ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

INVESTIGATING THE POTENTIAL OF SATELLITE IMAGES IN TOPOGRAPHIC MAP PRODUCTION

M.Sc. THESIS

Merve KESKİN

Department of Geomatics Engineering

Geomatics Engineering Programme

JUNE 2013

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

INVESTIGATING THE POTENTIAL OF SATELLITE IMAGES IN TOPOGRAPHIC MAP PRODUCTION

M.Sc. THESIS

Merve KESKİN
(50111162)

Department of Geomatics Engineering

Geomatics Engineering Programme

Thesis Advisor: Assist. Prof. Dr. A. Özgür DOĞRU

JUNE 2013

İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

UYDU GÖRÜNTÜLERİ KULLANILARAK TOPOGRAFİK HARİTALARIN ÜRETİM OLANAKLARININ ARAŞTIRILMASI

YÜKSEK LİSANS TEZİ

Merve KESKİN
(501111612)

Geomatik Mühendisliği Anabilim Dalı

Geomatik Mühendisliği Programı

Tez Danışmanı: Yard. Doç. A. Özgür DOĞRU

HAZİRAN 2013

Merve KESKİN, a **M.Sc.** student of ITU **Graduate School of Science Engineering and Technology** student ID **50111162**, successfully defended the **thesis** entitled "**INVESTIGATING THE POTENTIAL OF SATELLITE IMAGES IN TOPOGRAPHIC MAP PRODUCTION**", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Assist. Prof. Dr. A. Özgür DOĞRU** ....
İstanbul Technical University

Jury Members :

Date of Submission : 03 May 2013
Date of Defense : 06 June 2013

To my mother,

FOREWORD

This thesis is based upon studies conducted from September 2012 to May 2013 at the Department of Geomatics Engineering in Istanbul Technical University, Turkey. I would like to take this opportunity to thank all the people who supported me during this period.

First, I would like to express my sincere gratitude to my leading supervisor Assist. Prof. Dr. A. Özgür Doğru. Without his advise, unique support and feedback, this thesis would never had become a reality. In addition, much appreciation goes to Prof. Dr. N. Necla Uluğtekin for all the valuable discussions we have had together. I really learned a lot from her.

I also would like thank to *Center for Satellite Communications, Remote Sensing (ITU-CSCRS),* especially to Assoc. Prof. Dr. Elif Sertel for her great contribution of data providing within the *109Y277 numbered TÜBİTAK ÇAYDAĞ project,* and her methodologic advises, too. Hereby, I would like to thank to Emre Özelkan for preparing the data I used in my case study.

I am grateful to Assoc. Prof. Dr. Çiğdem Göksel and Assist. Prof. Dr. Filiz Bektaş Balçık as well for providing solutions to all the questions that I presented to them.

Of course, I would like to thank to my colleagues and friends from the Department of Geomatics Engineering. In particular, I am very grateful to Bahadır Çelik who supported me all the time and helped me about the softwares I used during the application stage.

Last but not least, I wish to express my greatest appreciation to my mother, who has supported me since the day I was born.

Thank you all for being always there. I hope you will find useful information about the use of satellite images at topographic mapping.

May 2013

Merve KESKİN
(Geomatics Engineer)

TABLE OF CONTENTS

Page

ABBREVIATIONS

ASPRS	**:** American Society of Photogrammetry and Remote Sensing
CAYDAG	**:** Çevre, Atmosfer, Yer ve Deniz Bilimleri
ED-50	**:** European Datum - 1950
EM	**:** Electromagnetic Spectrum
GIS	**:** Geographic Information System
GSD	**:** Ground Sampling Resolution
ICA	**:** International Cartographic Association
IGN	**:** Institut Geographique National
ITU-CSCRS	**:** Istanbul Technical University-Center for Communication and Remote Sensing
µm	**:** Micrometer
MSS	**:** MultiSpectral Scanner
NCDCDS	**: N**ational Committee-Digital Cartographic Data Standards
NIR	**:** Near InfraRed
RMSE	**:** Root Mean Square Error
RRMSE	**:** Relative Root Mean Square Error
SWIR	**:** ShortWave InfraRed
Swisstopo	**:** Swiss Society of Cartography
UTM	**:** Universal Tranverse Mercator
USGS	**:** United States Geological Survey
VNIR	**:** Visible NearInfrared
WGS-84	**:** World Geodetic System - 1984

LIST OF TABLES

Page

LIST OF FIGURES

Page

INVESTIGATING THE POTENTIAL OF SATELLITE IMAGES IN TOPOGRAPHIC MAP PRODUCTION

SUMMARY

Recently accessing fast, accurate and up-to-date information has become vitally important. In many scientific areas -cartographic mapping as well- it is not possible to meet the current needs by appyling only conventional methods. Remote sensing technology steps in at this stage, because remote sensing satellites are able to make 7/24 earth observations at different spatial, spectral, radiometric and temporal resolution. Moreover, all the information -that remote sensing satellites provide- is reachable when desired. Satellite images can be used for the following cartographic purposes; (i) topographic and thematic map and base-map production (ii) thematic information extraction or (iii) information extraction from image maps with data integration methods.

This thesis aims to examine the usage possibilities of remote sensing imagery at different spectral and spatial resolutions in topographic map production procedure. While considering the topographic maps, third dimension (i.e height information) was kept out of the thesis, only 2D information about map objects were mentioned. In this context, characteristics of satellite image data -as a source data- were examined based on the content and scale of map to be produced. For this purpose, the relationship between maps at different scales and related satellite images were introduced. Additionally, it is discussed whether a satellite image by itself is enough to produce a topographic map or not. As a result, “which satellite image is suitable for which topographic map production at which condition” is determined and end-maps were evaluted by means of thematic and geometric accuracy.

Within the scope of the study, first, map concept were described depending on the scale and content. Thematic and topographic maps were defined and topographic maps were classified as large, medium and small-scaled maps. Map content elements and their representation properties were explained considering the national and international mapping standards. These point, line and area based map content elements were classified into four fundamental categories: administration, hydrology, vegetation and transportation. Then, requirement matrices -belonging to object categories- were created based on the scales between 1 : 5 000 and 1 : 1 000 000. While creating the requirement matrices, legends of 1 : 25 000, 1 : 50 000 and 1 : 100 000 topographic maps -produced by General Command of Mapping- were used as a base and some other international standards such as USGS (United States Geological Survey) ve CORINE (Coordination of Information on the Environment) land cover classification standards were also used.

Second part of the study is related to the remote sensing systems and classification of remote sensing images. Usage purposes of imaging satellites were mentioned and satellite images were classified as very high, high, medium and low-resolution data. On the other hand, object characteristics were introduced based the detection range

of satellites at electromagnetic spectrum. At last, requirement matrices for remote sensing satellites were created with a similar approach as done for maps and same class names were used. Afterwards, obtained matrices were crosschecked and resolution-scale relationship between topographic maps and remote sensing images was tried to be determined.

In the application stage, a plot area (approximately 20.000 m²) was chosen to apply the theoretical information. The region is Biyikali village in Tekirdag (in the north-west of Turkey) with the geographic coordinates of 41°01'43.79"N, 27°20'18.04"E and 40°59'24.14"N, 27°24'45.54"E. The region has a rich detail variability and temporal resolution of remote sensing data belongs to the region was good enough for comparison and information extraction.

Before starting to work with remote sensing images, study area was divided into zones based on the land feature characteristics. At first, area of interests were determined for entities, and then subset images were created for each zone. Each zone represents one of main information themes (transportation, vegetation, administrative and hydrographic). After generating zones; entities which can be a subject for topographic maps were digitized. Feature class, feature type/geometry (polygon, line, point, multipoint, multipatch, etc.) and coordinate system were determined for each feature to be digitized. Each feature class was exported to a shape file and saved. At the end, several sample areas -based on detail variability and areal coverage- were created on three satellite images for roads, residential buildings, industrial buildings, water bodies, forests and arable lands. 3 samples from water, 3 samples from forest, 5 samples from arable land, 4 samples from residential area, 1 sample from industrial area and 7 samples from road were formed on each satellite image.

Based on individual zones, evaluation was done. Relative and percentage errors were calculated by considering Worldview-2 image as reference. Roads are extracted as two lines from Worldview-2 and SPOT-5 but as a single line from Landsat-5 TM image. Residential and industrial buildings can be digitized individually from Worldview-2 image. All of the satellite images give thematic information about forest and arable land. However geometric accuracy decreases with the lower spatial resolution. The water body was also successfully extracted from all of the images with some errors. Finally, accuracy assessment was conducted by considering Worldview-2 images as reference.

Regarding evalution of digitized features and requirement matrices, Worldview-2 images provide sufficient geometric and thematic accuracy for topographic mapping at 1 : 5 000. With SPOT-5, 1 : 25 000 scaled topographic maps can be produced and also based on the thematic content and purpose of mapping, larger scales can possibly be updated. In general, it has been found out that; it is not easy to achieve the expected thematic and geometric accuracy in practice. Satellite images may not meet the required accuracies determined theoretically. Moreover, to form a direct relationship between map scale and spatial resolution of satellite data is not a completely right approach. Because only spatial resolution parameter is not enough to interpret a remote sensing data in order to produce maps at relevant scale.

UYDU GÖRÜNTÜLERİ KULLANILARAK TOPOGRAFİK HARİTALARIN ÜRETİM OLANAKLARININ ARAŞTIRILMASI

ÖZET

Günümüzde hızlı, doğru ve güncel bilgiye erişim oldukça hayati bir bir anlam kazanmıştır. Pek çok alanda olduğu gibi, kartografik harita üretiminde de yalnızca geleneksel yöntemler kullanılarak güncel standartları yakalamak mümkün olmamaktadır. Uzaktan algılama görüntüleri bu anlamda sıkça kullanılmaktadır. Çünkü uzaktan algılama uyduları 7/24 gözlem yapabilme, farklı mekansal, spektral, radyometrik ve zamansal çözünürlükte görüntü üretebilmenin yanı sıra bu verilere istenildiği anda ulaşılabilir. Kartografik anlamda uydu görüntüleri; topografik ve tematik harita ve altlık üretimi, tematik bilgi çıkarımı ya da görüntü haritaları üzerinden veri entegrasyon yöntemleriyle bilgi üretimi gibi pek çok farklı amaç için kullanılmaktadır.

Bu tezin amacı topografik harita üretim süreçlerinde farklı spektral ve mekansal çözünürlükteki uydu görüntülerinin kullanım olanaklarını incelemektir. Topografik haritalar yükseklik bilgisi (eş yükseklik eğrileri) olmaksızın, sadece iki boyutlu olarak ele alınmıştır. Bu kapsamda üretilmesi amaçlanan haritanın ölçeği ve içeriğine bağlı olarak kaynak veri olarak kullanılabilecek uydu görüntülerinin özellikleri araştırılmıştır. Bu amaçla farklı ölçeklerdeki topografik haritalar ile ilgili uydu görüntüleri arasındaki ilişkiler ortaya koyulmuş ve uydu görüntülerinin yalnız başına topografik harita üretmek için yeterli olup olmadığı tartışılmıştır. Sonuç olarak hangi özelliklerdeki uydu görüntüsü ile hangi tip topografik haritaların hangi şartlarda üretilebileceği belirlenmiş ve sonuç haritalar tematik ve geometrik doğruluk kriterlerine göre değerlendirilmiştir.

Çalışma kapsamında ilk olarak ölçek ve içerdiği konu bakımından harita kavramı ele alınmıştır. Tematik ve topografik harita kavramlarına değinilmiş ve topografik haritalar büyük, orta ve küçük ölçekli olarak sınıflandırılmıştır. Her ölçekteki harita sınıfları; üretim amacı, içerik bilgisi, kullanım alanları ve içerdiği detaylar yönünden açıklanmıştır. Bunun yanı sıra haritaya konu olan objelerin gösterim özelliklerinden bahsedilmiş ve belli geometrik sınırlar verilmiştir. Bu karşılaştırmalar noktasal, çizgisel, alansal objeler ulusal ve uluslararası standartlardan yararlanılarak belirlenmiş ve temel geometrik ve tematik özelliklerine göre sınıflandırılmıştır. Sınıflandırma sonucunda haritaya konu olan objeler; yerleşim, hidrografya, bitki örtüsü ve ulaşım ana sınıfları altında toplanmıştır. Her temel obje sınıfı üç detay seviyesinde ele alınmıştır. Örneğin; "bitki örtüsü" temel sınıfında bulunan "tarım"; "ekili dikili alan" ve "ekili dikili alan" ise "çeltik tarlası" alt sınıflarını içermektedir.

Sonraki aşamada farklı detay seviyeleri ve ölçeklerine göre (1 : 5 000 ile 1 : 1 000 000 arasında) incelenen obje gruplarına ait gereksinim matrisleri oluşturulmuştur. Gereksinim matrisleri noktasal, çizgisel ve alansal detayların hangi ölçekte ve hangi biçimde gösterilmesi gerektiğini yansıtmaktadır. Matrisler oluşturulurken Harita Genel Komutanlığı tarafından üretilen 1 : 25 000, 1 : 50 000 ve 1 : 100 000 ölçekli

harita lejantları temel alınarak USGS (United States Geological Survey) ve CORINE (Coordination of Information on the Environment) arazi kullanım standartları gibi çeşitli uluslararası standartlardan yararlanılmıştır.

Çalışmanın ikinci bölümünde ise uzaktan algılama sistemlerine ve uydu görüntülerinin sınıflandırılmasına değinilmiştir. Görüntüleme yapan uyduların (imaging satellites) kullanım amaçları açıklanmış ve tablo halinde sunulmuştur. Uydu görüntüleri, mekansal çözünürlüklerine göre sınıflandırılmış; (i) 2,5 m ve daha yüksek çözünürlüklü uydu görüntüleri "çok yüksek çözünürlüklü" (ii) 2,5 m ve 10 m arasındakiler "yüksek çözünürlüklü" (iii) 10 m ve 100 m arasındakiler "orta çözünürlüklü" ve (iv) 100 m'den düşük olanlar ise "düşük çözünürlüklü" olarak adlandırılmıştır.

Ayrıca uzaktan algılama konusu kapsamında, spektral yansıtım özelliklerinden yararlanarak, obje karakteristikleri ortaya konmuş ve elektromanyetik spektrumdaki algılama aralıklarına göre uydu verileri incelenmiştir. Uydu görüntülerinden çıkarılması mümkün olan objeler, topografik haritalara konu olan obje sınıfları ile uyumlu bir şekilde gruplandırılmış ve bu sınıflar için yukarıda bahsi geçen ana sınıflar kullanılmıştır (yerleşim, hidrografya, bitki örtüsü ve ulaşım). Tüm bu işlemler gerçekleştirilirken uluslararası arazi örtüsü ve arazi kullanım sınıflandırma standartları dikkate alınmıştır.

Bir sonraki aşamada, mekansal çözünürlüklerine göre; çok yüksek, yüksek, orta ve düşük çözünürlüklü olmak üzere sınıflandırılan uydu görüntüleri için -haritalar için oluşturulan matrislere benzer şekilde- yerleşim, hidrografya, bitki örtüsü ve ulaşım ana sınıfları içeren gereksinim matrisleri oluşturulmuştur. Daha sonra elde edilen gereksinim matrislerinin çapraz karşılaştırılması ile topografik haritalar ve uydu görüntüleri arasındaki çözünürlük-ölçek ilişkisi belirlenmeye çalışılmıştır.

Uygulama aşamasında ise, Tekirdağ ilinde Biyikali Koyu pilot bölge olarak seçilmiştir (41°01'43.79"N, 27°20'18.04"E ve 40°59'24.14"N, 27°24'45.54"E.). Bu bölgeyi kapsayacak 1 adet 50 cm mekansal çözünürlüğe sahip Worldview-2, 1 adet 2,5 m mekansal çözünürlüğe sahip pankromatik SPOT-5 ve 1 adet 30 m mekansal çözünürlüğe sahip Landsat-5 TM görüntüsü kullanılmıştır. Görüntüler öncelikle gereksinim matrislerindeki detay sınıfları göz önünde bulundurularak, bölgelere ayrılmıştır. oluşturulan bölgeler yerleşim, hidrografya, bitki örtüsü ve ulaşım ana sınıfları altında gruplandırılabilecek bina, su kütlesi, tarım alanı ve yol alt sınıflarını içermektedir. Sonuç olarak, detay çeşitliliğine ve detayların kapladıkları alanlara bağlı olarak birçok örnek alan belirlenmiştir. everal sample areas -based on detail variability and areal coverage- were created. 3 adet su sınıfından, 3 adet orman sınıfından, 5 adet ekili-dikili alan sınıfından, 4 adet yerleşim, 1 adet endüstriyel ve 7 adet ise yol sınıfından oluşmak üzere her uydu görüntüsü üzerinden çalşma bölgeleri belirlenmiştir.

Daha sonra, belirlenen bölgelere ait topografik haritalara konu olabilecek noktasal, çizgisel ve alansal objelerin, uydu görüntüleri kullanılarak ekran üzerinden sayısallaştırılması işlemine geçilmiştir. Sayısallaştırma işleminde, öncelikle obje tiplerine ve geometrilerine bağlı olarak özellik sınıfları oluşturulmuş ve her özellik sınıfı için koordinat sistemi tanımlanmıştır. Örneğin tarım alanları poligon tipinde, yollar çizgi tipinde sayısallaştırılmıştır ve son olarak her özellik sınıfı, şekil dosyasına dönüştürülerek kaydedilmiştir.

Değerlendirmeler bölgesel bazda yapılmıştır. Worldview-2 görüntüleri referans kabul edilerek bağıl ve yüzde hatalar hesaplanmıştır. Yollar; Worldview-2 ve SPOT-

5 görüntülerinde çift çizgi, Landsat-5 görüntüsünde ise tek çizgi olarak üretilmiştir. Yerleşim alanları ve endüstriyel alanlar yalnız Worldview-2 görüntüsünde bina bazında, SPOT-5 görüntüsünde bina grubu biçminde sayısallaştırılabilmiş, Landsat-5 görüntüsünde ise hiçbir şekilde belirlenememiştir. Orman ve tarım alanları tematik olarak tüm görüntülerde üretilebilmiş ancak geometrik doğruluk çözünürlükle ters orantılı olarak değişmektedir. Göl objesi de her üç görüntüde sayıllaştırılabilmiş ve birbirine yakın alanlar elde edilmiştir. Landsat-5 görüntüsünde doğru bant kombinasyonu özellikle su bilgisinin çıkartılması için çok önemlidir; örneğin 7-4-2 kombinasyonu kısa dalga kızılötesi (SWIR) bant içerdiği için su yansıtım göstermeyeceğinden siyah görünecek ve kolayca ayırt edilecektir.

Sayısallaştırma işlemi sonrasında bağıl karesel ortalama hatalar hesaplanarak doğruluk analizi yapılmıştır. Worldview-2 görüntüsü referans olarak kullanılmış ve hatalar Worldview-2 görüntüsüyle elde edilen alansal ve çizgisel sayıllaştırma sonuçları baz alınarak hesaplanmıştır. Yerleşim ve endüstriyel alanlar haricinde SPOT-5 görüntüsüyle elde edilen sayısallaştırma sonuçları Worldview-2 sonuçlarına oldukça yakın değerler vermiştir. Ancak Landsat-5 görüntüsü üzerinden aynı alanlara ait sayıllaştırma yapılamadığından bağıl karesel ortalama hatalar hesaplanamamıştır.

Sayısallaştırma ve gereksinim matrisleri sonuçlarına göre, Worldview-2 1 : 5 000 ölçekli topografik harita üretimi için gerekli ve yeterli tematik ve geometrik doğruluğu sağlamıştır. SPOT-5 görüntüsünün ise, 1 : 25 000 ölçekli topografik haritaların üretiminde kullanılabileceği, hatta üretilecek haritanın konusuna ve kullanım amacına bağlı olarak, daha büyük ölçekli bazı haritaların üretiminde de yararlanılabileceği sonucuna ulaşılmıştır. Landsat-5 TM görüntüsünden, her ne kadar genel olarak tarım alanları, su bilgisi ve orman alanları hakkında tematik bilgi çıkarmak mümkün olsa da, büyük ölçekli harita üretimi için uygun değildir.

Genel olarak, uydu görüntülerinden yararlanılarak harita üretimi için, teoride varsayılan tematik ve geometrik doğruluklara pratikte ulaşmak kolay değildir. Uydu görüntüleri beklenen doğruluk kriterlerini karşılamayabilir. Dahası, uydu görüntüsünün mekansal çözünürlüğü ile harita ölçeği arasında doğruda ilişki kurmak tamamen doğru bir yaklaşım değildir. Bunun sebebi uydu görüntüsünün yorumlanmasında mekansal çözünürlük harici; spektral, radyometrik ve temporal çözünürlük gibi başka faktörler olmasıdır.

