and which will be used to simulate the interactions between cities and their surrounding regions, will soon be completed. This model will be tested on MOLAND study areas where extensive regional changes in land use are propable, due to major economic and infrastructural developments.

Landscape fragmentation refers to the environmental impact of urban expansion on the spatial structure of urban landscapes. Fragmentation of the countryside as a result of land use planning and management decisions made at local and regional levels, is identified in the Sixth Environment Action Programme of the European Community, for example, as a major environmental issue in the EU Member States. As a part of the MOLAND Project of the European Commissions Joint Research Centre, advanced spatial analysis is applied to the land use databases of the MOLAND study areas, in order to quantify and monitor landscape fragmentation. This way, indicators of the quality of life for citizens, as well as information about the impact of urbanisation on nature and biodiversity, are derived. Presenting the results as maps, different regions as well as different parts of the same region can be visually compared in terms of their landscape fragmentation.

8.2.2 Analysis of Fragmentation of Urban Landscapes

One aspect of landscape fragmentation, which is particularly important in urban environments, is the composition of the total urban edge. The total urban edge refers to the total length of the edge between urban fabric and all the other land use classes in the landscape. Analysis of the composition of the total urban edge is used to identify the land cover classes directly adjacent to urban fabric. This information can be used to compare different cities in terms of, for example, the potential negative impact of major traffic corridors on residential areas (e.g. noise, air pollution).

Another environmental indicator that is derived from the fragmentation analysis of the MOLAND databases is the Green Edge Index. This index shows how much of urban fabric of a region is adjacent to (i.e. has an edge with) vegetated areas. Areas with a high value for the index will have greater access to recreational facilities (e.g. gardens, parks, wooded areas, sports fields), and will be less affected by noise and air pollution from traffic. A basic view on this parameter is given in chapter 6.2

Another environmental indicator that is derived from the fragmentation analysis of the MOLAND database is the Habitat Suitability Index. This index shows the shape complexity of vegetated areas (e.g. woodland, arable land, pastures) in a landscape. The shape complexity of a vegetated area is one of the characteristics determining the suitability of that area as a natural habitat. This is because many species of wildlife tend to live at the edges of vegetated areas. Areas with complex shapes have much more edge than areas with simple shapes. Thus, the more complex the shapes of vegetated areas in a landscape are, the more suitable are those areas as habitats for edge-dwelling natural species.

8.2.3 Other potential scientific co-operations

First there are many strategies inside the Photogrammetric Division of the ITÜ around Prof. Orhan Altan, to use the MOLAND for Istanbul as a Meta-Database, building the basis for additional studies, more detailed and accurate – however, to be connected into a wider context. These studies can become more concrete based on the bigger scale of these data. One project proposed aims at analysing the city-structure along the Istiklal Caddesi, using close-range photogrammetry, laser-scanning, aerial images and determining the real use of the buildings in order to combine land-use and cultural heritage for development purposes. This main business street, from Taxim-Square along Galata-Serail to the Galata-Bridge, is the main shopping district with many historical buildings, equally liked by citizens and tourists.

Other projects aim at using the MOLAND-Data on mobile PC-Devices in order to do field-mapping and combined with sensors a Mobile Mapping System to update the extracted data and measure values like environmental parameters. GPS and Mobile GIS are basic components with the final strategy to create basic structures for a location-based service (LBS).

MOLAND results were integrated in a proposal by INIFES (Internationales Institut für empirische Sozialökonomie) under the BMBF Megacities-Programm, to perform a detailed study for SWOT-Analyses. A SWOT-Analysis combines a Strength-Weakness-Analysis and an Opportunities-Threats-Analysis. A Strength-Weakness-Analysis can provide information about Istanbul in sustainable urban development comparable to urban settlements. Research characteristics are e.g. socio-economic structure, diversity of life styles/subcultures, distribution of income, segmentation of society, crime rate, population growth, unemployment rate, and differentiation of economy, supply of infrastructure, air pollution, disaster potential, waste accumulation, landscape consumption, and supply corridors. Furthermore, there can be an estimation of opportunities and threats to “benchmark” Istanbul’s path to the future in sustainable urban development. Criteria can be social capital, social population structure (increasing middle class), level of education, wealth, welfare transfer, productivity, agglomeration effects, efficient consumption, and regulation of land use. Therefore, it is possible to describe the actual situation and trends in urban development involving their strengths and weaknesses, but also to identify alternative ways. Moreover, there is the need to comprehend the complexity of the coherences in order to be able to establish adequate mechanisms of management. The consolidated findings can be converted into a “sustainability and operation model” for the chosen district of the city (“district” in the sense of a subsystem of the greater Istanbul area with endogenous and exogenous factors). The analysis and findings relating to the system (subsystem and the system as a whole) may contain results that are conferrable to other mega-cities. Unfortunately, the proposal failed, but will be given to foundations after a review again.

Prof. Carsten Jürgens from the Geographic Institute of Bochum is interested in cooperation. Prof. Jürgens is an expert in Remote Sensing of Urban Areas and has organised several Symposia about this theme in Istanbul. Beside intensive discussions about the results, there is also interest to exchange data in order to develop additional analyses and to design an additional project

Prof. Derya Maktav of the ITÜ, Division of Remote Sensing, works on temporal analyses in the western part of Istanbul, which is part of the here analysed buffer zone, as well as on coastal problems. The good contacts to this division open the possibility to exchange the data in order to do a cross-validation.

The same could apply to a co-operation with Prof. Erdin of the forest-faculty. He already has done some forestry analyses by automatic classification of TM data around Istanbul. Validation of the MURBANDY data with his data could be made and has already been discussed. He is interested in the older historical imagery to develop a temporal brief view of the changes inside the forestry areas. His analyses are deeper in the classification of forestry, as far as this cooperation could be a good validation.

8.3 Interest of end - users

From the commercial point of view, there is some basic interest from tourist and management organisations. There is already a contact to “IGDAS” company, which works in the field of gas management. Up to now, there are no other contacts. For tourist or traffic planning, the possibility to prepare a WEB-GIS does exist, which could be offered based on this project. At the ITÜ, Photogrammetric Division, a Master thesis using GIS, aerial images, MOLAND-Data and panoramic images with additional tourist information has been perfomed, who could help to establish a closer contact. There is hope to find a way to investment-groups, which could be interested in the data for strategic planning of infrastructure, industrial or commercial objects.

There are contacts to the ministry via Prof. Altan, which must be intensified further. There are different groups, showing interest in the project and its results. At the department for architecture a presentation of the MOLAND-project has already taken place. But the data have to be updated in order to be used for strategical development. Small scaled planning could be done with these data, detailed data have to be collected or integrated if already available. Since the ITÜ already has started a WEB-GIS project, it ist suitable to integrate parts of the data into the WEB application. Planned activities and scenarios derived from the data can assist the citizens to understand the administrative activities and support a better acceptance.

In general it can be said, that the contacts have to be intensified in order to build a more closer relation. The partners in Istanbul have less a language problem than a lack of different opinion. Integrated data as shown on the medium-scaled level is not accepted by everyone.

8.4 Usability of the data for crises management

As described in the introduction parts of this study, Istanbul is faced with earthquake hazards due to the North Anatolian Fault Zone, just south crossing the Marmara Sea. The consequences of an earthquake can result in different disasters, the shock itself, slides and Tsunamis.

On the last big earthquake (Izmit in 1999), Istanbul was shocked too and 156 people lost their lives 2000 were injoured and many buildings destroyed or damaged. There are well defined rules for protected construction, but the illegally built-up (Gecekondus) and unsolid construction are poorly controlled. There is a big job to do in reorganizing this situation.

Along the North Anatolian Fault Zone, the epicentres seem to move westwards with every new shock. Istanbul as a dense urban area is confronted by such an extremely disaster hard due to the fact, that surly not all the buildings are constructed or built by the given rules and more stories have been added finally to a not sufficient foundation. The southern region of Istanbul is much more risky than the northern part: Some of these sensitive areas are faced with the problem that the estate price and the value of flats decreased extremely. This is a commercial problem as well and summits in bankruptcy of families and estate offices. These problems are specific in big cities, a difficult task for the planers and the decision makers.

To manage these problems, GIS and the MOLAND-Data can help to implement a crises preparedness-system, a crises prediction and warning system as well as a crisis management system.