1. INTRODUCTION

Cartographers used many tools to make maps since ancient times. With the developments in technology, the tools used in cartography have changed. In today's world, fast, accurate and up-to-date information has become a crucial demand in almost every scientific area as well as cartography. Today, traditional mapping methods alone may not be feasible in all cases of topographic or thematic mapping. So as to say, there should be more detailed and easily available data which is nothing more than an image data.

Image data of the earth, acquired from remote sensing satellites, are very good at observing and recording the environment, detecting land changes and investigating natural resources (Albertz and Wiedemann, 2003). The huge amount of data, that remote sensing provides, is commonly used for topographic and thematic map production. When back to history, multispectral scanner (MSS) image data has been utilized to produce maps since the launch of LANDSAT-1 in 1972 (Mach, 1981). With that data, first aerial photomaps were created with the similar methods used in conventional mapping process. Meanwhile the quality of satellite image data, the capacity and the efficiency of digital image processing and graphical data processing systems have been developed very fast. In fact, some satellites such as SPOT and KFA-1000 have been specially designed for cartographic mapping purposes (Albertz et al., 1992). In the following years, many other military or public satellites (e.g. CARTOSAT, Skynet, etc.) were also developed.

With the time, satellite images have become more beneficial for cartography, because they are obtained systematically, up-to-date and available when needed. There are three fundamental cartographic usage areas of satellite images: (i) to produce or revise conventional topographic maps by restitution and interpretation of the image data (ii) to produce satellite image maps (thus, making use of the integrated information which is available in the pictures) (iii) to produce thematic maps either by using satellite image maps as base maps for thematic mapping or by deriving thematic information from the image data (Albertz and Wiedemann, 2003).

1.1 Purpose of Thesis

This thesis focuses on the possibilities of topographic map production by using satellite imagery. While considering the topographic maps, third dimension (i.e height information) was kept out of the thesis, only 2D information about map objects were mentioned. In this context, basic topographic mapping requirements are going to be considered in detail in order to determine the information themes included in maps, regarding numerous of international and national topographic maps and mapping standards. All the information themes are going to be separated into sub-classes and examined in different level of details based on different map scales. This information compilation of map content elements is going to end up with requirement matrices. Then, remote sensing satellite data is also going to be investigated and requirement matrices for information themes are going to be created with a similar approach but this time, classification of information themes is going to be based on spatial resolution. Finally, two matrices are going to be evaluated together and results are going to be discussed. To illustrate the situation, a case study is going to be presented.

One of the main question of this thesis is to look for or introduce a concrete relationship between scale and resolution. In other words, is it possible to say directly that this spatial resolution substitutes this map scale? Other questions are listed as follows: Is remote sensing data alone is competence for topographic mapping or not? Can topographic image maps provide thematic and geometric accuracy at a specified/desired scale? Are image maps -produced directly from satellites images- cartographically correct and sufficient? This thesis tries to find answers for all those questions above.

Moreover, this work may be a review and a source for topographic map production based on satellite imagery. Because it includes information about map content elements which a map should contain at a specified scale and a specified spatial resolution intervals.

After this introduction chapter, map concept is going to be overviewed by considering the topographic classification based on scale, representation of map content elements and map accuracy (see Chapter 2). In Chapter 3, remote sensing imagery is going to be mentioned in terms of classification based on the spatial resolution, spectral characteristics of entities and effect of different band combinations on object identification. Methodolody is going to be explained in Chapter 4 by considering background research and creating requirement matrices for maps and remote sensing data (Figure 1.1). Chapter 5 is going to be consist of a case study in order to apply the theoretical information -mentioned in methodology-, the results of the study and the accuracy assessment based on the outcomes of the application. Last chapter is going to include discussions about object representation, object extraction and thematic and geometric evalution of the results obtained in Chapter 5. Besides, the thesis is going be concluded and some recommendations are going to be given for further researches.

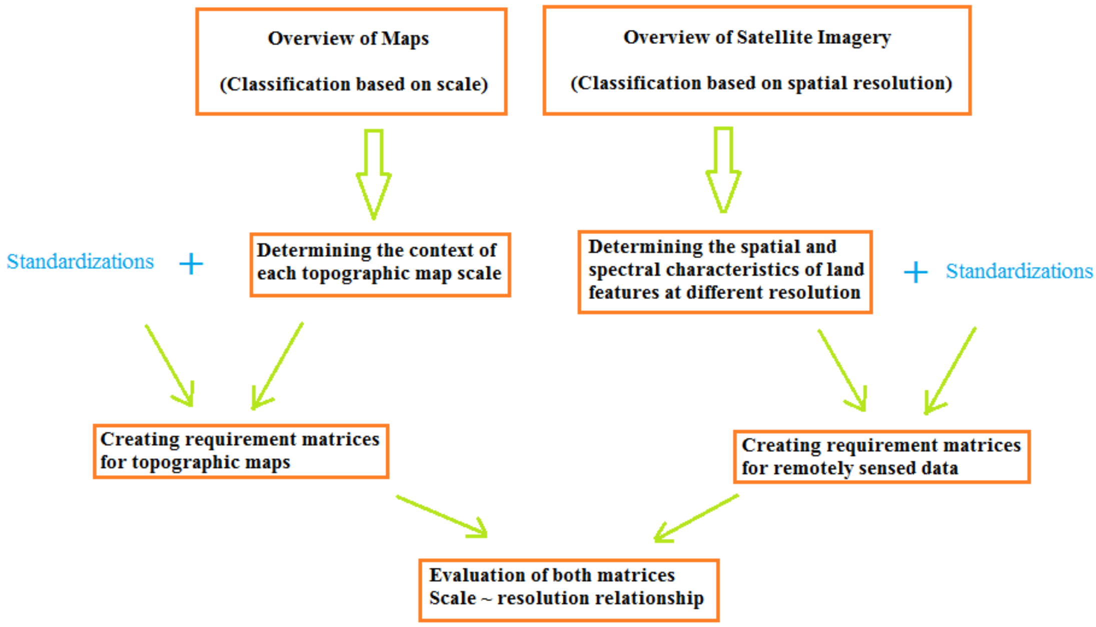


Figure 1.1 : Flowchart of the study.

2. OVERVIEW OF MAPS

Maps are the basic tools for spatial communication. There are hundreds of map definition and this definition has been changing from time to time with the developments in technology and concerning the needs. According to Robinson et al (1984) "the graphic representation of spatial relationships and spatial forms is what we call a map". On the other hand, Bertin’s (1983) definition states that; if cartography is to take advantage of developments in visualisation technology for exploring and communicating spatial reality through two-way maps, then it should regard maps as depictions of spatial, rather than geographic, phenomena. International Cartographic Association (ICA) defined the map as “a symbolised representation of geographical reality, representing selected features or characteristics, resulting from the creative effort of its author’s execution of choices, and is designed for use when spatial relationships are of primary relevance” (Rystedt et al., 2003). Different from above definitions, the map has also been defined as a meaningful extract of the highly detailed aerial photograph. The contents of this kind of map are not limited only the representation of planimetry, but undergo at smaller scales corresponding changes, involving the suppressing of unimportant items and the emphasizong and classifying of important features (Rytz, et al., 1977).

Maps can be classified based on content and scale. By content, there are special purpose (thematic) maps and topographic maps. Topographic maps represent spatial relationships between different geographic features emphasizing their location relative to each other (in other words; topological relations) whereas thematic maps show the spatial variation of particular variables, emphasizing the pattern of the distribution [Url-1]. Thematic maps are mostly made with a single purpose in mind and that purpose has generally to do with revealing the spatial distribution of one or two attribute data sets (e.g., demographic or population change map). Mapping of any kind of categorical and numerical data are the concerns of thematic mapping. Moreover, thematic maps can be used in decision-making (e.g. real-time traffic map for travel decisions) (Stevens et al., 2012; DiBiase, 1996) On the other hand, topographic maps illustrate both artificial and natural objects (hydrology, relief, vegetation, etc) topological relations on the terrain. [Url-2]. The distinctive property of a topographic map is that the shape of the Earth's surface is shown by contours which are imaginary lines joining points of equal elevation on the surface of the land above or below a reference surface. Measuring the height of mountains, depths of the ocean bottom, and steepness of slopes are possible with them. However topographic maps show more than contours, they have symbols representing street, building, stream, and vegetation features (USGS, 2012).

2.1 Classification of Maps

This thesis mainly focuses on how topographic maps are classified according to their scales. Map scale characterizes the relationship between distance on the ground and distance corresponding on a map. Thus, it refers to the size of representation. Maps are considered in different scale ranges varying from smallest to largest for different use cases. Below you can find a general classification of topographic maps based on scale according to Swiss Society of Cartography (Swisstopo) standards (Spiess et al., 2002).

2.1.1 Large-scale maps (≥ 1 : 10 000)

2.1.1.1 General survey plan/ base map at 1 : 5 000 – 1 : 10 000 scale

The purpose of a general survey plan is to represent a local area as complete as possible. It can be a base for applications in local administration and business, local post and rescue services, inventory mapping (planning on a local level), Geographic Information Systems (GIS) and the analysis of the local spatial data, town plans and charts. It includes complete traffic network, complete and differentiated representation of settlement with all buildings and infrastructure facilities, political boundaries (down to the lowest level of administration even with parcels), complete hydrographic network, detailed geometric relief representation (with contour lines, spot heights, embankments, rocks, scree and glaciers) and vegetation (forest, groups of trees, bushes, vineyards and fruit trees) (Spiess et al., 2002).

2.1.2 Medium-scale maps (1 : 25 000 – 1 : 300 000)

2.1.2.1 Topographic detail map at 1 : 25 000 scale

The purpose of a 1 : 25 000 scaled map is to cover an information about a relatively small area as complete as possible. They are also useful for orientation and navigation, detailed information about terrain structure, military purposes on a local level. Inventory mapping (for planning experts on a regional level), applications in local administration and business, applications in the field of rescue, all representations in smaller scales, representation and analysis of spatial data in GIS can also be done with a 1 : 25 000 scaled topographic detail map. It contains information about complete traffic network, complete and differentiated representation of settlement with all buildings (essential infrastructure and facilities), political boundaries (down to the municipality level), complete hydrographic network, detailed geometric relief representation (with contour lines, spot heights, embankments, rocks, scree and glaciers) and vegetation (forest, groups of trees, bushes, vineyards and fruit trees) (Spiess et al., 2002).

2.1.2.2 Topographic detail map at 1 : 50 000 scale

Maps at 1 : 50 000 scale are overviews of a region with a detailed information. They are used for orientation and navigation for regional and local motor traffic, for extracting information about terrain surface and for military purposes on all levels. They are base for: inventory mapping (planning purpose), representation and analysis of spatial data in GIS. These maps show complete traffic network, all settlements, important infrastructure and installations, political boundaries (down to the municipality level), complete hydrographic network, geometric relief representation (with contour lines, spot heights, embankments, rocks, scree and glaciers) and vegetation (forest, groups of trees, bushes, vineyards) (Spiess et al., 2002).

2.1.2.3 Topographic map at 1 : 100 000 scale

Maps at 1 : 100 000 scale aim to overview of a larger region. They are mostly used for orientation and navigation for regional and local motor traffic, for showing accessibility of settlements, for giving information about regional terrain surface, for applications in both administration and the field of rescue and for military purposes on all levels. They are base maps for thematic mapping over larger areas, representation and analysis of spatial data in GIS. Complete main traffic network, all settlements, important infrastructure, political boundaries (down to the province level), hydrographic network (with lake rivers and important streams), geometric relief representation (with contour lines, spot heights, rocks, scree and glaciers) and vegetation (forest) (Spiess et al., 2002).

2.1.2.4 Topographic map at 1 : 200 000 scale

Its purpose is to give a geographic and topographic overview of a large area, for orientation and navigation for traffic in a large area, information about the terrain structure over a large area, register of all places, water, landscapes, mountains and valleys. Planning and thematic mapping of large areas, representation and analysis of spatial data in GIS are done based on 1 : 200 000 scaled topographic maps. They consist main traffic network, all settlements, political boundaries (down to the province level), main hydrographic network (with lakes and rivers), relief representation (with contour lines, spot heights, rocks, scree and glaciers) and vegetation (forest) (Spiess et al., 2002).

2.1.2.5 Topographic overview map at 1 : 500 000 scale

1 : 500 000 scaled maps are the geographic overviews of a large area, They are necessary for traffic orientation in a large area, for supporting strategic planning of the military, for informing about the terrain structure over a large area and for showing important geographical names. They are also base for planning, thematic mapping, GISs over a large area. Content elements of 1 : 500 000 scaled topographic maps are main traffic network, selected settlements, national boundaries, main rivers and large lakes, relief representation (with contour lines, spot heights, rocks, scree and glaciers) and vegetation (forest) (Spiess et al., 2002).

2.1.3 Small-scale maps (≤ 1 : 1 000 000)

2.1.3.1 Topographic overview map at 1 : 1 000 000 scale

Similar to 1 : 500 000 scaled topographic maps, purpose of maps at 1 : 1 000 000 scale is to make a geographic overview of a large area. They are used for strategic planning of the military containing information about the terrain structure over a large area and showing important geographical names. They can be base maps for thematic mapping and GISs over a large area. They show main traffic network, selected settlements, national boundaries, main rivers and large lakes and relief representation (with contour lines, spot heights, rocks, scree and glaciers) (Spiess et al., 2002). Vegetation is not shown at this scale.

2.2 Representation of Map Content Elements

Map content elements were also examined based on representation considering scale changes. Content elements are shown in different ways at different scales. Similar to the information given in the previous chapter (see 2.1), general representation rules of some fundamental map content elements are mentioned at this stage. While representing the point-based, line-based or area-based elements, perception of human eye and cartographic drawing rules are considered. Map content elements such as residential objects, roads, rivers and lakes and vegetation categories are going to be discussed based on the following figures (Figure 2.1).

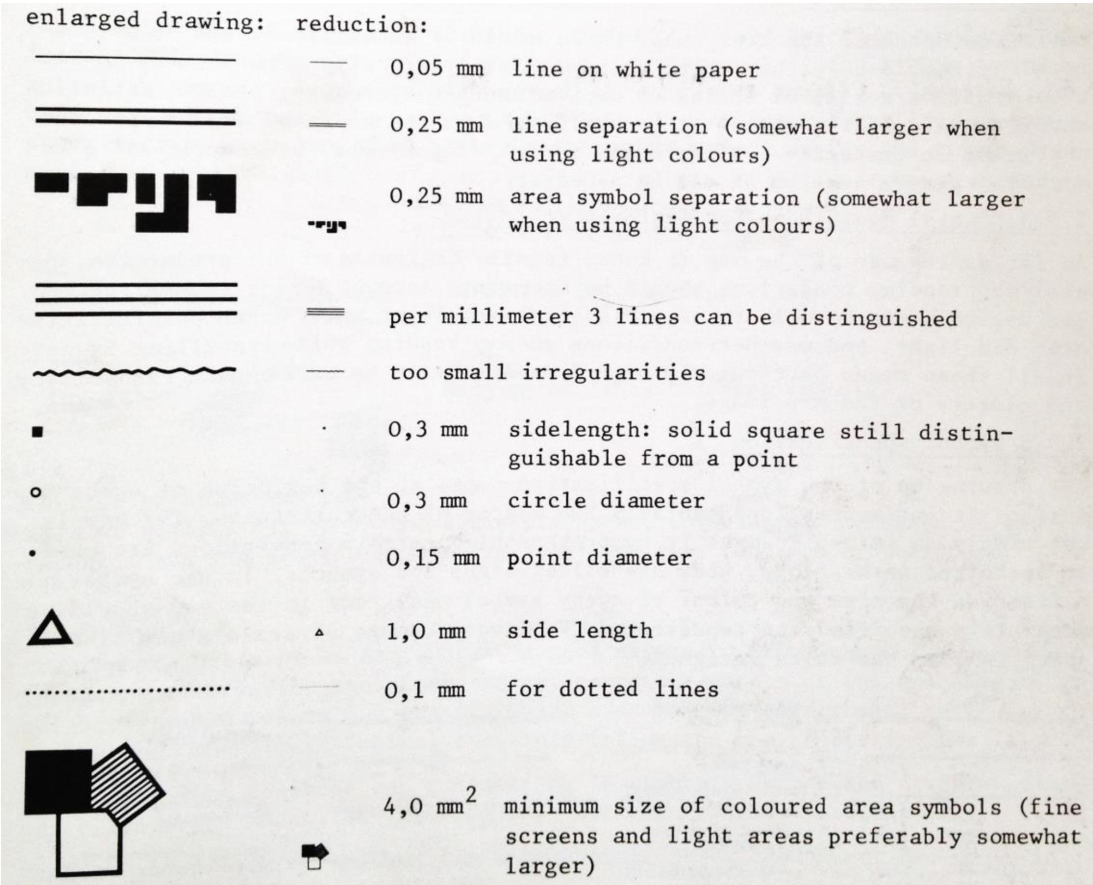


Figure 2.1 : Minimum sizes of cartographic representation (Rytz, et al., 1977).

2.2.1 Residential objects

Based on the values in Figure 2.1, minimum size of solid square distinguishable from a point is 0.3 mm. Thus, 1 : 5 000 scaled topographic map can show details up to 1.5 mm. Information about building types and heights can be given at 1 : 5 000 scale. 1 : 10 000 scale is the last limit of planimetric representation. Maps with a smaller scale than 1 : 10 000 are not able to show every detail about buildings, because minimum size of area symbol seperation is 0.25 mm. Thus generalization is needed. At 1 : 25 000 scale, adjacent buildings can be represented as blocks, some small buildings are exaggerated or some buildings are shifted. The location of characteristic objects are preserved. Priority of objects should be (i) Geodetic points, railways, main streets, (ii) Other roads and streets, rivers and lakes (iii) Buildings and other structures (iv) Topography, vegetation (Ulugtekin and Ucar, 2012; Figure 2.1).

Adjacent buildings are tried to show individually up to 1 : 25 000 scale. However starting from 1 : 50 000, buildings are aggregated geometrically. At 1 : 300 000 and smaller scales, it is impossible to give information about the residential structure of the city. That is why the city is represented by a single symbol (block representation) which covers the outer border of residential area. This representation can be applied up to 1 : 500 000 scale. At small-scale maps, point based or ratio based symbols (created according to population) stand for residential areas (Ulugtekin and Ucar, 2012).

2.2.2 Roads

The minimum symbol size to draw a road with a double line is 0.25 mm. Thus, at 1 : 5 000 scale, a road with a 1.25 m width can be drawn. However, roads are classified for representation at smaller scales. While road generalization, road widths are exaggerated and curves are simplified by preserving the characteristics of the road (Ulugtekin and Ucar, 2012; Figure 2.1.). This geometry change can be explained with an example; a footpath with a 1 m width on the ground is represented with a 0.15 mm line on the map. The size on the ground corresponds to 3.75 m for 1 : 25 000 and 7.5 m for 1 : 50 000. This means that at 1 : 50 000 scale, the road is exaggerated twice as it is done at 1 : 25 000 scale (Rytz, 1977).

2.2.3 Rivers and lakes

At 1 : 5 000 scale, streams with a width of 2 m can be drawn with a double line. This limitation is 4 m for 1 : 25 000 and 6 m for 1 : 50 000 and 1 : 100 000. Generalization process is similar to road generalization (Ulugtekin and Ucar, 2012). However, according to Ordnance Survey -also as known as National Mapping Agency of Great Britain-, rivers, streams, canals, permanent drains and ditches are shown by a single line (representing their centre line) if they are less than 2 meters wide on 1 : 2 500 scale maps [Url-3]. These two different information shows how the standardizations affect the represention of map content elements.

2.2.4 Vegetation

Areas such as forest, vineyard, orchard, marsh and pasteur are shown with their special symbols based on the regulation. When scale gets smaller, symbols turn into colours and object distinction gets weaker. For instance, 1 : 500 000 scale topographic maps show only forests and starting from 1 : 1 000 000 scale, vegetation is not displayed (Ulugtekin and Ucar, 2012; Spiess et al., 2002). In topographic maps vegetation is shown with color trim. Areas with substantial vegetation (forest, scrub, etc.) are shown with green color and areas with little or no vegetation (permanent snowfields and glaciers) are depicted with white color [Url-4].