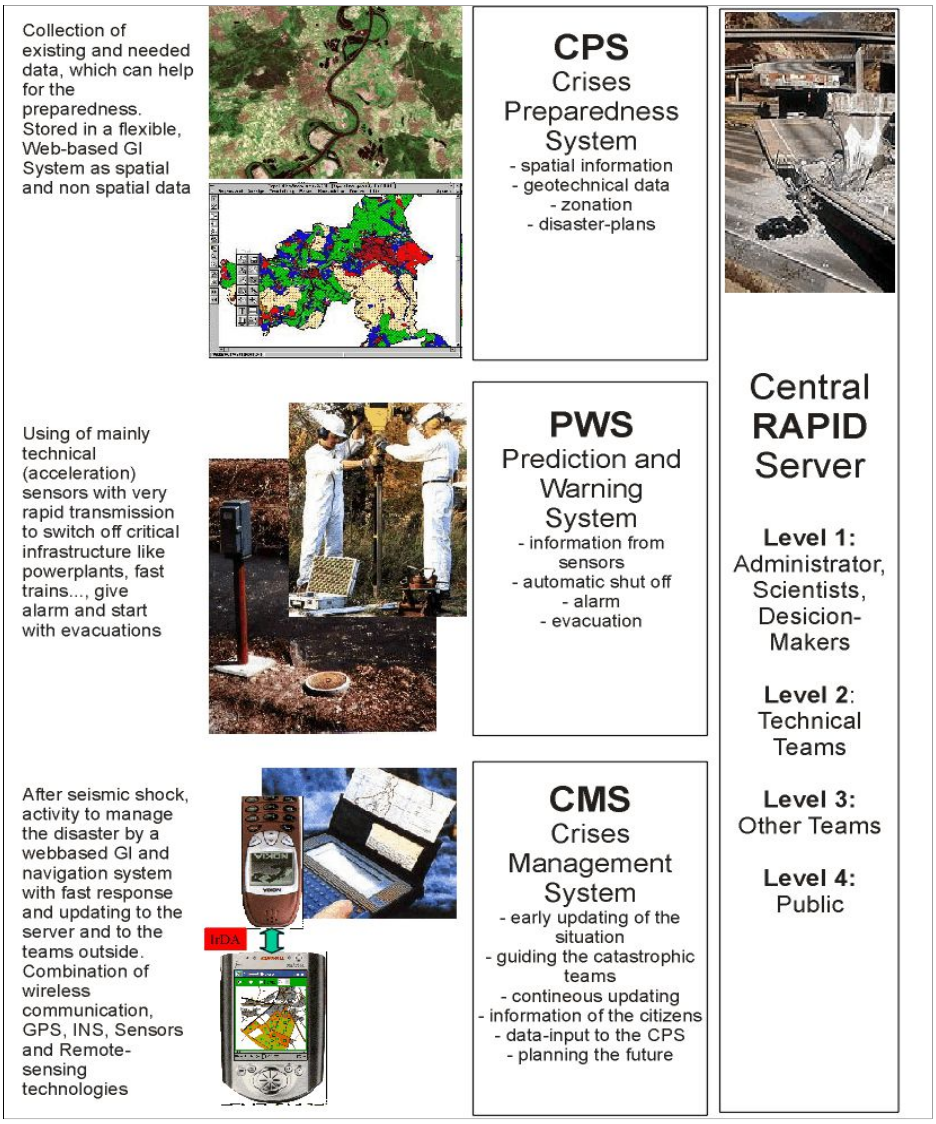


Figure 198*: Scheme of a proposed project for Earthquake-Management, (Shaozhong, S., Altan, O., Kemper, G., at al 2002)*

A proposal called RAPID is under development that aims at building on the MOLAND-data as shown in figure 198. Due to a lack of other complex coverage of data on Istanbul, these data are an essential part of this project, which hopefully will be launched in the near future. In order to integrate earthquake risk in local policy, Istanbul is just at the beginning of an integrated planning. Meanwhile since 1999 a lot of strong activities took place. A huge problem, however, is the database, which has to be refined step by step. Even the MOLAND data do not provide all the information in a suitable accuracy; they are ready to be used in smaller scales. Important information like the terrain, the building-structure, the traffic net and many more, are usable on basis of the data of the reference year 2000.

Beside this direct risk on buildings, the sliding basement in the hilly terrain bears a risk too. The highway Istanbul – Ankara was hardly damaged due to the Izmit-Shock by such slides, which hampered first aid and all the logistic operations inside, to, or from this area. This means that already during planning these possible negative effects have to be taken into account. This must be part of a successful crises-management.

The risk of Tsunamies born in the Sea of Marmara, bear a high risk for the densely populated coastlines on low terrain. The Tsunami Risk is totally underestimated; history shows that 6 m waves have already hit the city.

The coastal area of the Sea of Marmara is exposed to a nearfield hazard – a tsunami generated by a vertical shock needs less than 1 hours to hit the locality. Such a tsunami can propagate in any direction and thus, dependent on the location of the source, path of propagation and near-shore morphology form a risk to any vulnerable coastline. Throughout history, Istanbul has been beset by different-size tsunamis. The southern coastal area of Istanbul is subject to a near-field hazard. Different from far-field tsunamis, it may be difficult to generalise the effects of near-field tsunamis, because there is a large variety over short distances of the height of tsunamis and their destructive potential. The long interval between events in a specific position makes the problem more complicated. In 1766, the waves were recognised in the inner parts of the Bosphorus. In 1894, the sea receded up to 50 m and then returned. The wave height was less than 6 m. The bridges on the Golden Horn estuary were under water. In 1912, the sea lifted a rowing-boat up to a height of 2.7 m at Yesilköy. In the middle of the Strait of Istanbul, the waves demolished an anchored yacht. Finally, in 1999, some unusual events were observed around the Prince islands and in the Strait of Istanbul.

Based on the geocoded imagery, the extracted actual coastline, the modified DTM and an estimation of the follow-up, a risk map for Istanbul was computed out of the MOLAND Data as shown in figure 199:

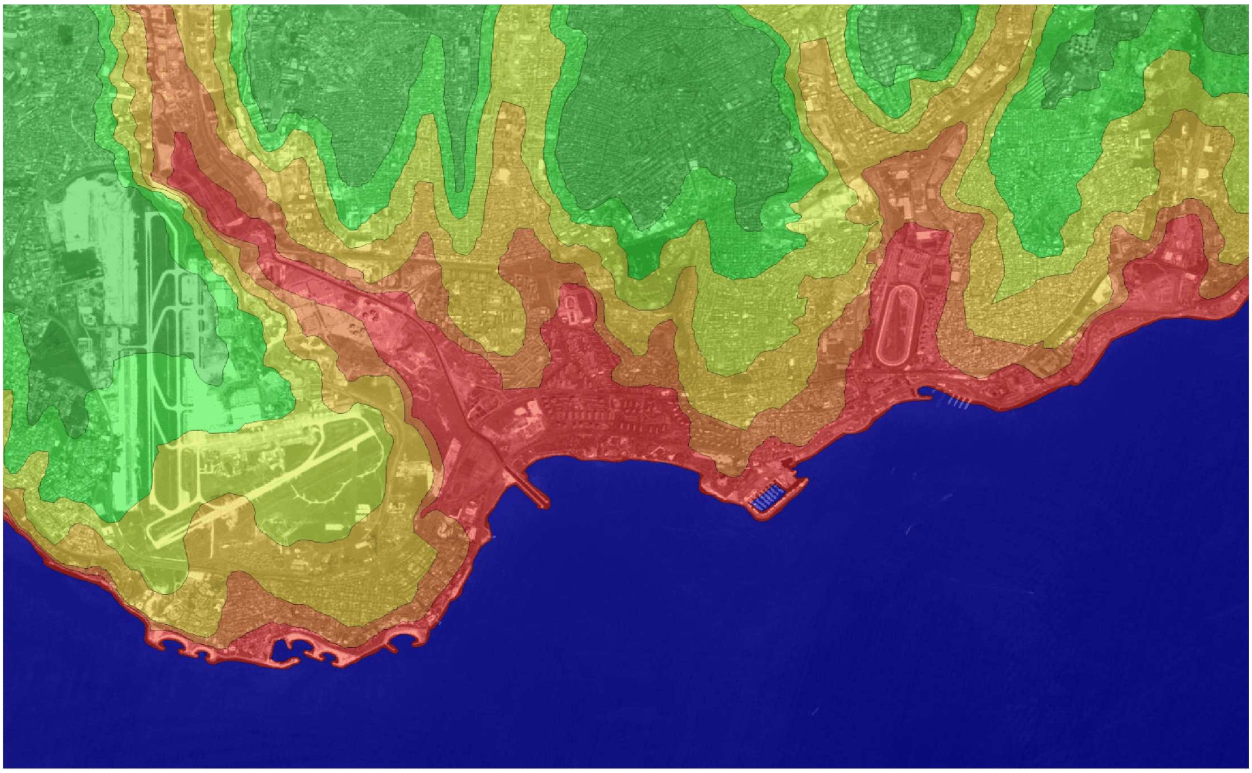


Figure 199: *Tsunami-Risk map of the low areas along the western coastline near the Airport.*

Such a risk map can only be a first estimation and does not apply to complex hydrological models. But this map gives a first information to city planners how to deal with risks like potentially flooded areas and the parts of the city that could be damaged. This is important for crises management to organise the evacuation of people and to bring in needed infrastructure (Mobile Hospitals, mobile powerstations …).
A risk-management for Istanbul is important in many ways: First of all, to save human lives, second to protect buildings and infrastructure, third to minimize the risk of pollution and resulting disasters (explosions, burning pipelines) and finally to keep the cities alive. This last point is important, taking into consideration that Istanbul contributes 20 % to the gross domestic product of Turkey.

9 Assessments

At the end of this thesis, I would like to include a self-critical assessment regarding the accuracy of the extracted information as well as a kind of summary of the results.

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

A characteristic of this study is the combination of data. As explained, the 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 presents an interesting data mixture for the study. Thus, very suitable results in both geometric and thematic accuracy are provided.

As a conclusion, it can be said that the methods and analyses used have been produced within a suitable budget and time. Within one year, the information needed for detailed analyses have been extracted including processing and digitisation. It is a proven and widely accepted way of studies, of course with limitations in accuracy and resolution. Nevertheless, there is a lot of space to improve the methods and techniques, always being aware that these data should keep pace to international comparisons. However, there is still a lack in handling those data by possible end-users where further attention should be paid to.