2.3 Map Accuracy and Quality

Map accuracy is the closeness of results of observations, computations or estimates to the true values or the values accepted as being true" (NCDCDS, 1988). There are two types of accuracy; positional (geometric) and attribute (thematic) accuracy.

Positional accuracy deals with the accuracy of the location of map features, and measures how far a spatial feature on a map is from its true or reference location on the ground (Bolstad, 2005). According to The Glossary of the Mapping Sciences (ASPRS and ASCE, 1994) definition; positional accuracy as “the degree of compliance with which the coordinates of points determined from a map agree with the coordinates determined by survey or other independent means accepted as accurate.” Positional accuracy uses sampling to estimate the discrepancy between a map or image feature’s coordinates or elevations and their “true” location on the earth's surface. Positional accuracy can refer to either horizontal (planimetric) or vertical (elevational) accuracy (Congalton and Green, 2008).

Vertical accuracy is related with contour interval, not map scale. Vertical map accuracy is defined as the RMSE in evaluation in terms of the project's evaluation datum for well-defined points only (ASPRS, 1990). For instance, according to United States Geological Survey (USGS), the vertical accuracy standard requires that the elevation of 90 percent of all points tested must be correct within half of the contour interval [Url-5].

The mean vertical positional error (mv)† is depicted in mapping applications by the vertical root-mean-square error (RMSEv) of the sample of vertical errors (evi) and is estimated by

$$\mathrm{RMSE}_v = \sqrt{\sum_i^n (e_{vi})^2/n} \quad \textbf{(2.1)}$$

where;

$$e_{vi} = v_{ri} - v_{mi} \quad \textbf{(2.2)}$$

and v_{ri} equals the reference elevation at the ith sample point, v_{mi} equals the map or image elevation at the ith sample point, and n is the number of samples (Congalton and Green, 2008).

Horizontal accuracy is related to the map scale. Horizontal map accuracy is defined as the root mean square error (RMSE) in terms of the project's planimetric survey coordinates (X,Y) for checked points as determined at full (ground) scale of the map. The RMSE is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation and final extraction of ground dimensions from the map (ASPRS, 1990). Horizontal accuracy is more complex than vertical accuracy because the error is distributed in two dimensions (both the x and y dimensions), requiring the calculation of the radial error and reliance on the bivariate normal distribution to estimate probabilities (Congalton and Green, 2008). The equation for the average horizontal error or horizontal root-mean-square error ($RMSE_h$) is calculated from the errors of the individual test sample points using the following equation:

$$\text{RMSE}_h = \sqrt{\frac{\sum_i^n e_{hi}^2}{n}}$$

(2.3)

where ehi is defined in the preceding equation and n is the number of test sample points (Congalton and Green, 2008).

Geometric error sources can be grouped as; the use of base maps with different scales, different national horizontal datum in the source materials or different minimum mapping units which are then resampled to a final minimum mapping unit. The only way for a map user to assess the geometric reliability of the final map, is to produce map legends by sticking to the geometric properties of original source data in terms of carto-bibliographic information. Moreover, for the case on producing map by there can be some extra information which gives an idea about root-mean-square error related with the resampling process. Additionally, when the legend also covers a text summary of data types, it will be helpful for identifying portions decreasing the reliability and provides better source for decision making (Lunetta et al., 1991).

Thematic accuracy deals with the labels or attributes of the features of a map, and measures whether the mapped feature labels are different from the true feature label (Congalton and Green, 2008). The thematic accuracy of a map describes how well the label of a region on a map matches the corresponding region on earth (Denham et al., 2009). On the other hand, attribute (thematic) accuracy, preferably a quantitative assessment, defined as "a value assigned to summarize the accuracy of the identification of the entities and assignments of values in the data set and the identification of the test that yielded the value (Federal Geographic Data Committee, 1998). Four main questions may be asked in order to evaluate the thematic accuracy of a map:

1. What is the error frequency: how often (i.e., over what proportion of the mapped area) does the map not agree with reality?
2. What is the nature of the errors: which themes or properties are not mapped correctly, and with which other classes or property values are they confused?
3. What is the magnitude of errors: how serious are they for a decision-maker?

4. What is the source of the errors: why did they occur? (Rossiter, 2001).

Thematic accuracy of maps has to be evaluated by answering the above questions. Determining error sources is the main consideration of detecting thematic accuracy. Above parameters are also going to be considered in the discussion part of the thesis when evaluating the thematic accuracy.

3. OVERVIEW OF REMOTE SENSING IMAGERY

Remote sensing imagery involves all types of photographs taken remotely; either from and aircraft of satellite. Images taken from an airborne system are called aerial photographs whereas called satellite images when captured from a satellite.

3.1 Aerial Photography

People always wanted to see the earth "as the birds do". Even though the use of aerial photography was limited in the 19th century, the coverage and technical properties of it improved among the 20th century. Now it is possible to use aerial photographs for all earth-resource application from small and simple to large and sophisticated (Aber et al., 2010). Aerial photos are the image sequences taken at predefined intervals from an aircraft. It is one of the most common, versatile and economical forms of remote sensing. Below the characteristics of aerial photography are given in detail. [Url-6]:

- Synoptic viewpoint: giving a bird's eye view of large areas enabling to see surface features in their spatial context and enabling the detection of small scale features and spatial relationships that would not be found on the ground

- Time freezing ability: virtually permanent records of the existing conditions on the Earth's surface at one point in time, and used as an historical document.

- Capability to stop action: providing a stop action view of dynamic conditions and useful in studying dynamic phenomena such as flooding, moving wildlife, traffic, oil spills, forest fires.

- Three dimensional perspective: providing a stereoscopic view of the Earth's surface and making it possible to take measurements horizontally and vertically a characteristic that is lacking for the majority of remotely sensed data.

- Spectral and spatial resolution: sensitive to radiation in wavelengths that are outside of the spectral sensitivity of the human eye (0.3 m to 0.9 m versus 0.4 m to 0.7 m).

- Availability: readily available at a range of scales for much of the world.

- Interpretation: by following basic characteristics of photograph such as tone, texture, pattern, place, shape, shadow and size (Digital image interpretation keys) [Url-6].

3.2 Satellite Images

In the beginning, photography referred to images (visible pictures) made after a photochemical reaction. In mid-20th century, with the developments in technology, people started to create aerial images with electronic devices. Multi Spectral Scanner (MSS) that used in Landsat I satellite is one of the first examples of this technology. Fast development of electronic scanners followed for both airborne and space-based platforms and many types of sensors and imaging systems were employed by remote sensing companies (Aber et al., 2010). The product of each satellite system vary depending on the type of satellite and sensor.

Due to the topographic mapping purposes, the main consideration is to classify imaging satellites, which have wide usage areas. They can be used for;

- global information (i.e. meteorological satellites receiving information once a day with a very broad resolution),

- land information (i.e. satellites having a high spectral but low geometric resolution for mainly classification purposes),

- mapping application (i.e. satellites having very high geometric resolution and limited spectral resolution but can be enhanced (creating stereoimages or pansharpening) (Jacobsen, 2004).

3.2.1 Classification of Satellite Imagery

In this thesis, satellites are examined according to their resolution (spatial resolution). Additionally, the detection range on the electromagnetic spectrum (spectral resolution) and temporal resolution is also going to be important while interpreting the satellite images. Considering the last development in satellite technology, satellites can be grouped into four categories by means of their resolution; very high, high, medium and low (Jacobsen, 2004; Özbalmumcu and Erdoğan, 2001).

3.2.1.1 Very high resolution satellites (≤2,5 m)

With the invention of new satellites, there has become a new category called very high resolution satellites. They have both great spatial and spectral capabilities. Worldview, TerraSAR and Orbview-2 are examples of very high resolution satellites.

3.2.1.2 High resolution satellites (2.5 m – 10 m)

High resolution satellites have panchromatic and multispectral sensors and analog camera systems. They are able to produce topographic maps between 1 : 10 000 and 1 : 50 000 scales, because they have high radiometric and spatial resolutions (Özbalmumcu and Erdoğan, 2001). OUICKBIRD, CartoSAT and SPOT-5 can be given as example for high resolution satellites.

There are several high resolution satellites. The current very high and high resolution imaging satellites are indicated in Table 3.1.

3.2.1.3 Medium resolution satellites (10 m – 100 m)

Medium resolution satellites have panchromatic and multispectral sensors and analog camera systems. They are mostly used for producing and revising topographic maps between 1 : 50 000 and 1 : 250 000 scales and land-cover classification purposes. LANDSAT, MOMS and KFA-1000 can be given as example for medium resolution satellites (Özbalmumcu and Erdoğan, 2001).

3.2.1.4 Low resolution satellites (≥ 100 m)

They are used for observing regional and environmental facts (climate change, meteorological purposes, etc.) about very large areas such as continents, countries, regions. The satellites included in this category, such as ENVISAT, METEOSAT and MODIS, usually have multispectral sensors. 1 : 500 000 and smaller scale maps can be produced by low resolution satellites (Özbalmumcu and Erdoğan, 2001).

Table 3.1 : Current very high - high resolution imaging satellites (Jacobsen, 2004).

Satellite	Launch time	Country	GSD PAN	GSD MS	Swath	View Direction
SPOT1	1986	France	10m	20m	60km	across
SPOT2	1990	France	10m	20m	60km	across
SPOT3	1993	France	10m	20m	60km	across
MOMS02	1993	Germany	4.5m	13.5m	80km	3 x orbit
IRS-1C	1995	India	5.8m	23.5m	70km	across
MOMS-2P	1996	Germany	6m	18m	105km	3 x orbit
ADEOS	1996	Japan	8m	16m	80km	Nadir
IRS-1D	1997	India	5.8m	23.5m	70km	Across
SPOT4	1998	France	10m	20m	60km	Across
IKONOS 2	1999	USA	0.8m	2.4m	11km	Free
KITSAT 3	1999	S.Korea	15m	15m	50km	-
UoSAT 12	1999	UK	10m	30m	10km	-
Kompsat1	1999	S.Korea	6.6m	-	17km	across
EROSA1	2001	Israel	1.8m	-	12.6km	free
QuickBird	2001	USA	0.6m	2.4m	16.8km	free
TES	2001	India	1m	-	8km	free
SPOT5	2002	France	5(2.5)m	10m	60km	across
OrbView3	2003	USA	1m	4m	8km	free
Resourcesat	2003	India	5.8m	5.8m	70km	across
BilSat	2003	Turkey	12m	28m	12km	free
ROCSat	2004	ROChina	2m	4m	24km	free
Cartosat1	2004	India	1m	2.5m	27km	2xorbit
Kompsat2	2004	S.Korea	1m	4m	15km	free
Topsat	2004	UK	2.5m	5m	15km	free
ALOS	2005	Japan	2.5m	10m	70km	3 x orbit
Resurs DK2	2005	Russia	1m			
Cartosat 2	2005	India	0.8m	-	9.6km	free
RazakSat	2005	Malaysia	2.5m	5m	Free	
ChinaDMC+4	2005	PRChina	4m	32m	Free	
EROS B	2006	Israel	0.7m	-	7km	free
WorldView	2006	USA	0.5m	2m	16.8km	free
IKONOS BI.II	2006	USA	0.4m	1.6m	Free	
OrbView 5	2007	USA	0.4m	1.6m	Free	
Pléiades HR	2007	France	0.7m	2.8m	21km	free
THEOS 2	2007	Thailand	2m	15m	24km	free
RapidEye	2007	Germany	6.5m	6.5m	80km	free
EROS C	2009	Israel	0.7m	2.8m	11km	free

3.2.2 Satellites used in the study

Satellites used in the context of this study are Landsat-5 TM, SPOT-5 and WorldView-2. These satellies were chosen, because they all have different spatial resolutions. Thus, they are used for different mapping purposes at different scales. The detailed information about these satellies is given below:

3.2.2.1 Landsat Thematic Mapper 5 (Landsat-5 TM)

It is the fifth satellite of Landsat programme, was launced in 1984 with a primary goal of providing a global archieve of satellite photos. Its temporal resolution is 16 days. It has a maximum transmission bandwidth of 85 Mbit/s. It was deployed at an altitude of 705.3 km with a swath width of 185 km [Url-7].

Table 3.2 : Spatial and spectral properties of Landsat-5 TM.

Bands	Spectral Band Definition	Spatial Resolution (m)
Band 1	0.45-0.52	30
Band 2	0.52-0.60	30
Band 3	0.63-0.69	30
Band 4	0.77-0.90	30
Band 5	1.55-1.75	30
Band 6	10.40-12.50	60 * (30)
Band 7	2.09-2.35	30

3.2.2.2 SPOT-5

SPOT-5 is a high resolution optical imaging earth observation satellite system, was lauched in 2002. It provides an ideal balance between high resolution and wide-area coverage. The coverage offered by SPOT-5 is a key asset for applications such as medium-scale mapping (at 1:25 000 and 1:10 000 locally), urban and rural planning, oil and gas exploration, and natural disaster management. It has improved spatial resolution for both panchromatic (2.5 and 5 meter) and multispectral images (10 meter visible, 10 meter Near Infrared). Revisit time of SPOT-5 is 2-3 days depending on the latitude with a swath width of 60 km x 60 km to 80 km at nadir [Url-8]. Spatial and spectral characteristics are given in Table 3.3.

Table 3.3 : Spatial and spectral properties of SPOT-5 [Url-9].

Bands	Spectral Band Definition	Spatial Resolution (m)
Panchromatic	0.48 - 0.71 µm	2.5 m or 5 m
B1 : green	0.50 - 0.59 µm	10 m
B2 : red	0.61 - 0.68 µm	10 m
B3 : near infrared	0.78 - 0.89 µm	10 m
B4 : mid infrared (MIR)	1.58 - 1.75 µm	20 m

3.2.2.3 Worldview-2

WorldView-2, launched October 2009, is the first high-resolution 8-band multispectral commercial satellite. It operates at an altitude of 770 kilometers and provides 46 cm panchromatic resolution and 1.85 m multispectral resolution. WorldView-2 has an average revisit time of 1.1 days and is capable of collecting up to 1 million square kilometers of 8-band imagery per day [Url-10]. Following table shows spectral bands of WorldView-2 (Table 3.4).

Table 3.4 : Spatial and spectral properties of Worldview-2 [Url-10].

Bands	Spectral Band Definition	Spatial Resolution (m)
Pan	0.450 - 0.700 µm	0.46
Coastal Band	0.400 - 0.450 µm	0.52
Blue	0.450 - 0.490 µm	0.52
Green	0.490 - 0.585 µm	0.52
Yellow Band	0.585 - 0.625 µm	0.52
Red	0.625 - 0.705 µm	0.52
Red Edge Band	0.705 - 0.745 µm	0.52
Near Infrared Band 1	0.860 - 0.104 µm	0.52
Near Infrared Band 2	1.58 - 1.75 µm	0.52

3.3 Object Characteristics and Spectral Curves

Electromagnetic energy is the energy source required to transmit information from the target to the sensor. It is a crucial medium that is described as an electromagnetic spectrum. On this spectrum, many forms exist that describe energy in a specific region of the electromagnetic spectrum. These are visible light, radiowaves, microwaves, heat, UV rays, X-rays and Gamma rays [Url-12]. Each interval of electromagnetic spectrum gives different information about entities. For instance; in near-infrared portion, it is easy to identify water bodies whereas vegetation identification is better in red portion of the electromagnetic spectrum. Following figure shows more detail about which object characteristics can be extracted from which part of the electromagnetic spectrum (Figure 3.1).

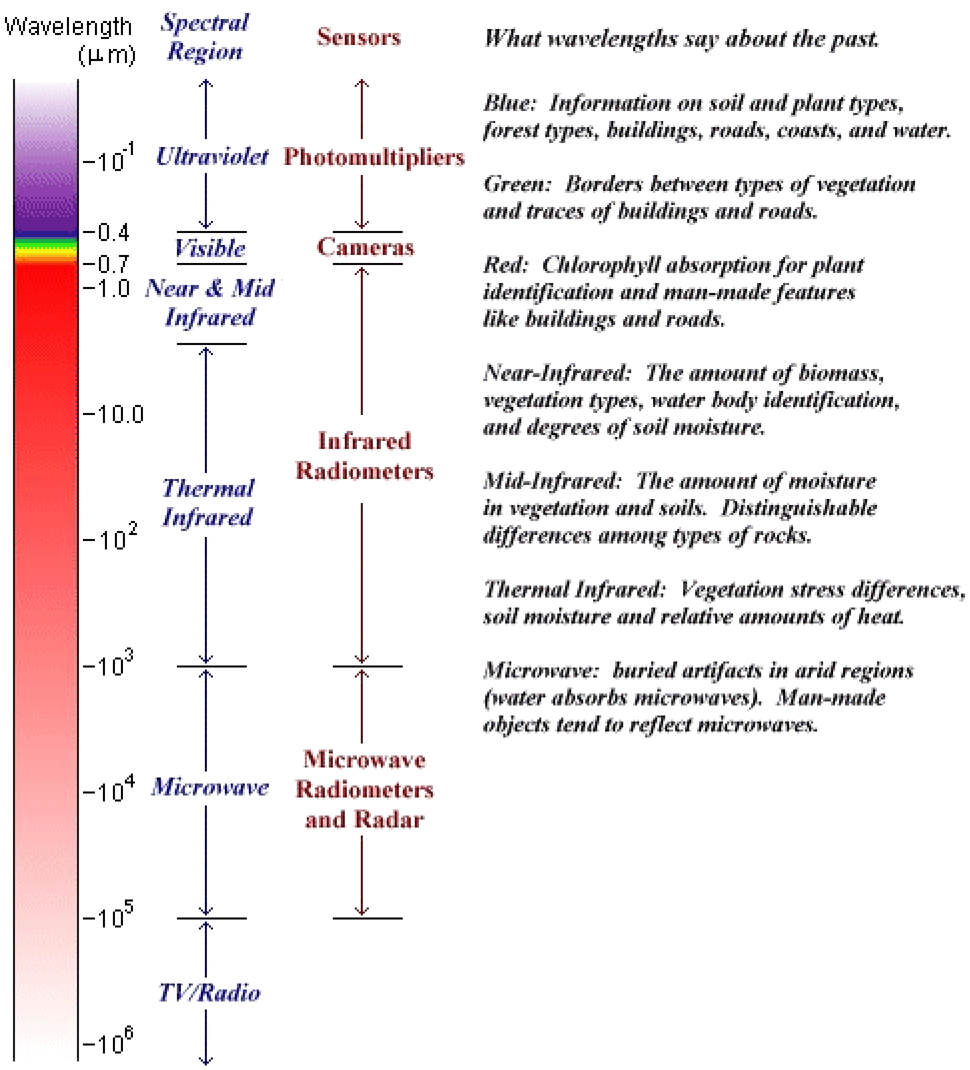


Figure 3.1 : Electromagnetic spectrum and information extraction [Url-13].

Remote sensing is based on the measurement of reflected or emitted radiation from different bodies. Objects having different surface features reflect or absorb the sun's radiation in different ways. The reflectance properties of an object depend on the particular material and its physical and chemical state (e.g. moisture), the surface roughness as well as the geometric circumstances (e.g. incidence angle of the sunlight). The most important surface features are colour, structure and surface texture. These differences make it possible to identify different earth surface features or materials by analysing their spectral reflectance patterns or spectral signatures. These signatures can be visualised in so-called spectral reflectance curves as a function of wavelengths [Url-14]. “Spectral curves” show the characteristic shapes for various materials. The term "spectral signature” should be interpreted as meaning that each separate example of a material will have a subtly unique signature

(Belward and Valenzuela, 1991). Each land-cover type has its own unique spectral curve. While water shows no reflection, vegetation shows maximum reflectance in the infrared part of the spectrum. Following figure shows the spectral characteristics of water, soil and vegetation by considering the electromagnetic spectrum (Figure 3.2).