9.1 Methodological annotations

The methods demonstrated are mainly standardised procedures, adapted to the specific needs of this project. Finally, those methods have been the most effective ones to produce the entire dataset in an acceptable frame of time and costs. There might be a way to get a slightly higher accuracy in the geometry by using a more detailed procedure in order to make it valid for the interpreters.

The first technical step was the scanning and the georeferencing of the hardcopy topographical maps. However, the use of maps for the geocoding limited the geometric accuracy. Nevertheless, the big number of used points and the use of additional sources like digital vector data gave this base the best possible accuracy of a few metres and a very high reliability. Only with geodetic surveying methods, a better accuracy can be obtained with much higher costs and personnel. The coordinate system of the hardcopy topographical maps from a scale of 1:25k is UTM 6^{o} with middle meridian 27 ^{o} east. The coordinate system of the study was selected as UTM 3^{o} with middle meridian 30^{o} east. This was done because the topographical maps from large scale (1:5k and 1:1k) have been produced in this coordinate system. Thus, to validate the results in some cases it would be easier to use the 1:1k and 1:5k maps outside of control mechanism such as georeferenciation or interpretation.

In most cases, the process of transformation of satellite data resulted in an acceptable resolution. However, a sub-pixel accuracy of IKONOS imagery, often mentioned in literature, could not be reached in this study, as the geometric accuracy of IRS panchromatic is higher than IKONOS. Considering the specification and ground resolution of both imageries, this result seems to be unreal, but we must not forget that those results are determined to use deviations. The ground resolution is not a parameter of this geometric accuracy mentioned above. This result is the accuracy of the producer. Accuracy of the user, which means the degree of a data collection of 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 the producer. The KVR Satellite photos caused problems in order to receive acceptable deviations in the transformation-equation, in so far that they have been used mainly for the thematic interpretation. Additional tools would be needed to determine sensor-orientated pre-processing or orthorectification.

The photogrammetric work is confronted with a lack of suitable control points for the external orientation. This is finally a detective's work to get the orientation. More images with a better overlap would allow to do a tie-point based aerotriangulation, which could speed up this long lasting procedure. Compared to the workflow for orthophotos nowadays, this work done here was extremely time-consuming. Nevertheless, for the last two years there has not been found a real alternative way to prepare this data source.

Huge amounts of ancillary data have been pre-processed but only parts of them are finally used in this study. However, the effort put in this step gave the best possible result, which was in some cases better than the original data, which was demonstrated by the example of the bus-map.

The extraction of the vector-data in order to define the geometry of areas of similar use was not achieved by automated classification methods as shown by an example of cluster analyses. Even the used tools did not support an automated extraction of vectors from the raster source. The classified data out of the automated process have also been rasters and the conversion into vectordata would have to be done again.

The most effective way was, as also recommended by the JRC, the manual digitizing and the interpretation by the operator. This allows a reliable and smooth extraction of vectors in an acceptable time. This work is a hard job but it is faster than the correction of automated procedures. We also tried to use existing vector-data, but they had to be prepared for other tasks, the curves would not match to the studies need. So far, a new production of the curves and polygons has been faster than the updating of existing ones. The digitising in TopoL is rather fast and because of topological functionality most effective and accurate. The tools to cut, delete, move, or intersect curves helps a lot for a rapid data-production. The decision for a land-use type would take longer than the final set of the labelled point and the filling of the database.

The interpretation was done by strictly following the given MOLAND-legendary. However, in some cases the typical multi-used areas in the centre of Istanbul had to be squeezed in by the estimated main user. This is an effect, which is common for all types of classification or cartographic work. Due to the very detailed legendary, these problems are rare. This points out, that it is sometimes easier and faster to use a detailed nomenclature than a brief one – besides that, the higher quality of information is obtained.

In some cases, the downdating of the data was a difficult task due to changes in the geometry and the land-use. However, with the functionality of TopoL this job was done in a proper way. In many cases, it had to be decided, if a curve had to be moved a few meters or if it was an inaccuracy in the image. Changes smaller than 5 m were edited only in the case of reliable exceptions.

The spatial statistical analyses are the typical method of interpretation and are similar to other MOLAND areas. There are many other possibilities of spatial procedures with intersection methods in GIS. However, not all possibilities have been performed in order not to expand this study unnecessarily. The task to point out the key actions was solved by the used methods. Finally, there are many reasons for the urban sprawl of Istanbul interfering with each other.

The use of mixed data processing was only illustrated with a few examples, as demonstrated by the population density based on the residential structure. There is always a need to do estimations and modelling in order to combine spatial and non-spatial data. In that case, the result should be interpreted very carefully, nevertheless it is just a so-called "semi-quantitative" solution and shows a result which cannot be achieved without a combined analysis like done here. Such combinations have not been used for all possible models in order to keep the study compact.

9.2 Thematic remarks

As mentioned in the first chapter, the aim of this thesis is to fulfil the first task of the project, which is defined as “change detection”. The results can be data for two further steps for “understanding” and “forecasting”. By evaluation, it was difficult to digitize every linear and planar object in the whole study area. But it was finally carried out with suitable geometrc accuracy and spatial information.

The MOLAND-Legend used has its origin in CORINE and was adapted to the specific urban need during the MURBANDY projects and resukted to its here presented latest form. Most MOLAND cities are western-european ones with different urban structure, which led to some difficulties in the land-use classification. A strict separation of well definable uses cannot be only one found for all cases in Istanbul. Especially in Istanbul’s downtown a surprising mixture of uses in single building can be seen. A shop in a basement, a hotel in the first two floors, a doctor in the third and residences and offices in the upper floor might demonstrate the flexibility of Istanbul’s live. In some cases, the flat roof is used for skilled trade.

All classifications we focused on such vague areas, this is not peculiar to Istanbul. In any case we do not think that any legend can fulfil all land-use structures. In the case of mixed use like that, the main one should be taken as the representative. But weighing up of what is more important, was not defined. Here we are faced with a decision of the operator, which is definitely guided by individual “brain” models.

Mainly satellite imagery, printed orthophotos and other data have been used for the land-use detection. Of course, not all areas could be proved by a field test; mainly people with knowledge in those areas were interviewed.

Analyses made on the accuracy of the definitions on the reference data have shown to be very similar. In nearly all classes the errors where less than 5% and major errors could not be detected. The main error usually was a shift in the class f.e. from 1.1.1.1 to 1.1.1.2. This does not influence the final interpretation in this thesis at all.

The statistical interpretations open a wide field of interpretations, depending on how the data are combined. Due to the difference of the data, there is not a strict way to analyse them. Serious attention was paid to reliable and realistic analyses for pointing out the important facts. That might be the reason why in some cases the same data have been recalculated and presented in a different way twice. Often a mixture of both, of absolute and relative values have been taken into account to show a objective result.

Especially in the comparison of Istanbul with other cities, Excel-diagrams have been used to point out the international and national relationships. Here we have been confronted with the problem that the data, published in literature, are not clearly defined by their accuracy and relation to the administrative city, agglomeration, or district. In that case, the relative dynamism was emphasized in the foreground to cover inadequate sources. Nevertheless, even with official sources (World Urbanisation Prospects - Revision 2003) we meet limitations, which we have to be aware of.

9.3 Considered as low important and still open tasks

The comparison of Istanbul in context Turkey and other Turkish cities was due to a lack of numeric data limited to qualitative remarks. Other data surely could be found. Spatial data exist in the different administrations in Ankara i.e. the Forest Administration, the Agricultural Department, the Ministry of Home Affairs. To get access to such data is a difficult and long process, which would burst the frame of this thesis. In a new project, with the upcoming program for CORINE in Turkey, a new cooperation might be initiated to integrate and validate the data of this study.

Non-spatial data, i.e. curent census data have not been published in a convenient way. However, results with interpretations have already been presented. With some more efforts, this census data could have been made available, but unfortunately, the time for the project was limited. This can be a motivation to plan some ongoing studies on this data in the future.

The use of the multi-scaled and multi-source data in a GIS warehouse was done in an extensive way. TopoL handles different spatial data in vector or raster format quite well, but does not supply a Meta-data system with access to a database, which allow a complex data-warehouse. It has to be mentioned here that such a system practically cannot be installed. This thesis is embedded in the field of scientific research and not in the field of already practically used systems. Even the use on non-spatial data in a GIS has not been really managed by any software solution yet. This study points that out. To discover and manage synergy effects in such different data, a tool is urgently needed. The new TopoL LX components with option to Oracle GeoDB show a way to meet up with those needs in the near future.

The comparison to other MOLAND data was done on the statistical values only. There is of course the possibility of making a more intensive comparison on the changes of the different cities. Especially by the use of “Fragmentation analyses” and the use of “cellular automata”, models on Istanbul could supply new information for possible scenarios. These models were not available in this project and this study and are too complex to be added to this thesis. It will be solved by partners of the JRC and the data will hopefully be available in the near future.

There is still room for more current but also older data to enlarge the urban growth of Istanbul. Some old maps have already been pre-processed, which unfortunately do not cover the entire study area. Many maps are published for cultural heritage affairs, thus building a historical dataset. Also the outlook on the future is of interest. The huge amount of construction sites demonstrates the need for a new dataset that can be used to update the MOLAND data. An aerial survey campaign is planned to cover entire Istanbul with aerial images with a final resolution of 20 cm. This opens the chance to come into contact with the local authorities for a cooperation on this topic.