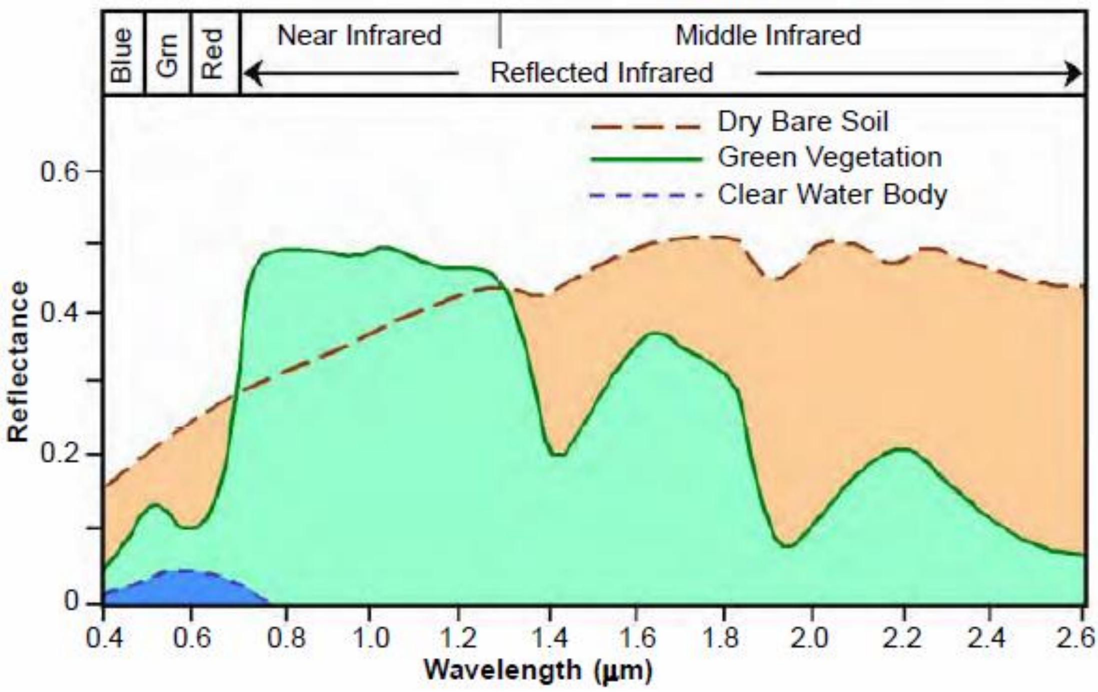


Figure 3.2 : Spectral reflectance curves of common earth surface materials [Url-15].

3.3.1 Vegetation

For visible portion of electromagnetic (EM) spectrum; the spectral response of plants is dominated by reflection. Plants use light energy from the visible part of the spectrum to synthesize the organic compounds necessary for maintenance and growth -which is called photosynthesis-. In visible portion, pigments in plants affect the reflection. All the pigments show strong absorption of blue light, with the chlorophyll also showing strong absorption of red light. Maximum reflectance occurs in the green part of the spectrum. That is the reason why plants are seen as green (Belward and Valenzuela, 1991).

However, near infrared (NIR) energy is not affected by pigments and almost completely penetrates through them. As Bird (1991) stated, measurements of spectral reflectance for the red and the near-infrared are effective in identifying the presence of vegetation because they highlight both the absorptance feature and the high reflectance feature of the spectral curve. The spectral response of plants is dominated by transmission. The energy levels of NIR light are not great enough to drive photochemical reactions within the photosynthetic cycle, thus the pigment containing chloroplasts are transparent to NIR light. Shortly, leaf structure is important in the NIR region (Belward and Vanezuela, 1991).

The middle-infrared region (1.301 μm - 2.5 μm) contains information about the absorption of radiation by water, cellulose and lignin and several other biochemical constituents. This region of the vegetation spectrum allows the identification of vegetation stress due to drought [Url-16].

Water has strong absorption bands in shortwave infrared region (SWIR). Rather than absorption bands, reflectance of leaves generally increases when leaf liquid water content decreases. This property can be used for identifying tree types and plant conditions from remote sensing images. The SWIR band can be used in detecting plant drought stress and delineating burnt areas and fire-affected vegetation [Url-17]. As a result, the combination of low visible reflectance and high near-infrared reflectance is unique for most vegetation types and that is why it is known as the vegetation spectral signature [Url-14] (Figure 3.3).

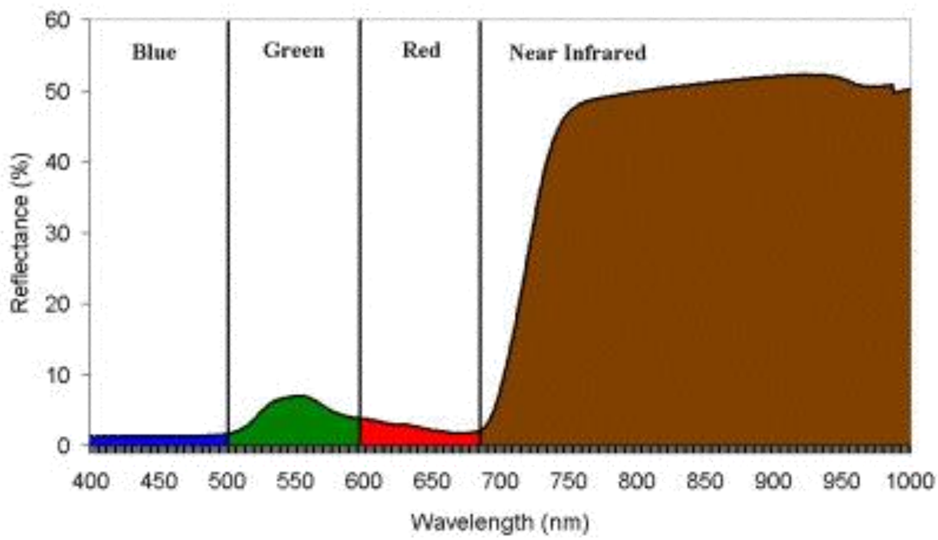


Figure 3.3 : Vegetation spectral signature [Url-14].

3.3.2 Water

Majority of the radiation incident upon water is not reflected but is either absorbed or transmitted. Longer visible wavelengths and near infrared radiation is absorbed more by water than by the visible wavelengths. Thus, water looks blue or blue green due to stronger reflectance at these shorter wavelengths and darker if viewed at red or near infrared wavelengths. The factors that affect the variability in reflectance of a water body are depth of water, materials within water and surface roughness of water (Aggarwal, 2003).

On the other hand, water behaves as a specular reflector because water bodies are three-dimensional. Therefore, any measure of reflectance can include a component from the bottom, surface or water column itself. In the infrared, relationships between reflectance and water quality parameters tend to be random because of the effect of the fundamental and overtone water absorption bands (Bird, 1991).

3.3.3 Soil

Soil has very different characteristics to water with spectral reflectance increasing with wavelength in the VNIR (Visible Near Infrared). The increase in reflectance with wavelength in the visible is consistent with the human eye's observation that soils can have a red or brown colour to them. There is usually a strong correlation between the value of spectral reflectance in the visible and the value of spectral reflectance in the near infrared for soils whether the soils are inherently light or dark. The overall level of reflectance is of the order of 20% in the visible and 30% in the near infrared. For this reason, the land-water boundary is simple to identify on a satellite image (Bird, 1991).

3.4 Band Combination and Appearance of Entities

Band combination is very important while extracting information about entities. Besides, classifying objects, different color composites helps to make visual interpretation, too. In this chapter, Landsat satellite images (used in the case study) are given as an example to show different land feature characteristics with different band combinations (Figure 3.4 - 3.6). 3-2-1 (Natural color) band combination provides the most water penetration and superior sediment and bathymetric information. It is also used for urban studies. 4-3-2 (False color) is a frequently used band combination and is useful for vegetation studies, monitoring drainage and soil patterns and various stages of crop growth. 7-4-2 (Natural-like) color composite is useful for geological, agricultural and wetland studies [Url-18]. Following table shows the appearance colors of main land cover types based on true color, false color and geocover composites (Table 3.5). There numerous of other band combinations for determining different land cover types. For instance, 1-4-7 band combination is good at extracting water, urban, vegetation and forest features while 1-2-3 band combination is good at extracting arable land and green areas [Url-18].

Table 3.5 : Appearance of features on composite images [Url-19].

	True Color Red: Band 3 Green: Band 2 Blue: Band 1	**False Color** Red: Band 4 Green: Band 3 Blue: Band 2	**SWIR(GeoCover)** Red: Band 7 Green: Band 4 Blue: Band 2
Trees and Bushes	Olive green	Red	Shades of green
Crops	Medium to light green	Pink to red	Shades of green
Wetland Vegetation	Dark green to black	Dark red	Shades of green
Water	Shades of blue and green	Shades of blue	Black to dark blue
Urban Areas	White to light blue	Blue to gray	Lavender
Bare Soil	White to light gray	Blue to gray	Magenta, lavender or pale pink

In Figure 3.4, the resulting image with a true color band combination is fairly close to realistic. But there is little contrast and features in the image are hard to distinguish. In this false color rendition, vegetation jumps out as a bright red because green vegetation readily reflects infrared light energy. It is very useful for studying vegetation (Figure 3.5). Shortwave Infrared (SWIR) rendition looks like a vibrant true color rendition. Especially water objects are more recognizable (Figure 3.6).

Figure 3.4 : True Color: Band 1= Blue - Band 2= Green - Band 3= Red.

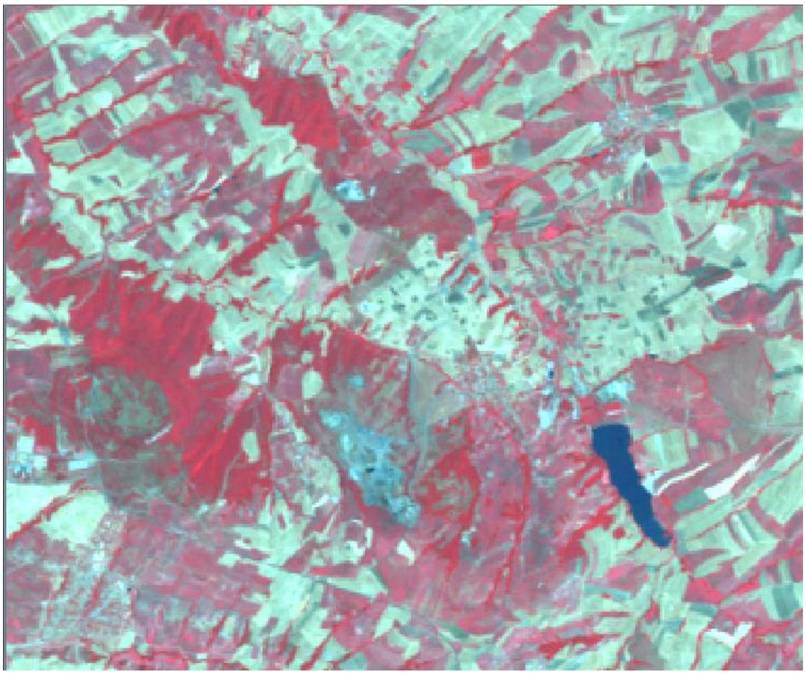


Figure 3.5 : False-Color (or NIR): Band 2= Blue - Band 3= Green – Band 4= Red.

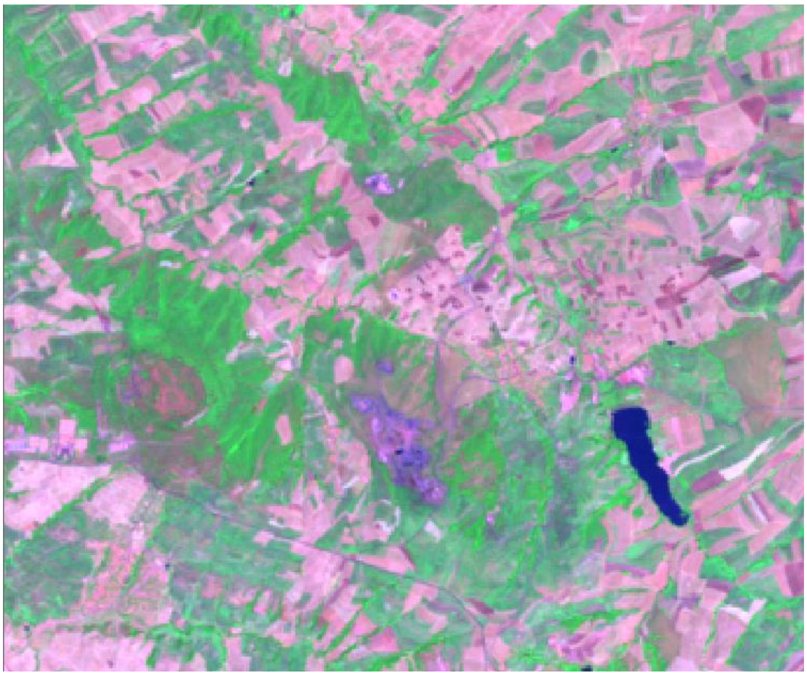


Figure 3.6 : SWIR: Band 2= Blue - Band 4= Green - Band 7= Red.

The above figures (Figure 3.5 - 3.6) belong to the study area which is going to a subject to the case study in Chapter 5. As mentioned before, band combination is very important for visual interpretation. When the figures are examined based on the on Table 3.4., it can be seen that the appearance colors of entities and the related band combinations overlap. For instance, green color represents trees and bushes with true color band combination, whereas red color represents the same feature with false color band combination. On the other hand, water is seen as greenish in Figure 3.5 but it is seen as blue in Figure 3.4 and dark blue in Figure 3.6. The effect of different band combinations is going to be explained in detail in the application stage.

4. METHODOLOGY

4.1 Background Work

Map compilation procedure has to have a strong database, which is able to store and manage thematic and geometric data. Both thematic and geometric organization of the data specifies map content characteristics. This thesis focuses on introducing and organizing the information themes that each map has to contain. Frye (2006) states that organization creates its map a profound impact on the quality and utility of any publicly disseminated information that will come from that map. Information themes can be described as the head content elements (like administrative, transportation, etc) that a map contains. Designing a geodatabase for a map starts with thematic organization, which is actually organizing the information themes. For the purpose of the thesis, this thematic organization had to be valid for both map content elements and remote sensing land cover and land use features, because the will is to produce maps with the use of satellite image data. When tried to determine fundamental information themes for maps, it has been come across that there were several standardization varying from country to country or even producer to producer. For this reason, it was tried to stick to national standards by means of naming and integrate international standards by means of organization. Thus, the organization of information themes (i.e. map content elements) was carried out by benefiting from below national and international standards and some printed maps.

Taking a closer look at national and international published and unpublished standards is going to be useful to make a better categorization of map content elements. Below are some examples taken from sources used in this thesis:

- Legends of 1 : 25 000, 1 : 50 000, 1 : 100 000 and 1 : 250 000 scaled Topographic Maps produced by General Command of Mapping in Turkey was used as the base source while listing the map content elements. It includes all the point, line and area-based map objects belonging to the relevant scale and their vector symbolization. Following figure is an example legend of road theme on 1 : 25 000 scale. There is also a hierarchical relationship between map objects in the legend. Roads are divided into highways and unimproved roads and highways are divided into hard surface highways and loose surface highways. Moreover, each type of highway has also its sub-classes such as dual highway, two or more lanes wide, etc. (Figure 4.1).

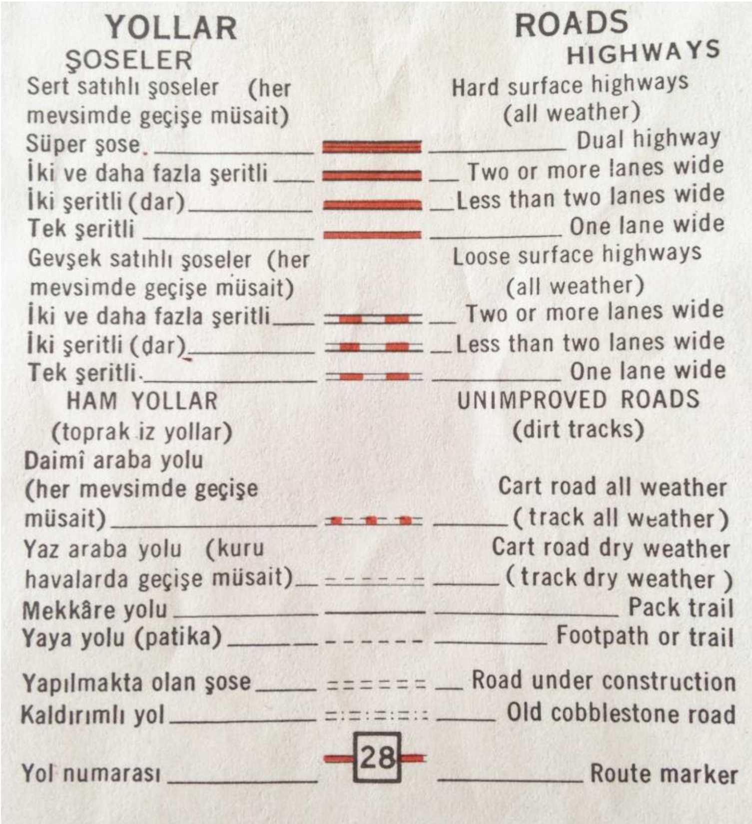


Figure 4.1 : Representation of roads in 1 : 25 000 map legend (GCM, 2002).

- Second example is from “Swiss Society of Cartography Topographic Map Production” publication. This standardization was mostly used to specify map content elements at each topographic map scale and form hierarchical relationships between information themes. Similar to Figure 4.1, Figure 4.2 also shows the hierarchical order of administrative boundaries besides giving the vector representation of object at different scales. To see the change in representation based on scale gives an idea about how generalization plays an important role in mapping.

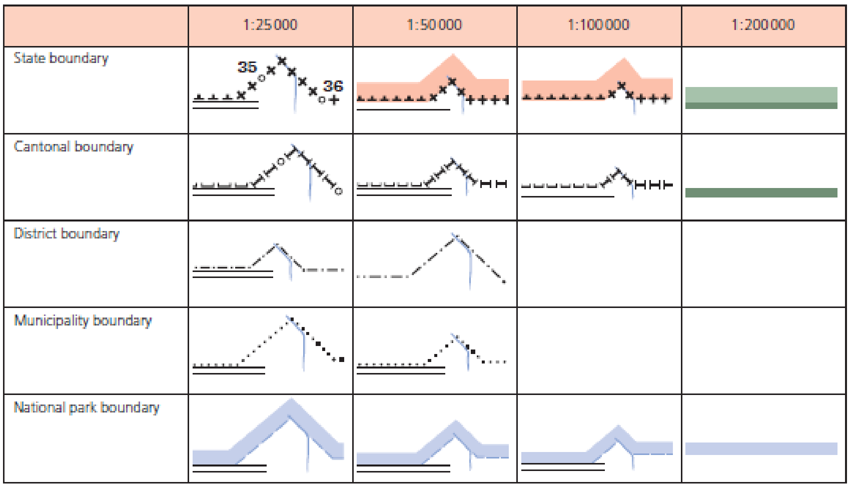


Figure 4.2 : Administrative object classes based on Swisstopo (Spiess et al., 2002).

- "Land Cover Classification System for the Use of Remote Sensing Data" standardization of United States Geological Survey (USGS) was useful to learn which land cover objects are identified from remote sensing data and determining level of details while organizing the contextual database. There are two specified level of details and Level III is up to the person who runs classification process or extracts information for mapping purposes. Thus, it can be said that it is a relatively flexible standardization. Following figure shows the detail levels of urban theme. Level I is the broadest category and it has sub-classes such as Level II and Level III. This means that urban category can be divided into seven classes such as residential, commercial and services and etc. Residential class can also be divided into sub-classes such as single family units, multi family units, etc. (Figure 4.3).

Level 1	Level II	Level III
1. Urban or built-up	11. Residential	111. Single-family Units
		112. Multi-family Units
		113. Group Quarters
		114. Residential Hotels
		115. Mobile Home Parks
		116. Transient Lodging
		117. Other
	12 Commercial and Services	
	13 Industrial	
	14 Transportation, Communications, and Utilities	
	15 Industrial and Commercial Complexes	
	16 Mixed Urban or Built-up Land	
	17 Other Urban or Built-up Land	

Level III - Subcategorization is flexible

Figure 4.3 : Level of detail organization of urban areas (Anderson et al., 1976).

- CORINE (Coordination of Information on the Environment) land-cover classification standards was used in order to gain different aspects about mapping with remotely sensed data. It is pretty similar to USGS standardization. However, third level is already determined in this classification, it does not depend on user (Figure 4.4).

Level 1	Level 2	Level 3
1. Artificial	1.1. Urban fabric	1.1.1. Continuous urban fabric surfaces 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 and associated land 1.2.3. Port areas 1.2.4. Airports
	1.3. Mine, dump	1.3.1. Mineral extraction and construction sites 1.3.2. Dump sites 1.3.3. Construction sites
	1.4. Artificial non-agricultural	1.4.1. Green urban areas vegetated areas 1.4.2. Sport and leisure facilities
2. Agricultural	2.1.Arable land	2.1.1. Non-irrigated arable land areas 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

Classification based on level of details

Figure 4.4 : Level of detail organization of urban areas (Bossard, 2000).