The use of the data for a crisis management was presented as an example to demonstrate, what these data can be used for, especially if the ancillary data are combined with the MOLAND-results and the images. There are still many unsolved tasks to do and only some could be solved, demonstrated, or mentioned in this study.

10 Conclusion

The use of the MOLAND-Project was a perfect basis for this study; otherwise, a project like this could not have been worked out in the frame of a PhD thesis. The arrangements of so many data-sources and their processing represent a wide basis for technical and thematic research.

A detailed introduction to the MOLAND-Projects, the city of Istanbul and the geography of Turkey built the background for this study. Due to its geographical position as the bridge between Europe and Asia, the connection between the Black Sea to the Mediterranean Sea, and, this should not be underestimated, the relatively good environmental conditions with areas suitable for agriculture, relatively warm winters and warm summers, enough rain etc. Istanbul is a very attractive city for migration.

Throughout history, Istanbul was very important and always ranked among the most important cities in the world. Istanbul is the biggest city in Turkey and it is its business centre. Although Ankara is the capital with the administrative power, Istanbul has got international embassies or consulates due to its historical function as former capital and its economic importance.

It was pointed out that, due to the fine conditions mentioned; Istanbul is very attractive for immigrants from eastern and northern Anatolia as from other countries too. There are many emigrants from Bulgaria and other former socialist countries i.e. from the Muslim regions of the Balkans who came to Turkey during the time of the collapse of former Yougoslavia. More than 100.000 of these immigrants have been setteled in the Istanbul region.

The annual growth rate of the population dropped from 6.7 % in 1970 to 2.6% in 2000 and is prognosed to reach 1.3% in 2015. The enormous size of Istanbul, however, has already exceeded the level of 10 Mio inhabitants. Istanbul 2000 is the seventh fastest growing city in the world while it is the 22nd in number of inhabitants. Compared to the strongest growing cities in the world, especially India, South America and China, Istanbul is about to become a “threshold” city.

Compared to other MOLAND-cities, which are situated in Western Europe, Istanbul is still growing much faster by inhabitants and sprawling in urban size. Istanbul, measured in absolute and relative figures leads the highscore one of all the analysed 25 MOLAND-cities.

The MOLAND-project with its legend is a powerful concept to analyse the urbanisation in cities through its spatial but also structural dynamics. Remotely sensed data-sources, the use of photogrammetry, GIS, ancillary data, and combined analyses allows a temporal spatial analysis over a period of 45 years in Istanbul. Big efforts have been made to lead to an accurate and reliable geometry of the raster-data and the finally produced vector-layers. The thematic accuracy was validated to guarantee a reliable and correct result of the land-use maps.

With the help of combined analyses, the population density was calculated for different residential classes concerning the different years. This result shows that in general the population density grows due to more dense residential urban structures, but finally, the number of people living in flats decreases due to social changes from growing families to single households. This effect partly compensates the structural changes in the urban fabric and is supported by the growth of weekend-flats in the suburbs of Istanbul. That finally enhances the urban sprawl of Istanbul.

The increase is not only due to the residential structures, but also to the business areas. Mainly the industrial areas grew strongly but more slowly than residential areas. Comparing both parts of Istanbul, Asia and Europe, the sprawl was influenced by the infrastructural improvements of the two Bosporus bridges. While the growth of residential and business areas on the European side developed in a homogeneous way, east of the Bosporus the growth accelerated within the construction of the 2 Bosporus bridges and the related motorways end 1980 and strongly supported the establishment of residential fabric.

The urban sprawl is based on the loss of agricultural land. Forests are not significantly influenced due to state and army-protection, natural areas like grassland, pastures and others are influenced on a small level. The loss of agricultural land shows in comparison to other MOLAND-cities similar relative figurs. But it bears the risk that food production is shifted to other regions and the dependency on transport structures increases. Agricultural areas are commonly used for Gecekondus since their terrain can easily be used. Loss of agricultural land, minimizing the size of productive soils, forces the dependency on industry and trade in this region.

In the city, many urban green areas have been lost, as a consequence of a lack of city planning and management. In comparison to other MOLAND-cities, Istanbul ranks third last. Only administrative efforts can change this situation. The increase of the number of roads and the resulting road density is amazing. Compared to other MOLAND-cities Istanbul in absolute figures is on the second, and related to the growth-rate on the first place. This is not surprising because it is known that the transport in Istanbul is nearly completely road-based. The system of busses and minibuses (Dolmush) works perfectly and helps Istanbul to avoid a total traffic collapse. In combination with ferries and water-taxies, such a system builds an operable public transport system. However, due to the dependency on the road-network, their operability collapses in rush hours too. There are plans to increase the public transport e.g a tunnel under the Bosporus is planned. Nevertheless, the financial limitations prevent such activities. In same time length of the metro-system increases 1 km, the population growths by another 100.000 people. The rate of population increase is 100 times higher than the overall transportation network, a very serious problem.