- Another source represents some examples of printed maps produced by Institut Geographique National (National Geography Institute) (IGN). IGN produces cartographic map series varying small to larger scales. It is also good to examine printed maps because the legends of maps show details -that are mapped- based on the relevant scale. It is possible to compare detail levels of maps by looking at map legends. For instance,

- 1 : 100 000 scale shows: Motorways, dual carriage ways with road characteristics, main roads (i) two lanes or more (ii) narrow lanes or less, secondary roads (i) two lanes or more (ii) narrow lanes or less, roads-streets (i) regularly maintained (ii) not regularly maintained, carttrack, footpath, hiking trail, prohibited road.
- 1 : 1 000 000 scale shows: Motorways, dual carriage ways with road characteristics, main roads, regional connecting roads, secondary roads, single carriage ways (3 or 4 lanes), roads with two wide lanes and roads with two narrow lanes (IGN printed maps).

As inferred from above example, 1 : 100 000 scale shows even small footpath while 1 : 1 000 000 scale is only able to show road details up to secondary roads (Figure 4.5 - 4.6).

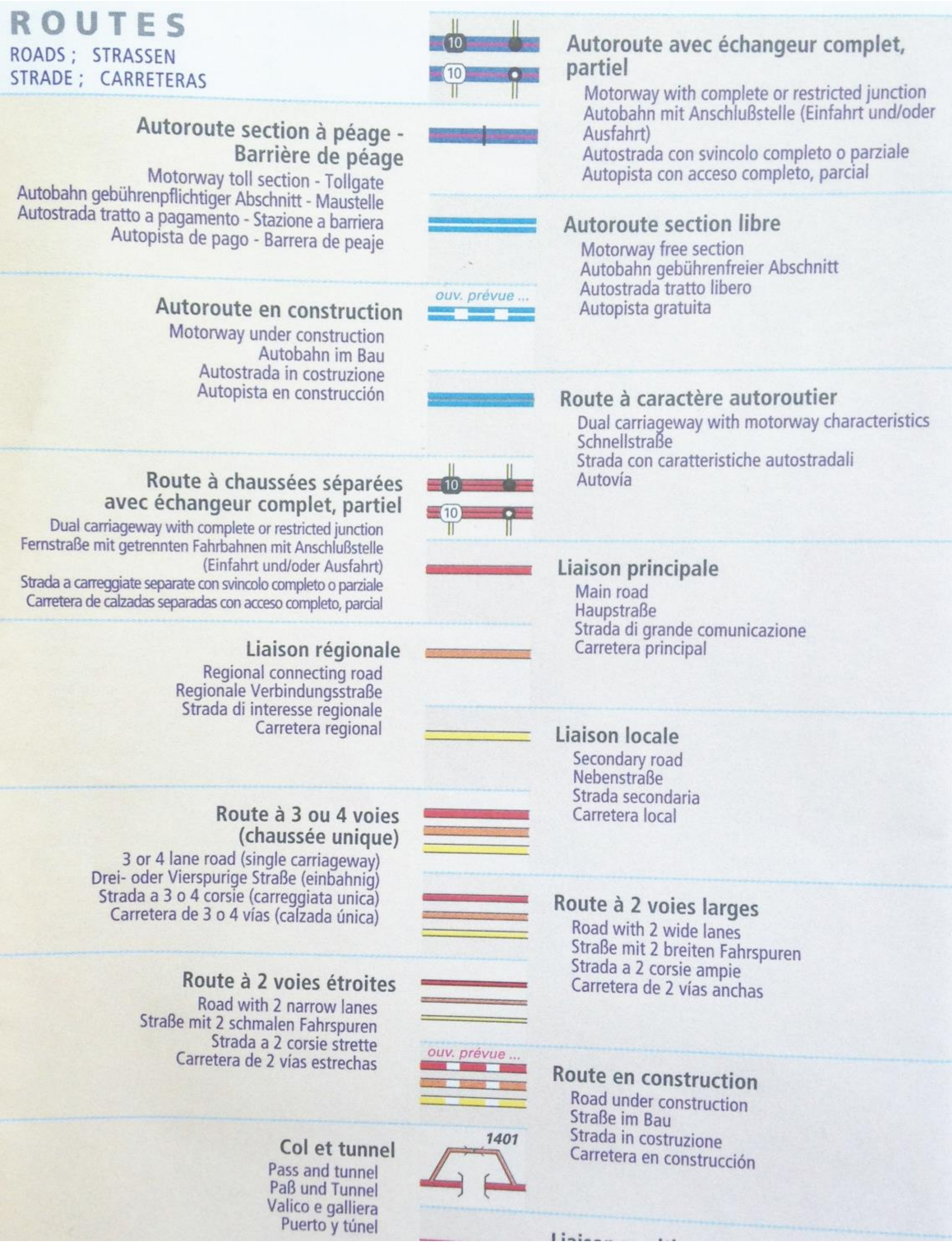


Figure 4.5 : Legend of transportation at 1 : 1 000 000 scale (IGN printed maps).

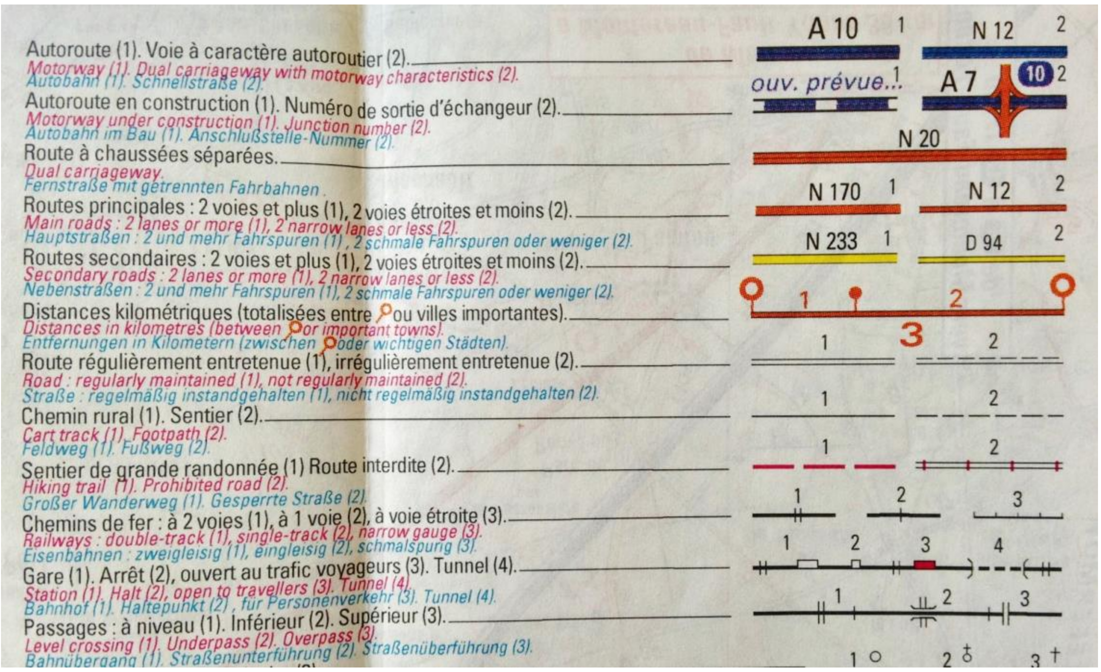


Figure 4.6 : Legend of transportation at 1 : 100 000 scale (IGN printed maps).

The rewieving process of all published and unpublished sources yields a lot of idea about organizing map content elements. The names for information themes has to be general names covering all the land structures that can be subjects of a topographic map. As a result, four main information themes were determined as transportation, vegetation, administrative and hydrography and these themes were handled as different level of details (sub-classes).

4.2 Creating Requirement Matrices

A requirement matrix can be described as a table showing requirements that are needed to be verified when they fulfill their purposes based on some pre-defined criteria. In this thesis, the information themes (consisting of map content elements) are said to be the requirements, and scale and resolution parameters are pre-defined criteria. Thus, there are going to be two types of requirement matrices for each information theme; (i) based on scale (for maps) and (ii) based on resolution (for remotely sensed imagery).

4.2.1 Requirement matrices for topographic maps

First step was to list the contextual information that each map scale needs to cover its purpose. All the contextual information was handled under the administrative, transportation, vegetation and hydrographic information themes. When entitling the information themes, Swisstopo standardization were used (Spiess et al., 2002). Then, the themes and sub-classes of each theme were examined based on different map scales. Sub-classes were determined based on the legends of 1 : 25 000, 1 : 50 000, 1 : 100 000 and 1 : 250 000 scaled Topographic Maps produced by General Command of Mapping in Turkey. This process is called thematic data organization. For thematic data organization, structure of USGS and CORINE classification was used as a base (Anderson et al., 1976; Bossard et al., 2000). Following figure shows the resultant data organization of themes and sub-classes which are going to be a subject for requirement matrices (Figure 4.7).

Administrative

- **Boundaries**
  - National Boundaries
  - Province Boundaries
  - Municipal Boundaries
  - Town Boundaries
  - Village Boundaries
  - District Boundaries
- **Settlement**
  - Residential/Urban Built-up Areas
  - Commercial and Services
  - Industrial

Transportation

- **Road Network**
  - **Hard Surfaced**
    - ✓ 1st class road (S1)
    - ✓ 2nd class road (S2)
    - ✓ 3rd class road (S3)
  - **Soft Surfaced**
    - ✓ 1st class road (G1)
    - ✓ 2nd class road (G2)
    - ✓ 3rd class road (G3)
- **Railway Network**
  - Tracks
  - Stops
- **Seaway Network**
  - Ferry
  - Pier
  - Port
- **Airway Network**
  - Airport

Vegetation

- Agricultural
  - **Arable Lands**
    - ✓ Rice field
    - ✓ Olive grove
    - ✓ …
- Forests and Semi-natural Areas
  - **Forests**
    - ✓ Coniferous
    - ✓ Broad-leaved
    - ✓ …
  - **Individual Trees**
    - ✓ Coniferous
    - ✓ Broad-leaved
    - ✓ …
- Wetlands
  - **Inland Wetlands**
    - ✓ Fan
    - ✓ Swamp
    - ✓ Reed bed
  - **Coastal Wetlands**
    - ✓ Sandy areas

Hydrographic

- Linear Objects
  - **Boundaries**
    - ✓ Sea danger boundary
    - ✓ Permanent lake boundary
    - ✓ …
- Areal Objects
  - **Running Water**
    - ✓ Spring
    - ✓ Stream
    - ✓ …
  - **Stagnant Water**
    - ✓ Permanent lake
    - ✓ Lake with changeable edge
    - ✓ …
  - **Special Objects and Facilities**
    - ✓ Overflowing area
    - ✓ Water distinction point
    - ✓ …

Figure 4.7 : Thematic data organization.

On the other hand, geometric characteristics such as line, polyline, polygon or point of each sub-classes were also determined at this stage.

“Administrative” information theme is going to be used as an example to explain the process. Administrative theme has “boundary” sub-class and “boundary sub-class has another sub-class called “national boundary”. At 1 : 5 000 scale, national boundaries are shown and geometric characteristic of this object is defined as polyline (Table 4.1).

Table 4.1 : Example contextual information about “administrative theme.

			1 : 5 000	1 : 10 000	1 : 25 000
Administrative	Boundaries	National Boundaries	polyline	polyline	Polyline
		Province Boundaries	polyline	polyline	Polyline

Another consideration is limiting resolution, i.e., the size of the smallest object that can be seen legibly on a map. Smallest detail at cartographic representation had to be determined in order to identify the representation limits of each scale. It is usually assumed to be approximately 0.15 mm and is often called the zero dimension [Url-20]. This means that smallest detail that 1 : 5 000 scaled topographic map can show is 0,75 m. If this statement is formulated as follows (4.1);

$$m_{object} = +/-[\ (0.15\ M) / 1000]\ (meter) \quad \textbf{(4.1)}$$

In the formula, “m” represents the cartographic drawing error if there is no other error exists, “M” is the scale factor and dividing by 1000 is for unit transformation. Thus, cartographic drawing errors i.e. theoretical position errors of drawing at different scales are presented in Table 4.2;

Table 4.2 : Theoretical position errors at different scales.

Error (m)	Scale
+/- 0.75	1 : 5 000
+/- 1.5	1 : 10 000
+/- 3.75	1 : 25 000
+/- 7.5	1 : 50 000
+/- 15	1 : 100 000
+/- 30	1 : 200 000
+/- 75	1 : 500 000
+/- 150	1 : 1 000 000

The relationship between “how buildings should be represented” (individually, block representation or point representation) and geometry of representation (by means of smallest detail) were determined by concerning generalization rules based on scale. (see Chapter 2.2.1). As a result, smallest detail for administrative buildings were integrated to administrative requirement matrix as a representation criterion and following values are obtained (Table 4.3).

Table 4.3 : Theoretical position errors at different scales.

			1 : 5 000	1 : 10 000	1 : 25 000
Administrative	Buildings	Urban Buildings	individual buildings	individual buildings	individual buildings shown individually and neighboring buildings are merged
		Represen-tation	Smallest detail is 1.5 m	Smallest detail is 3 m	Smallest detail is 7.5 m

Same procedure was also done for other three information theme (transportation, vegetation and hydrographic). However there are some other specifications that are needed to be considered for linear objects such as roads and rivers. As mentioned in Chapter 2.2; at 1 : 5 000 scale, a road with a 1.25 m width and a stream with a 2 m width can be drawn with a double line. (Ulugtekin and Uçar, 2012). Based on this representation rule smallest widths of linear feauteres were calculated (Table 4.4).

Table 4.4 : Theoretical position errors at different scales.

Width of Roads (m)	Width of Streams (m)	Scale
1.25	2	1 : 5 000
2.5	4	1 : 10 000
6.25	10	1 : 25 000
12.5	20	1 : 50 000
25	40	1 : 100 000
50	80	1 : 200 000
125	200	1 : 500 000
250	400	1 : 1 000 000

From Table 4.4, it is understood that applying the theoretical position errors is impossible at scales smaller than 1 : 100 000, because there is no such road or a river with a width of 50 m, 125 m or 250 m in reality. Thus, it is not entirely correct to calculate smallest widths with the direct proportion. The reason for this situation is generalisation. The roads are exaggerated, as the scale gets smaller. The same procedure is applied for also streams and rivers.

Last step was to integrate all themes and sub-classes and object representation characteristics of sub-classes were in order to create requirement matrices for maps. As a result, there have been four requirement matrices obtained for administration, transportation, vegetation and hydrographic themes (see Table A1 - D1).

4.2.2 Requirement matrices for remote sensing imagery

Next step was to investigate the contextual information that each remote sensing imagery (having different spatial resolution) has in order to cover its purpose. Same contextual information -which was previously listed in Chapter 4.2.1- was examined by considering entities which can be a subject of remotely sensed imagery. Thus, scale and spatial resolution relationship was tried to be formed. For the information contents based on experience, there is this practical rule that the pixel size on the ground GSD (Ground Sampling Distance) shall not exceed 0.05 up to 0.1mm in the map scale (Jacobsen, 1998). This statement is formulated below (4.2):

$$\text{Resolution} = \text{Scale} * \text{GSD} \quad \textbf{(4.2)}$$

To generate 1 : 10 000 scaled map, 0.5 - 1 m GSD (Ground Sampling Distance) image is needed. Unless this condition is verified by the available images, not the whole required map contents can be extracted. The range between the lower and the upper value of this rule is depending upon the structure of the area and the national map standards (Jacobsen, 1998). Based on this formula resolution-scale relationship were calculated and approximate resolution values corresponding to the relevant scale are obtained (Table 4.5). Scales and their corresponding resolution intervals were used to create a requirement matrix for remotely sensed data.

Table 4.5 : Map scale and satellite image resolution relationship.

Scale	Resolution (m)
1 : 5 000	0.25 - 0.5
1 : 10 000	0.5- 1
1 : 25 000	1.25 – 2.5
1 : 50 000	2.5 – 5
1 : 100 000	5 - 10
1 : 200 000	10 - 20
1 : 500 000	25 - 50
1: 1 000 000	50 - 100

The requirements for each spatial resolution were tried to be specified by considering the pixel sizes of remote sensing images and their corresponding lengths or widths in real world. At this stage, each sub-class was determined based on its existence and scale-resolution relationship in order to create contextual information about the information theme (Table 4.6). For instance, on a satellite image with 0.5 m spatial resolution, one pixel represents 0.25 m2 area. Thus, 0.5 m resolution will be enough to determine individual residential buildings. With the same way, 1 m and 2,5 m spatial resolutions can also be used for individual building extraction. As a result, there should be a (√) for all very high resolution satellites (Table 4.6).

Table 4.6 : Example contextual information of “administration” information theme.

			Very High Resolution (≤2,5 m)		
			0.5 m	1 m	2.5 m
Administrative	Settlement	Residential	√	√	√
		Commercial And Services	√	√	√

However, it is not always the case because, on the other hand, there is a spatial resolution rule is that there needs to be a minimum four spatial observations (i.e. pixels) with an urban ibject to identify it which means the spatial resolution of the sensor should be one-half-diameter of the smallest object of interest. For instance, a construction that is 5 m wide can be identified from a high quality image with a spatial resolution of 2.5 m if there is no haze or other problems (Cowen, et al., 1995).

There are also other parameters which have to be considered while mapping from satellite imagery; such as spectral and temporal resolution. According to Jensen (1999), to remotely sense the urban/suburban attributes, it is necessary to determine temporal, spectral and spatial resolution characteristics of these attributes. It is significant to use a high spatial (less then 5 m) and high spectral (large number of multispectral bands) while extracting urban/suburban information. At the same time, temporal resolution plays an important role at satellite image mapping. Firstly, "*the temporal development cycle of urban phenomena*" must be understood by the image analyst. Secondly, "*how often it is possible for a remote sensor system collect data of the urban landscape*" must be taken into consideration. Finally, "*how often land managers/planners need a specific type of information*" must be determined (Jensen, 1999).

When spatial, temporal and spectral resolution requirements are taken into account, following table can be created (Figure 4.8). Jensen (1999) compiled all the information about urban attributes by using several sources.

Figure 4.8 includes the minimum temporal, spatial and spectral resolution requirements for different level of land use/land cover (mainly USGS detail levels). According to this classification, one needs;

- 5-10 years temporal, 20-100 m spatial and V-NIR-MIR-Radar spectral resolution for mapping land use/land cover at Level I.
- 5-10 years temporal, 5-20 m spatial and V-NIR-MIR-Radar spectral resolution for mapping land use/land cover at Level II.
- 3-5 years temporal, 1-5 m spatial and Pan-V-NIR-MIR spectral resolution for mapping land use/land cover at Level III.
- 1-3 years temporal, 0.25-0.5 m spatial and panchromatic spectral resolution for mapping land use/land cover at Level IV.

Attributes	Minimum Resolution Requirements		
	Temporal	Spatial	Spectral
Land Use/Land Cover			
L1-USGS Level I	5–10 years	20–100 m	V-NIR-MIR-Radar
L2-USGS Level II	5–10 years	5–20 m	V-NIR-MIR-Radar
L3-USGS Level III	3–5 years	1–5 m	Pan-V-NIR-MIR
L4-USGS Level IV	1–3 years	0.25–1 m	Panchromatic
Building and Property Infrastructure			
B1-building perimeter, area, height and cadastral information (property lines)	1–5 years	0.25–0.5 m	Pan-Visible
Transportation Infrastructure			
T1-general road centerline	1–5 years	1–30 m	Pan-V-NIR
T2-precise road width	1–2 years	0.25–0.5 m	Pan-V
T3-traffic count studies (cars, airplanes, etc.)	5–10 min	0.25–0.5 m	Pan-V
T4-parking studies	10–60 min	0.25–0.5 m	Pan-V
Utility Infrastructure			
U1-general utility line mapping and routing	1–5 years	1–30 m	Pan-V-NIR
U2-precise utility line width, right-of-way	1–2 years	0.25–0.6 m	Pan-Visible
U3-location of poles, manholes, substations	1–2 years	0.25–0.6 m	Panchromatic
Digital Elevation Model (DEM) Creation			
D1-large scale DEM	5–10 years	0.25–0.5 m	Pan-Visible
D2-large scale slope map	5–10 years	0.25–0.5 m	Pan-Visible
Socioeconomic Characteristcs			
S1-local population estimation	5–7 years	0.25–5 m	Pan-V-NIR
S2-regional/national population estimation	5–15 years	5–20 m	Pan-V-NIR
S3-quality of life indicators	5–10 years	0.25–30 m	Pan-V-NIR
Energy Demand and Conservation			
E1-energy demand and production potential	1–5 years	0.25–1 m	Pan-V-NIR
E2-building insulation surveys	1–5 years	1–5 m	TIR
Meteorological Data			
M1-weather prediction	3–25 min	1–8 km	V-NIR-TIR
M2-current temperature	3–25 min	1–8 km	TIR
M3-clear air and precipitation mode	6–10 min	1 km	WSR-88D Radar
M4-severe weather mode	5 min	1 km	WSR-88D Radar
M5-monitoring urban heat island effect	12–24 hr	5–30 m	TIR
Critical Environmental Area Assessment			
C1-stable sensitive environments	1–2 years	1–10 m	V-NIR-MIR
C2-dynamic sensitive environments	1–6 months	0.25–2 m	V-NIR-MIR-TIR
Disaster Emergency Response			
DE1-pre-emergency imagery	1–5 years	1–5 m	Pan-V-NIR
DE2-post-emergency imagery	12 hr–2 days	0.25–2 m	Pan-V-NIR-Radar
DE3-damaged housing stock	1–2 days	0.25–1 m	Pan-V-NIR
DE4-damaged transportation	1–2 days	0.25–1 m	Pan-V-NIR
DE5-damaged utilities, services	1–2 days	0.25–1 m	Pan-V-NIR

Figure 4.8 : Urban/suburban attributes and minimum requirements (Jensen, 1999).

Furthermore, other specifications were also determined based on different mapping purposes of different land use/land cover attributes. For instance, general road centerline information can be extracted from 1-30 m spatial resolution satellite imagery, while 0.25-0.5 m spatial resolution is needed for determining parking areas.

The requirement matrices for remotely sensed data were formed based on both approximate map scale-resolution values (Table 4.5) and minimum remote sensing resolutions required to provide such information about land attributes (Figure 4.8). All the information themes were handled with this approach and resultant requirement matrices were obtained (see Table A2-D2).

5. CASE STUDY

The aim of the case study is to investigate the relationship between map scale and spatial resolution by using different satellite image data having different resolutions belonging to the same area. To find out the effect of spatial resolution on object identification and possibilities of topographic mapping with remote sensing data, images are going to be handled by considering target information themes defined previously as administrative, transportation, vegetation and hydographic. For this reason, images are going to be divided into zones and related objects belonging to each zone are going to be digitized. Linear and aeral evaluation is going to be conducted and results obtained from different resolutions are going to be compared. On the other hand, satellite images are going to be classified and visual interpretation is going to be handled based on different band combination. Digitization results and classification results are going be compared in order to set out the influence of both spatial and spectral resolution on object identification. At last, accuracy assessment is going to be done by calculatinf relative root mean square errors considering the digitization results.

5.1 Study Area and Data

A plot application area (approximately 2700 hectares) was chosen to illustrate the theoretical information mentioned in Chapter 4. The region is Biyikali village in Tekirdag (in the north-west of Turkey) with the geographic coordinates of 41°01'43.79"N, 27°20'18.04"E and 40°59'24.14"N, 27°24'45.54"E. The reason for choosing the study area was that the region has a rich detail variability and temporal resolution of remote sensing data belongs to the region was good enough for comparison and information extraction (Figure 5.1).

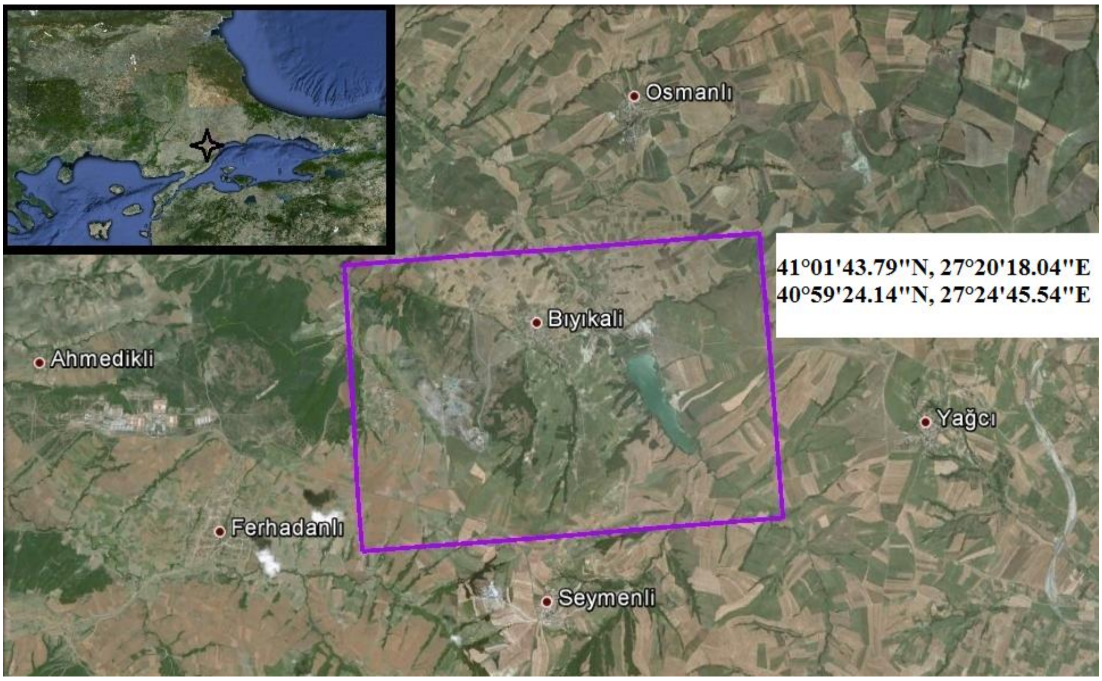


Figure 5.1 : Study area.

Three satellite images were used in this application: (i) September 2011 dated, 30 cm spatial resolution Worldview-2 image, (ii) August 2011 dated, 2,5 m spatial resolution SPOT-5 pan-sharpened image and (iii) August 2011 dated, 30 m spatial resolution Landsat-5 TM image. Worldview-2 and pan-sharpened SPOT-5 satellite image data were provided by Istanbul Technical University - Center for Satellite Communications and Remote Sensing (ITU-CSCRS) under the 109Y277 numbered TUBITAK CAYDAG project and Landsat-5 TM data was downloaded from United States Geological Survey (USGS) http://earthexplorer.usgs.gov website (Figure 5.2). On the left-hand side Worldview-2, in the middle SPOT-5 and on the right-hand side Landsat-5 images are depicted. Also 1 : 5 000-scale topographic maps related to same study area were obtained in order to use as a ground truth and 1 : 25 000-scale topographic maps were used to check symbolization of map objects. Topographic maps are provided by GAZDAS Trakya Region Natural Gas Distribution Company (Figure 5.3).

No pre-processing operation was carried out for Worldview-2 and SPOT-5 data, because they were already atmospherically and geometrically corrected by ITU-CSCRS before received. The geometric accuracy of Worldview-2 image is 1,5 m. For Landsat-5 data, individual bands were only layer stacked before study. Topographic maps were created from orthophotos and cadastral details were integrated to the maps having Transversal Mercator (TM) projection and European Datum (ED-50). The satellite images have Universal Transversal Mercator (UTM) projection and World Geodetic System (WGS-84) datum. Thus, projection and datum transformations were applied before the case study. The coordinate system of topographic maps were converted to the coordinate system of satellite images. As a result, topographic maps were georeferenced.

Figure 5.2 : Satellite image data used in the study.

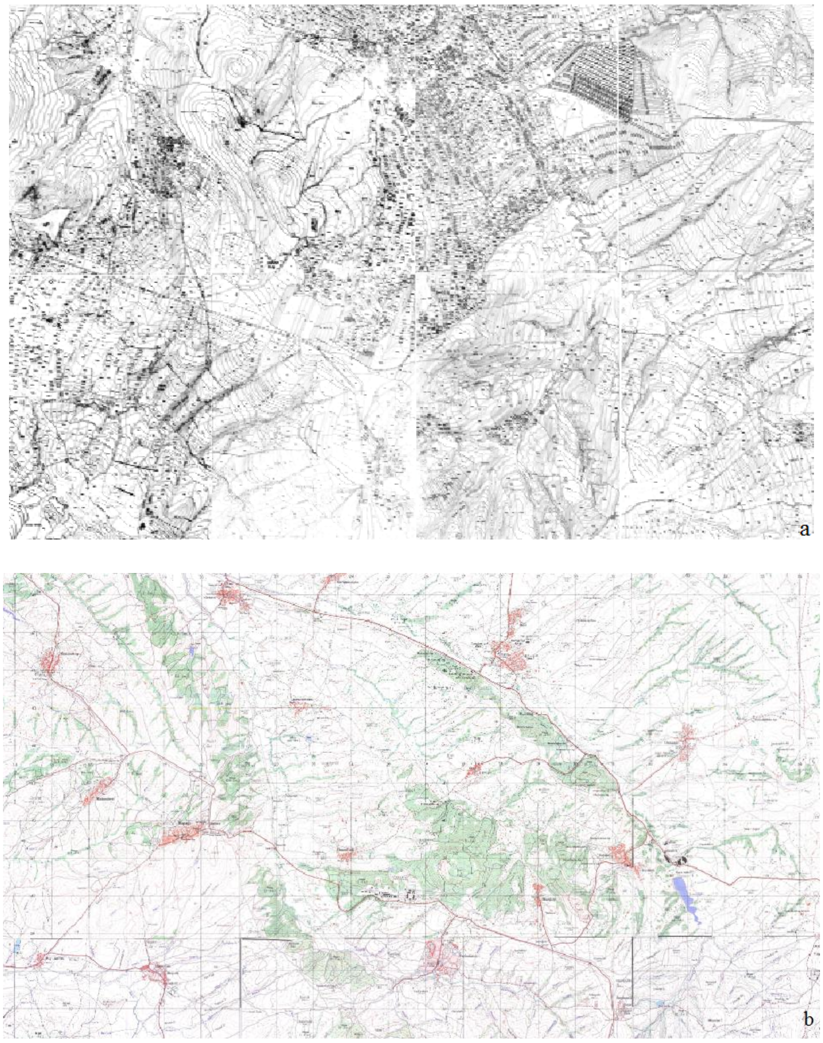


Figure 5.3 : Topographic maps (a: 1 : 5000-scale, b: 1 : 25 000-scale).

5.2 Methodology

Implementation of methodology can be explained in three main stages; first one is preparing remote sensing data and topographic maps for application, second one is digitizing the entities (possible map content elements) from images and the third one is classification of remote sensing images.

First of all, every topographic maps related to the study area was examined in order to see the recognizable details that each map has. Topographic maps were not convenient for extracting small details such as buildings, fields and parcels because of several reasons: (i) the maps were not up-to-date (ii) some details were lost because of scanning (iii) buildings were not generalized based on the cartographic generalization rules. (i.e. some buildings which can be represented individually were depicted as block representation). Thus, topographic maps can not be entirely used as ground truth for every detail. That is the reason why Worldview-2 image having 1,5 m geometric accuracy was used as a ground-truth (Figure 5.4).

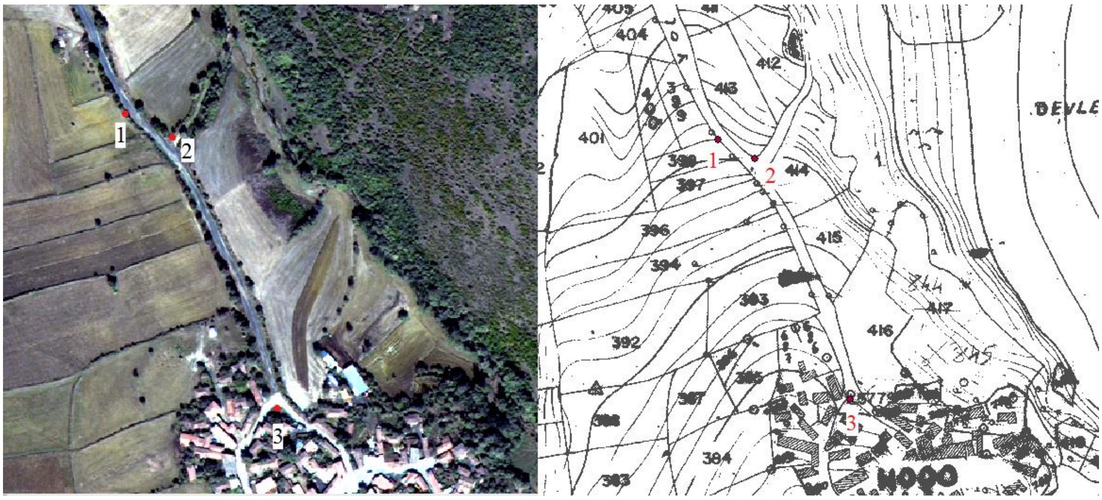


Figure 5.4 : Comparison of Worldview-2 image and topographic map.

Before starting to work with remote sensing images, study area was divided into zones and zones were cretead. Firstly, area of interests were determined for required entities and based on these areas of interests, subset images were obtained for each zone. Each zone represents one of main information themes determined previously in Chapter 3.1. For instance, one zone only includes road features, thus, this zone represents transportation theme (Figure 5.5).

Figure 5.5 : Worldview image zones (a: transportation, b: vegetation).

After generating zones; point, line and area based entities which can be a subject for topographic maps were started to digitized. Primarily; feature class, feature type/geometry (polygon, line, point, multipoint, multipatch, etc.) and coordinate system were determined for each feature to be digitized. For instance, features described by its length like roads were considered as line objects whereas fields or building features (with areal characteristics) were represented as polygons. While digitizing from the satellite images, magnification size and digitization unit were kept same for all images to eliminate the user based relative digitization errors. Secondly, each feature class was exported to a shape file and saved. Shape file is a digital vector storage format for storing geometric location and associated attribute information [Url-21]. Eventually, several sample areas -based on detail variability and areal coverage- were created on three satellite images for roads, residential buildings, industrial buildings, water bodies, forests and arable lands. 3 samples from water, 3 samples from forest, 5 samples from arable land, 4 samples from residential area, 1 sample from industrial area and 7 samples from road were formed on each satellite image. Following figure is an example of a digitization result for water bodies (Figure 5.6).

Figure 5.6 : Digitization-Lake Biyikali (a:Landsat-TM b:SPOT-5 c:Worldview-2).

Third step was to classify the satellite images which were divied into zones. The classification was done only for possible Landsat-5 TM image zones. The reason for applying classification was to understand the effect of spectral characteristics of satellite image on object determination and comparing the results with the digitization results. Unsupervised classification was conducted by selecting different band combination for each Landsat-5 image zones and then resultant clusters were labeled and land feature classes were obtained. The area of each class was calculated for comparison with the digitization results.

5.3 Evaluation

5.3.1 Evaluation of digitization results

Evaluation of digitization was conducted based on individual zones defined in Chapter 4.2. Line and area-based digitization results were shown and discussed (Figure 5.7 - 5.11). Additionally relative and percentage errors were calculated by considering Worldview-2 image as reference. Relative errors are found by subtracting lengths and areas measured on SPOT-5 and Landsat-5 TM from the ones on Worldview-2 image. (-) sign on tables means that features can not be extracted from imagery (Table 5.1 - 5.4).

First zone was chosen to extract information about roads which is a sub-class of transportation theme. As seen in Figure 5.5, it is possible to extract the road feature with two lines from SPOT-5 and Worldview-2 images whereas it is only one line from Landsat-5 image because of the spatial resolution. When cartographic representation rules are considered, at 1 : 5 000 scale, smallest width can be shown is 1.25 m and based on Table 4.4, 1 : 5 000 scale corresponds 0.5 m spatial resolution. Thus, an image with a 0.5 m spatial resolution is able to show a road with 1.25 m width. This road has approximately 6.65m width (measured on google earth). That is why, from Landsat-5 TM having 30 m spatial resolution, the road can hardly be extracted with a single line. Figure shows the digitization results of roads for each image (Figure 5.7).

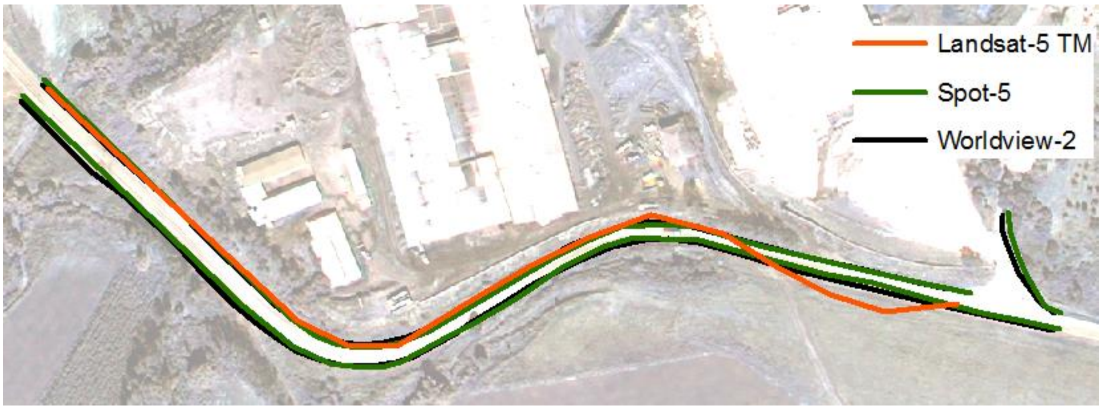


Figure 5.7 : Digitization results of roads.

Road lengths were measured after digitization and relative and percentage errors were calculated in Table 5.2.

Table 5.1 : Evaluation of roads.

	Feature	Worldview-2	SPOT-5	Landsat-5 TM
Length (m)	Road-1	560.508	565.251	506.084
	Road-2	54.947	56.947	-
	Road-3	497.679	509.594	-
	Road-4	1526.442	1535.584	-
	Road-5	855.061	862.026	-
	Road-6	308.361	292.028	-
	Road-7	961.994	967.348	-
Relative Error (m)	Road-1	0	4.743	54.424
	Road-2	0	2.000	-
	Road-3	0	11.915	-
	Road-4	0	9.142	-
	Road-5	0	6.965	-
	Road-6	0	16.333	-
	Road-7	0	5.354	-
Percentage Error (%)	Road-1	0	0.84	10.75
	Road-2	0	3.51	-
	Road-3	0	2.34	-
	Road-4	0	0.60	-
	Road-5	0	0.81	-
	Road-6	0	5.59	-
	Road-7	0	0.55	-

Second and third zone include residential and industrial administrative area respectively. All the buildings can be drawn individually from Worldview-2 image whereas they are seen as blocks on SPOT-5. From Landsat-5, it is impossible to extract any of the buildings. Maps shall have a horizontal standard deviation of approximately 0.25mm in the representation scale (Doyle, 1984). For 1 : 5 000 scale, a horizontal accuracy of 1.25m (5 000 ∗ 0.25mm = 1.25m) is required. This is not a problem for 0.5 m spatial resolution, however at 2,5 m resolution, it is limited. For instance, SPOT-5 was better at extracting industrial buildings rather than residential (Figure 5.8). This situation can be a result of sun elevation, time of the day, terrain inclination or shadow effects.

Figure 5.8 : Digitization results of residential and industrial buildings.

On the other hand, none of the individual buildings or building area can be extracted from Landsat-5 TM imagery. There is one main reasons for it; the selected area is too small and individual building extraction is not expected based on the spatial resolution of Landsat-5 TM. Medium resolution satellites are used to extract residential area (Table A.2). For this reason, a wider area of interest was determined to see if residential area can be recognized or not (Figure 5.9). According to Table 3.4 in Chapter 3.4, urban areas appear light blue/gray with true color band combination. Thus, existence of the residential area can be proved and this information is useful for smaller scales, starting from 1 : 200 000 (Table A.2).

Figure 5.9 : Residential area on Landsat-5 TM imagery.

Following table shows the errors of area-based digitized administrative objects for each imagery (Table 5.2) It can easily be seen that spatial resolution of SPOT-5 is not enough to map buildings individually.

Table 5.2 : Evaluation of administrative area.