The trend analyses have shown that the increase of urban fabric is going on and those solutions, like the public transport, cannot keep pace. The rate of increase however is slowing down. The data and results of this study can be used for the future tasks in Istanbul. The study can give an integrated overview with advice to planning purposes. The data, of course, cannot be used for a detailed planning, but they can be a base for a first inventory. Some detailed planning for city development were done, but only partly and/or only for specific subjects. These data can help to fill this gap to bridge single activities

Basically the results have shown what is already known. Some detailed analysis has been carried out which can help to understand why the development worked that way. Scenarios might help to point out the problems to the decision makers and might helps to make forecast activities with these results. However, it is not only a problem of planning. Especially in Turkey, it is a financial and political problem.

On the other hand, it is amazing how well a lot of things work in Istanbul. There is canalisation almost everywhere, as well as electricity, fresh water and somehow flowing traffic. In Istanbul, there is a mixture of cultures and the crime-rate comparatively low. That gives the city the chance to develop in a positive way. Considering, that Istanbul has a bridge function between continents, cultures and economics, it might also be of international interest to help Istanbul finding its way to a sustainable development.

The construction of the two bridges urgently needed solved the transportation problems and triggered an enormous increase in activity on the Asian side. This could have been foreseen and a public transport system has consequently been implemented. The scenario mentioned analyses “cellular automata” could help to run scenarios to support further planning.

The economic centre is still in the European part of Istanbul, the heart of Istanbul. This is the part where most guests (tourists and business guests) go. The growth of density on the European side is definitely common to other European cities in the 70ies and 80ies. The relatively small density on the Asian side shows a deficit in good planning. The density of people in the residential area on the Asian side is half that on the European side. It is still the case that for business most people travel from the Asian to the European side. This again causes enormeous traffic problems, resulting in the daily traffic jam on the bridges. On the other hand, the financial budget is too small to implement a suitable public transport system in short time.

There is still no suitable method to control the “Gecekondo” phenomena and there is no overall co-ordinated planning. Some institutions still do a good job in this field (like the water management institution). For future planning, scenario development and forecast planning are needed. Another problem is the political situation and corruption in Istanbul. Not all administrative districts already have a leadership working on sustainable development. There is a lack of innovative ideas to manage city-development at the divisions for city planning and architecture at the different universities .What is missing is the political power, the willingness and also the money. Thus, planning fails in most cases. Istanbul is dependent on foreign investors due to a lack of their own fundings. A shocking trend is observed in the illegal destruction of old buildings in the centre to make room for parking lots. This seems to be a very profitable business and since corruption is widely spread, it is difficult to stop this trend.

In my opinion, the situation in Istanbul is better than its planning and management. There is a relatively homogeneous social structure and only a small number of very poor people. Although these “Gecekondo” areas are illeagal, extremely poor people do not populate them. The daily needs in Istanbul are met: fresh water, food, electricity, wastewater trust, and it functions all year through. This demonstrates that there is a basis to manage the city with a large number of operational structures.

Istanbul is very interesting for people from Anatolia, especially to those from the eastern part where the economic situation is poor. It is difficult to improve the situation in this hinterland. The Turkish government makes big efforts in afforestation, irrigation, dam-buildings,…. The climate is rough, the terrain difficult and agriculture and livestock are carried out at a small profit. Other cities benefit from this situation too, mainly in the southern or western part of Turkey like Izmir, Bursa, Antalya and Adana. These regions also profit from a booming tourism that ensures income in a direct or indirect way. Meanwhile, those cities show a higher annual growth-rate than Istanbul.

Istanbul needs an entire management to capitalise on foreign investment in the city. There still is no entire planning and no entire database. The data produced in this study can be the first input for the large-scale database and a system that can create scenarios for the whole of Istanbul. A multi-scaled GIS is needed to cover all needs. The new tunnel will support the transportation from Asia to Europe but it will also force the increase of the urban growth on the Asian part. It is necessary to develop independent structures, for life and work, on both sides of the Bosporus. Flexibility in the working - and shopping hours and a well priced public transport system can help to avoid traffic jams.

Istanbul is just in the beginning of the procedure to integrate earthquake risks in city planning process. The risk of Tsunamies born in the Marmara Sea, bear a high risk for the densely populated coastlines on deep terrain. There are rules for shock-resistant construction, but the illegally built structures (Gecekondus) and later legalized with the enlargement of the buildings with more storeys are in contrast to these rules. Also bad foundation and the often poor quality of the material are responsible for disasters. Areas with higher risk can lead to financial problems due to loss of real estate values. It was demonstrated that in combination with ancillary data, this study could give first risk-information as a basis for a crisis management system.

There is still a lot to do for planning Istanbul’s sustainable future - this study can add data and information to support this job.

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