	Feature	Worldview-2	SPOT-5	Landsat-5 TM
Area (m^2)	Residential-1	698.829	1051.604	-
	Residential-2	255.299	289.829	-
	Residential-3	176.226	136.622	-
	Residential-4	232.133	161.849	-
	Industrial-1	10243.9	8563.493	-
Relative Error (m)	Residential-1	0	352.775	-
	Residential-2	0	34.530	-
	Residential-3	0	39.604	-
	Residential-4	0	70.284	-
	Industrial-1	0	1680.407	-
Percentage Error (%)	Residential-1	0	33.55	-
	Residential-2	0	11.914	-
	Residential-3	0	28.988	-
	Residential-4	0	43.426	-
	Industrial-1	0	19.62	-

Forth and fifth zones represent forest and arable land sub-classes which belong to vegetation theme. For forest sub-class, SPOT-5 and Worldview-2 digitization result are close to each other and they both succeed to extract forest area. Thematic characteristics of the area can be understood from Landsat-5 imagery but forest area may not be geometrically correct. On the other hand, it is possible to determine individual field boundaries with SPOT-5 and Worldview-2 imagery. However with Landsat-5 TM imagery, five individual fields are seen as one arable area and boundaries are not easily recognizable (Figure 5.10).

Figure 5.10 : Digitization results of forest and arable land.

Following table shows error values based on the digitization results of vegetation objects (Table 5.3). If one pixel of Landsat-5 TM imagery represents 900 m² area, relative errors correspond approximately 52 pixels for forest area and 5 pixels for arable land.

Table 5.3 : Evaluation of vegetation.

	Feature	Worldview-2	SPOT-5	Landsat-5 TM
Area (m²)	Forest-1	287250.609	281996.838	240716.147
	Forest-2	12880.976	13321.864	-
	Forest-3	16385.269	15536.224	-
	Arable-1	10509.108	10440.340	-
	Arable-2	12516.244	12661.768	-
	Arable-3	7574.225	7332.871	-
	Arable-4	5199.026	5583.471	-
	Arable-5	35798.603	36018.450	31581.461
Relative Error (m)	Forest-1	0	5253.771	46534.462
	Forest-2	0	440.888	-
	Forest-3	0	849.045	-
	Arable-1	0	68.768	-
	Arable-2	0	145.524	-
	Arable-3	0	241.354	-
	Arable-4	0	384.445	-
	Arable-5	0	-219.847	4217.142
Percentage Error (%)	Forest-1	0	1.863	19.332
	Forest-2	0	3.310	-
	Forest-3	0	5.465	-
	Arable-1	0	0.659	-
	Arable-2	0	1.149	-
	Arable-3	0	3.291	-
	Arable-4	0	6.885	-
	Arable-5	0	0.61	13.35

Last zone is a lake which is an element of hydrographic content. Besides, Worldview-2's object extraction capabilities, both SPOT-5 and Landsat-5 TM succeeded to extract the lake object. Besides the spatial resolution of Landsat image, some geometrical differences may occur because of the date of the images. Even if all images belong to the same year and same season, difference in mouth may cause areal change; because lake is not a permanent land feature (Figure 5.11). On the other hand, band combination also affects the extraction of features. To give an example; for Landsat, water has no reflection on SWIR bands (7-4-2), so it looks black. It is easier to distinguish water bodies by using SWIR bands.

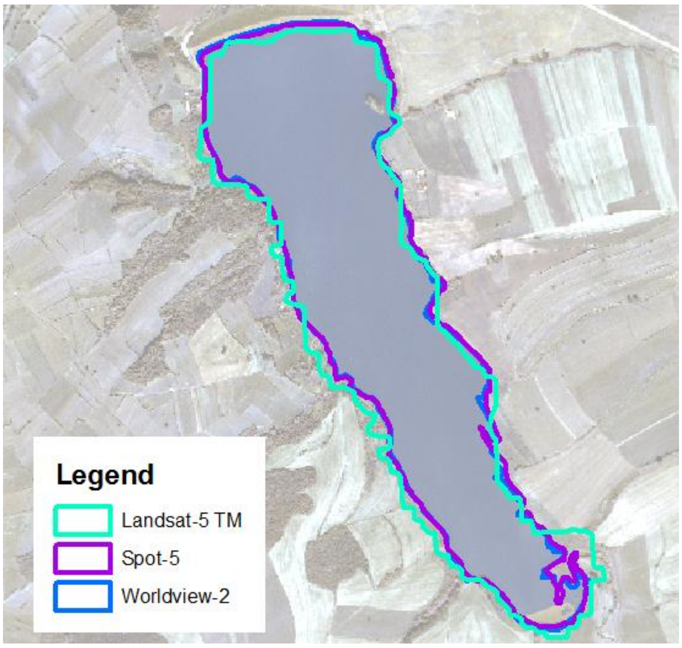


Figure 5.11 : Digitization results of water.

When the following table is interpreted, relative errors are approximately 33 pixels for Landsat-5 TM and 900 pixels (5638.375/6.25) for SPOT-5 image (Table 5.4).

Table 5.4 : Evaluation of water.

	Feature	Worldview-2	SPOT-5	Landsat-5 TM
Area (m²)	Water-1	494962.823	500601.198	524307.03
	Water-2	4446.581	4921.334	-
	Water-3	2080.468	1428.207	-
Relative Error (m)	Water-1	0	5638.375	-29344.207
	Water-2	0	474.753	-
	Water-3	0	652.261	-
Percentage Error (%)	Water-1	0	1.12	5.60
	Water-2	0	9.647	-
	Water-3	0	45.679	-

5.3.2 Evaluation of classification results

As a last step of evalution, unsupervised classification was conducted as explained in Chapter 5.2. First classification was handled in order to extract water features with the SWIR (7-4-2) band combination. SWIR band combination was selected, because water objects look black or dark blue and will be easily distinguished from other entities with these bands. Thus the pixels appearing dark blue represent the water area (see Table 3.4). To label other clusters, again Table 3.4 was used; (i) the areas which appear green on the image were determined as trees and bushes, (ii) light green areas as crops, (iii) lavender areas as bare soil. The areas obtained after unsupervised classification were calculated in hectar. The area of the lake was found out as 50.94 hectares (Figure 5.12). Evaluation of digitization was conducted based on individual zones defined in Chapter 4.2.

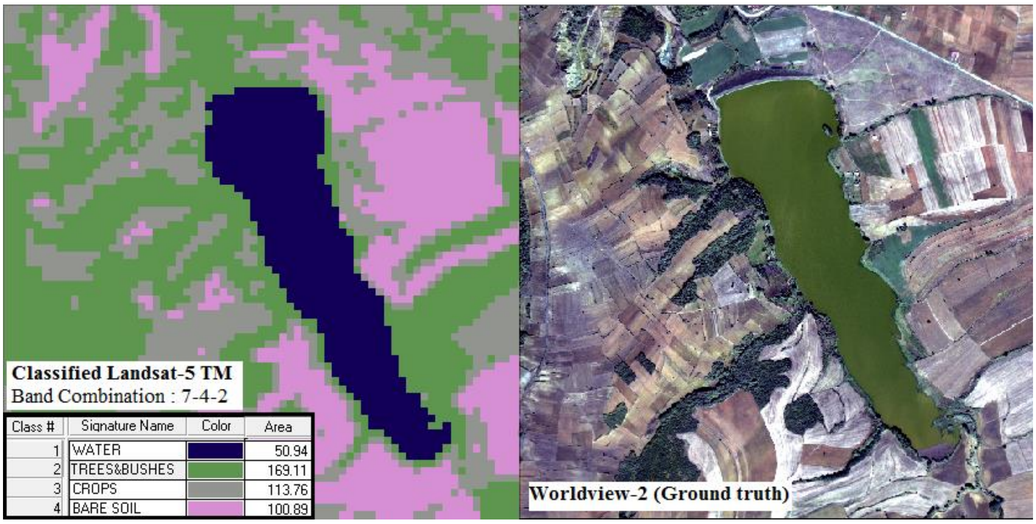


Figure 5.12 : Classification of Landsat-5 TM (RGB: 7-4-2).

Second classification was handled in order to extract forests with the false color (4-3-2) band combination. False color band combination was selected, because forest (trees and bushes) look red and will be easily distinguished from other entities with these bands. Thus, the pixels appearing red represent the forest area (see Table 3.4). To label other clusters, again Table 3.4 was used; (i) the areas which appear pinkish on the image were determined as crops, and (ii) blue-green areas as bare soil. The areas obtained after unsupervised classification were calculated in hectares. The forest area was found out as 21.06 hectares (Figure 5.13).

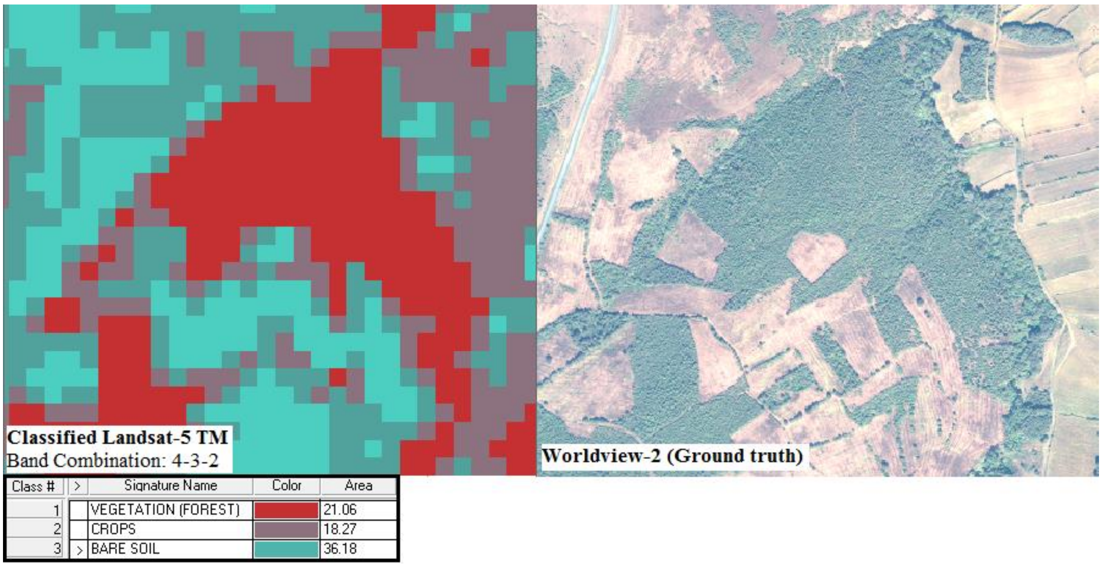


Figure 5.13 : Classification of Landsat-5 TM (RGB: 4-3-2).

Third classification was handled in order to extract arable lands with the true color (3-2-1) band combination. True color band combination was selected, because arable land (crops) look green and other entities like wetland vegetation and bare soil will look black and gray respectively, so arable lands will be easily distinguished from other land feature. However, the pixels representing the arable land appeared in different color (close to black) which is described as wetland vegetation (see Table 3.4). When compared to ground truth, the arable land may be irrigated and this may be the reason why the pixels look darker. To label other cluster seen on the image, again Table 3.4 was used and the areas which appear gray were determined as bare soil. The areas obtained after unsupervised classification were calculated in hectares. The arable land area was found out as 7.11 hectares (Figure 5.14).

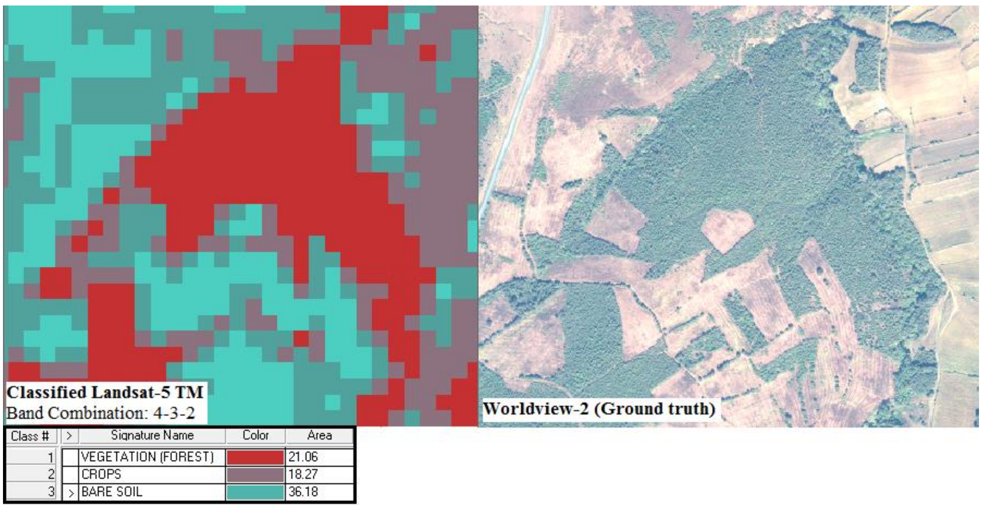


Figure 5.14 : Classification of Landsat-5 TM (RGB: 3-2-1).

5.3.3 Comparing digitization and classification results

The areal-based comparison was conducted based on the areas of entities calculated after digitization and classification of Landsat-5 TM imagery (see Chapter 5.3.1 and 5.3.2). First comparison was done for water features; after digitization of water, water area was calculated as 524307 m^2 and after classification, it was calculated as 509400 m^2 (50.94 hectares) (Table 5.5 - Figure 5.11). The difference between two area is approximately 15000 m^2 and it corresponds 17 pixels on the image. Secondly, digitized and classified forest areas were compared. The forest areas were calculated 240716 m^2 after digitization and 210600 m^2 (21.06 hectares) after classification. The difference between two areas is approximately 30000 m^2 which corresponds 34 pixels on the image. The third comparison was between arable lands which are digitized and classified on Landsat-5 TM image. The digitized and classified arable areas were found out as 31581 m^2 and 71100 m^2 (7.11 hectares) respectivelty (Table 5.4 – Figure 5.10). The difference between digitized and classified area is very big, the reason for this is the classification, because there are mixed pixels and unsupervised classification was not an appropriate method for such area (Figure 5.10). Another reason is that the application was too small when compared to the spatial resolution of Landsat-5 TM imagery. More accurate values can be acquired with the optimum classification method and optimum size of the application area. digitization results.

5.4 Accuracy Assessment

Accuracy assessment was conducted by calculating relative root mean square errors (RRMSE). The reason for selecting RRMSE method is that there was no ground truth to be used as a reference for accuracy assessment. Thus, for calculating relative root mean square errors (RRMSE), Worldview-2 results were accepted as reference and errors were calculated based on Worldview-2. By using the following formula (5.4) (Boucher et al, 1999), relative root mean square errors were calculated (Table 5.5).

$$\sigma_r = \sqrt{\frac{1}{N}\sum\left(\frac{\rho_{model} - \rho_{measure}}{\rho_{measure}}\right)^2} \tag{5.4}$$

Table 5.5 : Relative root mean square errors (RRMSE).

	SPOT-5	Landsat-5 TM
Road-1 Length (m)	0.0085	0.0971
Road-2 Length (m)	0.0364	-
Road-3 Length (m)	0.0239	-
Road-4 Length (m)	0.0060	-
Road-5 Length (m)	0.0081	-
Road-6 Length (m)	0.0530	-
Road-7 Length (m)	0.0056	-
Residential-1 Area (m²)	0.5048	-
Residential-2 Area (m²)	0.1352	-
Residential-3 Area (m²)	0.2247	-
Residential-4 Area (m²)	0.3028	-
Industrial-1 Area (m²)	0.1640	-
Arable-1 Area (m²)	0.0061	0.1178
Arable-2 Area (m²)	0.0065	-
Arable-3 Area (m²)	0.0116	-
Arable-4 Area (m²)	0.0319	-
Arable-5 Area (m²)	0.0739	-
Forest-1 Area (m²)	0.0183	0.1620
Forest-2 Area (m²)	0.0342	-
Forest-3 Area (m²)	0.0518	-
Water-1 Area (m²)	0.0114	0.0593
Water-2 Area (m²)	0.1068	-
Water-3 Area (m²)	0.3135	-

This time ρ_{model} represents the Worldview-2 results (areal or linear) and $\rho_{measure}$ represents the lengths or areas obtained after digitization on each satellite image. RRMSE values for Landsat-5 TM imagery could not be calculated for Road-2, Road-3, residential and industrial areas, because they could not be extracted from imagery (see Table 5.1 and 5.2).

5.5 Results

Results of the study are handled in two stages. First outcomes are obtained based on creating requirement matrices (see Chapter 4), and the second ones are based on the application as a substitution of the requirement matrices (see Chapter 5).

5.5.1 Resulting requirement matices

Requirement matrices were created for both maps and remote sensing imagery based on the main information themes (see Chapter 4).

First requirement matrices represent the administrative theme (Appendix-A) and Table A.1 shows the administrative features of maps whereas Table A.2 for remote sensing images. On Table A.1, each element of the matrix was represented with a polygon, polyline or point depending on the topographic map scale. All of the boundaries (national, province, municipal, etc.) have polyline geometric characteristics; they are added as an additional information and shown in every topographic maps. Settlements are defined with polygons up to 1 : 200 000 scale and they are defined with points for 1 : 500 000 and 1 : 1 000 000 scales. The reason for that representation is the generalization. While buildings are shown individually at 1 : 5 000 scale, they are simplified at 1 : 10 000 scale. Starting from 1 : 25 000, only important buildings are shown individually and neighboring buildings are merged. Generalization operators such as elimination, exaggeration and displacement can also be applied. Between 1 : 50 000 and 1 : 200 000 scales, buildings are merged which is called geometric aggregation. Lastly, point-based representation -based on the population- is used for 1 : 500 000 and 1 : 1 000 000 scale. Furthermore, the smallest details were calculated for residential areas and those values were added to the requirement matrix (see Chapter 2.2.1). On Table A.2, each element of the matrix was examined based on its existence on the remote sensing imagery regarding the spatial resolution. Boundaries are irrelevant when the images of real world phenomena are considered. Building extraction can differ based on the area and type of the building. With high resolution imagery, it is possible to extract individual buildings. However, with high resolution imagery, buildings are seen as blocks. On the other hand, building-based extraction is not expected with the medium resolution satellite images, but residential area can be determined. Low resolution satellites are not suitable for administrative information extraction. Despite this result, the texture or the general information can be obtained with low resolution satellites based on the size of the residential area.

Second group of requirement matrices includes map content elements about transportation (Appendix-B) and Table B.1 represents transportation theme for maps and Table B.2 for remote sensing data. On Table B.1, each element of the matrix was represented with a polygon, line or point depending on the topographic map scale. Areal objects such as airport, pier and station are represented with polygons in large-scale topographic maps. Starting from 1 : 200 000, road constructions such as bridge or tunnel are represented as a point with some specific symbols. Lineer objects such as roads (highway, 1st , 2nd and 3rd class road, path, etc), and railways (multiple or single track, tramway, etc) are shown with lines with changing representation styles. For small-scaled topographic maps, generalization is applied and lines are exaggerated. Furthermore, the smallest widths for roads were calculated and those values were added to the requirement matrix (see Chapter 2.2.2). On Table B.2, each element of the matrix was examined based on its existence on the remote sensing imagery regarding the spatial resolution. With very high resolution imagery, it is possible to extract linear objects depending on the width and with high resolution imagery, it is hard to determine the object types. For instance, highways can be determined on high resolution images, but additional information may be need to determine which class they belong to. Low resolution satellites are not suitable for extraction of transportation information.

Third information theme is vegetation (Appendix-C), thus requirement matrix in Table C.1 shows vegetation map content element for maps and Table C.2 shows the same information for remotely sensed data. On Table C.1, each element of the matrix was represented with a polygon and point depending on the topographic map scale. Areal objects such as arable lands (rice fields, meadow, videyards, etc), forests (coniferious, mixed, etc.) and wetlands are represented with polygon. Starting from 1 : 200 000 scale, conceptual generalization is applied. For instance; forest areas are shown as forest without determining their types. At 1 : 000 000, vegetation is not shown. Individual trees are represented as points by using specific symbolization only between 1 : 5000 and 1 : 100 000. On Table C.2, each element of the matrix was examined based on its existence on the remote sensing imagery regarding the spatial resolution. With 0.5 m and 1 m resolution imagery, it is mostly possible to extract individual trees, but starting from the 2,5 m resolution individual trees are not expected to be recognized. For medium and low resolution imagery, based on area coverage of land feature, general characteristics of agricultural areas and forests can be obtained.

The last group of matrices represent hydographic content (Appendix-D) for maps (Table D.1) and for remotely sensed data (Table D.2). On Table D.1, each element of the matrix was represented with a point, line, polyline and polygon depending on the object type and the topographic map scale. Some special objects like fountain, reservoir or water tunnel are shown as a point symbol at every scale except from 1 : 500 000 and 1 : 1 000 000. Boundaries including sea, lake, pond or pool are represented with polyline for the relevant scales shown in the requirement matrix. Linear features such as river, stream and ditch are shown with lines and water bodies are represented with polygons up to 1 : 200 000 scale. Point based objects are not shown at small scale topographic maps. They give information only about the general water characteristics. On Table D.2, each element of the matrix was examined based on its existence on the remote sensing imagery regarding the spatial resolution. Up to 10 m resolution, it is mostly possible to extract detailed water information. However for medium and low resolution satellites, determination of water bodies depends on the area of the water feature.

Also, satellite images and 1 : 25 000-scale topographic maps of the study area were compared by means representation (and symbolization) of each map content elements stated in the requirement matrices. In 1 : 25 000-scale maps, buildings are generalized and represented as blocks. Roads are exaggerated but even small roads and paths are depicted in the map. Vegetation is shown with a color value (Figure 5.15).

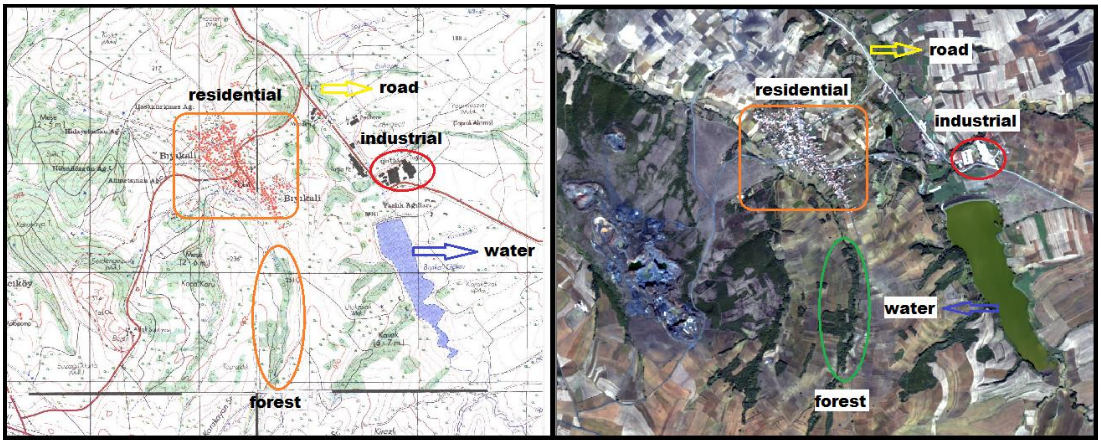


Figure 5.15 : Comparison of topograhic maps and satellite data.

5.5.2 Digitization results of map content elements

The major limitation for mapping purposes is the image resolution. The general rule of required GSD (0.5 mm – 1mm) has been confirmed, but there are still some problems affecting the object identification such as shadow, sun inclination and temporal resolution. In addition, object itself (size, color, extention, shape and orientation of object) can cause some difficulties (e.g. reflection) at identification.

For road features such as minor road network and footpath, Landsat-5 can not be used. Although the medium resolution satellite data is not good for road extraction, some roads can be determined depending on the width. Because linear objects have continuity. Even pan-sharpened SPOT-5 imagery (with 2.5 m spatial resolution) may not be enough to extract some minor roads. When considered that 0.5 m GSD corresponds to a map scale 1 : 5 000, with a Worldview-2 imagery it is possible to reach the required accuracy of 1.25 m (Table A1 – Table A2).

For identification of administrative objects, it is obvious that medium resolution satellite data such as Landsat-5 is not suitable. Besides, building extraction is not something expected from medium resolution imagery. However, residential area can be identified based on the areal coverage of it. With 2,5 m spatial resolution of SPOT-5 images, it is even difficult to map the right shape of the buildings. Buildings (especially small/residential buildings) are mostly seen as blocks on SPOT-5 imagery. At 1 : 25 000 scale, some individual buildings are shown and close buildings are merged based on cartographic rules. So as to say, 2,5 m spatial resolution is partly enough and partly not to produce 1 : 25 000 scaled topographic map. However, no problem occurred with 0.5 m spatial resolution while digitizing the buildings with their characteristic details. Thus, urban buildings can be identified from Worldview-2 imagery with the required accuracy and 1 : 5 000 scaled maps can be produced (Table B1 – Table B2).

Extracting information about vegetation requires a knowledge about the area. Even with a high resolution imagery it is hard to recognize the thematic information about the object. With a very high resolution imagery, details belonging to Level III (USGS-Classification) can be identified (i.e. vineyards). Vegetative areas which are arable land and forest area can be determined individually with a spatial resolution of 0,5 and also 2,5 m. Agricultural and forest areas can be recognized from medium and low resolution satellite imagery based on the areal of the land feature (general characteristics). However, based on the areal evalution results (Table 5.3) spatial resolution of Landsat-5 TM is not sufficient for determining arable or forest areas individually, but thematic information can be extracted. Selecting small areas may be the cause of this situation, because one pixel corresponds 900 m² on Landsat-5 TM imagery (Table C1 – Table C2).

Identification of water bodies is possible with all satellite images based on areal evalution of water given in Table 5.4. Biyikali Lake was extracted from all satellite images with changing areal sizes. Most of the other small lakes cannot be recognized by using SPOT-5 (2,5 m spatial resolution) while they can be recognized from Worldview-2 imagery. Landsat-5 was better at identifying hydrographic content when compared to other entities. There may be several reasons for this situation such as areal size of the lake and correct band combination (Table D1 – Table D2).

6. CONCLUSIONS AND RECOMMENDATIONS

Details (object representation)

In cartographic map design, especially when mapping a large area with small entities, the shapes and sizes of map features may need to be emphasized in order to meet the specific map requirements. These emphases are called exaggeration, which is one of the generalization operations. Exaggeration changes the geometry of objects in the representation. For example, road hierarchy, main road names, parking areas or important stations are exaggerated if the map must depict navigation or transportation information. Exaggerated objects may even be point based objects those are not possible to show when theoretical geometric errors of the map are considered. However, according to aim of mapping, user group and especially national or international mapping standards; some details have to be shown. Individual symbols are mostly used for point-based details.

In remote sensing, even if the image has a high spatial and spectral resolution, some small details may not be detected. This problem can occur due to the spectral characteristics of surface features, date and time of the acquisition, sensor capabilities (look angle, radiometric resolution, etc.) and many other related parameters. Thus, maps which are produced directly from the remote sensing imagery may not be adequate. In some cases, images alone can fail to show required details based on mapping standards.

Object identification

According to cartographic object classification based on perception, objects are divided into abstract and absolute objects. Absolute objects consist of any natural or man-made objects that can be a subject for maps. Buildings, roads, rivers, lakes and vegetation are the main examples of absolute objects. However, boundaries, contour lines, names of places, etc. that do not exist in real world are considered as abstract objects. Although they are not actually visible, they are shown on maps as an additional information. Symbolization and different techniques (for instance interpolation can be used to draw contour lines) help to illustrate abstract objects.

Remote sensing imagery is a reflection of the real world at different resolutions. Apparently, it is not possible to extract abstract objects from the remote sensing data. Therefore, additional data has to be integrated to the image data. For instance, a digital elevation model can be integrated in order to get the elevation information, implicitly to draw contour lines.

Thematic and Geometric Accuracy

Remote sensing imagery may not provide the expected theoretical geometric accuracy in practice. The reasons can be various such as temporal resolution, surface reflection, sun elevation, sun azimuth.

When requirement matrices for administrative information theme (see Table A.1 and A.2) are compared, first of all, abstract map object problem occurred. Abstract objects like boundaries, city centers or etc. are not real world objects, thus they can not be extracted from satellite images. If they are needed to be mapped, some additional land information is required.

It is not easy to reach the expected thematic and geometric accuracy in practice. Satellite images may not meet the required accuracies determined theoretically. As seen in Figure 5.8, Landsat-5 TM image failed to determine even the general characteristics of the residential area. However, it is possible to extract the residential areas with medium resolution satellites based on the requirement matrix in Table A.2. This lack of information may have several reasons rather than spatial resolution; such as temporal and spectral resolution, surface or object reflectance, sun elevation and especially selected area for digitization. When a wider area was selected for digitization, it can be seen that the residential area is recognizable. Figure 5.9 proves that the boundaries of residential area can be identified from Landsat-5 TM imagery and it can be used for mapping at 1 : 200 000 and smaller scales based on Table A.2.

On the other hand, experience is highly required while extracting thematic information from satellite image data. There should be a spectral library for land objects and field works should be conducted. Additionally, visual interpretation is very important for object identification. Size, color, texture and shadows can give important ideas about objects.

Errors of digitization may influence both thematic and geometric accuracy of results. Error sources should be specified by means of the error frequency, nature of the error, magnitude of the error, etc. (see Chapter 2.3). At this stage, error sources of digitization can be listed as follows:

- Spatial resolution of the satellite image is inversely proportional to the precision of the digitization. (The less the spatial resolution of satellite images, the less the precision of digitization).
- The mix-pixel problem affects the digitization accuracy.
- The magnitude of errors should be determined and, it has to be decided whether they are acceptable or not based on the required accuracy for a map scale.

Other Concerns

Band combination plays an important role at object identification. Some unidentified features can be determined by changing the band combination. For instance, water shows no reflection on SWIR bands (7-4-2) of Landsat. Thus, water objects look black with 7-4-2 band combination. To distinguish water, using SWIR bands is going to be logical. The effect of different band combinations were proved by considering SWIR, False Color and True Color band combination for water, arable and vegetation features (Figure 5.9 - 5.11).

As a result of all above issues, it is hard to determine the entities belonging to USGS-Level III with a spatial resolution less than 2,5 m. With a Worldview-2 imagery, if the ground control points having at least 0.5 m geometric accuracy, 1 : 5000 scaled maps can be produced according to the purpose and the user. Pan-sharpened SPOT-5 images can be used generating 1 : 25 000-scale maps with some limitations. Spatial resolution is very important and a limiting issue in satellite image mapping, but it is not only case. Considering the size of the object, land-use or land-cover near by the object, areal objects are recognized better than the linear objects. However, when it comes to the geometric accuracy this statement is not valid. Experience is highly required while extracting thematic information from satellite image data (or spectral library and fieldworks are needed).

Finally, it is possible to produce topographic maps from satellite imagery with considering additional data sources when needed. However, to form a direct relationship between scale and spatial resolution does not always work. The reason is that only spatial resolution parameter is not enough to interpret a remote sensing data in order to produce maps at relevant scale.

This study is convenient to be extended and detailed. To get better results in areal evalutation of entities, supervised classification can be handled for all the satellite images. Moreover, a ground truth for the study area can be found and Worldview-2 image zones can also be evaluated. Same study can be handled for specific thematic mapping purposes and satellites used for the application can be diversified.

REFERENCES

Aber, J. S., Marzolff, I., Ries, J. (2010). Small-Format Aerial Photography: Principles, Techniques and Applications. Elsevier Science. ISBN: 978-0-444-53260-2.

Aggarwal, S. (2003). Principles of Remote Sensing. Satellite Remote Sensing and GIS Applications in Agricultural Meteorology, 23., p. 38-39.

Albertz, J., Lehmann H., Scholten F., Tauch R. (1993). Satellite Image Maps-Experiences, Problems and Chances. International Archives of Photogrammetry and Remote Sensing, 29, 309-309.

Albertz, J., Wiedemann, A. (2003). Topographic And Thematic Mapping From Satellite Image Data. Technical report. Department for Photogrammetry and Cartography, TU Berlin. Retrieved from: http://alwie.net/lit/IstMap.pdf

Anderson, J. R., Hardy, E. E., Roach, J. T., Witmer, R. E. (1976). A Land Use And Land Cover Classification System For Use With Remote Sensor Data. Washington, DC: Government Printing Office (US Geological Survey, Professional Paper 964).

ASPRS (American Society for Photogrammetry and Remote Sensing Specifications Standards Committee). (1990). ASPRS Accuracy Standards For Large-Scale Maps. Photogrammetric Engineering and Remote Sensing, 56(7), 1068-1070.

ASPRS and ASCE. (1994). Glossary of the Mapping Sciences. ASPRS, Bethesda Maryland and ASCE, New York.

Belward, A. S., Valenzuela, C. R. (Eds.). (1991). Remote Sensing And Geographical Information Systems For Resource Management In Developing Countries (Vol. 1): *Spectral Characteristics of Vegetation Soil and Water in the Visibile, Near Infrared and Middle-Infrared Wavelengths*, p. 47-50. Kluwer Academic Print on Demand.

Bertin J. (1983). Semiology of Graphics: *Diagrams, Networks, Maps*. 1967/1983, The University of Wisconsin Press.

Bird, A. C. (1991). Remote Sensing And Geographical Information Systems For Resource Management In Developing Countries (Vol. 1): *Principles of Remote Sensing : Interaction of Electromagnetic Radiation With the Atmosphere and the Earth*, p. 45. Kluwer Academic Print on Demand.

Bolstad, P. (2005). GIS Fundamentals. 2nd edition. Eider Press, White Bear Lake, MN. 543 pp. 395-463.

Bossard, M., Feranec, J., Otahel, J. (2000). CORINE (Coordination of Information on the Environment) Land Cover Technical Guide - Addendum 2000. European Environmental Agency Technical Report No. 40, Copenhagen, Denmark.

Boucher, Y., Cosnefroy, H., Petit, D., Serrot, G., Briottet, X. (1999). Comparison of Measured and Modeled BRDF of Natural Targets," Proc. SPIE 3699, 16-26 (1999) doi:10.1117/12.352945.

Congalton, R. G., Green, K. (2008). Assessing the accuracy of remotely sensed data: principles and practices. 2nd ed. Boca Raton, FL: CRC/Taylor & Francis, ISBN-13: 978-1-4200-5512-2, pp. 19, 37, 41, 42.

Cowen, D. J., Jensen, J. R., Bresnahan, P. J., Ehler, G. G., Graves, D., Huang Xueqiao, Wiesner, C., Mackey, H. E. (1995). The design and implementation of an integrated geographic information system for environmental applications Photogrammetric Engineering and Remote Sensing, 61 (11) , pp. 1393-1404.

Denham, R., Mengersen, K., Witte, C,. (2009). Bayesian analysis of thematic map accuracy data, Remote Sensing of Environment 113(2), 371–379.

DiBiase, D. (1996). Rethinking laboratory education for an introductory course on geographic information. Cartographica: The International Journal for Geographic Information and Geovisualization, 33(4), 66-72.

Doyle, F.-J., (1984). Surveying and Mapping with Space Data, ITC Journal, 4, 314-321.

Federal Geographic Data Committee. (1998). Content Standard for Digital Geospatial Metadata. FGDC-STD-001-1998. U.S. Geological Survey, Reston, VA.

Frye, C. (2006). A Product Driven Approach to Designing a Multi-Purpose Multi-Scale GIS Base Map Database that Supports High Quality Mapping. InProceedings of AutoCarto 2006. Retrieved from: www.cartogis.org/docs/proceedings/2006/frye.pdf.

GCM (General Command of Mapping of Turkey) (1962, 1965, 2003). 1:25 000. 1:50 000, 1: 100 000 and 1 : 250 000 printed maps. Ankara, Turkey.

IGN printed maps. (2007). 1: 1 000 000 Carte Nationale IGN and 1 : 100 000 Mini Carte Routiere IGN. Realise Et Edite Par L'institut Geographique National, IGN Paris. Edition 35. Paris - www.ign.fr.

Jacobsen, K. (1998). Mapping with IRS-1C images. Proceedings of the 1998 ASPRS Annual Conference, Tampa, Florida, May 1998.

Jacobsen, K. (2004). Use of Very High Resolution Satellite Imagery. In: Tagung der Polnische Gesellschaft für Photogrammetrie Fernerkundung und GIS, 2004, Warschau. Proceedings. Retrieved from: http://www.ipi. unihannover.de/html/publikationen/2005/paper/jac_warschau_05.pdf

Jensen, J. R., Cowen, D. C. (1999). Remote sensing of urban/suburban infrastructure and socio-economic attributes. Photogrammetric engineering and remote sensing, 65, 611-622.

Lunetta R., S., Congalton, R. G., Fenstermaker, L. K, Jensen, J. R., McGwire, K. C., Tinney, L. R. (1991). Remote Sensing and Geographic Information System Data Integration: Error Sources and Research Issues, Photogrammetric Engineering Remote Sensing' Volume: 57, Issue: 6.

Mach, P. E (1981). Space science for applications - The history of Landsat. *Space science comes of age: Perspectives in the history of the space sciences*; Proceedings of the Symposium, Washington, DC, March 23, 24, 1981. (A82-36607 17-88) Washington, DC, Smithsonian Institution Press, 1981, p. 135-148. NASA-supported research.

NCDCDS (National Committee for Digital Cartographic Data Standards). (1988). The Proposed Standard for Digital Cartographic Data. The American Cartographer 15(1), p. 28.

Özbalmumcu, M., Erdoğan, M. (2001). Uzaktan Algılama Amaçlı Uydu Görüntüleme Sistemleri, Harita dergisi, sayı:125, p. 59-82, Ankara. Retrieved from: http://www.hgk.msb.gov.tr/dergi/makaleler/125_6.pdf

Robinson, A.H., Sale, R.D., Morrison, J.L. and Meuhrcke, P.C. (1984) Elements of Cartography. Wiley, New York, 5th edition. p. 3.

Rossiter, D. G. (2001). Assessing the Thematic Accuracy of Area-Class Soil Maps. Soil Science Division, ITC. Enschede, Países Baixos. Retrieved from: http://www.itc.nl/~rossiter/does/AccuracySoilMaps-Preprint 31Aug2001.pdf.

Rystedt, B., Konecny, M., Virrantaus, K., Ormeling, F. (2003). A Strategic Plan for the International Cartographic Association. Durban, South Africa. Retrieved from: http://ns1.icaci.org/files/documents /reference_docs/ICA_Strategic_Plan_2003-2011.pdf

Rytz, A., Bantel, E., Hoinkes, C., Merkle, G., Schelling, G. (1977). Cartographic Generalisation: Topographic Maps. Cartographic Publication series (2). Swiss Society of Cartogtaphy (Swisstopo), Zurich. p. 9.

Spiess, E., Baumgartner, U., Arn, S., Vez, C. (2002). Topographic Maps–Map Graphics and Generalisation. Cartographic Publication series (17). Swiss Society of Cartogtaphy (Swisstopo).

Stevens, J., Smith, J. M., Bianchetti, R. A., (2012), Mapping Our Changing World, Editors: Alan M. MacEachren and Donna J. Peuquet, University Park, PA: Department of Geography, The Pennsylvania State University.

Topan, H., Büyüksalih, G., Jacobsen, K. (2005). Information contents of high resolution satellite images. In EARSel 3D–Remote Sensing Workshop, Porto. Retrieved from: http://www.earsel.org/SIG/3D /Dati/Porto/Topan.pdf

Uluğtekin, N., Uçar D. (2012). Kartografyaya Giriş (Introduction to Cartography), Lecture notes, İstanbul Teknik Üniversitesi.

USGS (United States Geological Survey). (2012). Topographic Map Symbols. U.S. Department of Interior, 509 National Center, Reston, VA 20192, USA. Retrieved from: http://egsc.usgs.gov/isb/pubs/booklets/symbols/topomapsymbols.pdf

Url-1 <*http://science.jrank.org/pages/1249/Cartography-Types-maps.html*> date retrieved 14.04.2013.

Url-2 <*http://www.icsm.gov.au/mapping/maps_topographic.html*> date retrieved 14.04.2013.

Url-3 <*http://www.boundary-problems.co.uk/boundary-problems/osmaps.html* data retrieved> 27.06.2013.

Url-4 <*http://www.ussartf.org/topo_map_basics.htm*> date retrieved 27.06.2013.

Url-5 <*http://egsc.usgs.gov/isb/pubs/factsheets/fs17199.html*> date retrieved 14.04.2013.

Url-6 <*http://www.cdioinstitute.org/papers/Day1/AERIAL%20PHOTOGRAPHY_ Abraham _Thomas.pdf*> date retrieved 19.05.2013.

Url-7 <*http://landsat.gsfc.nasa.gov/about/L5_td.html*> date retrieved 22.04.2013.

Url-8 <*http://www.satimagingcorp.com/satellite-sensors/SPOT-5.html*> date retrieved 22.04.2013.

Url-9 <*http://www.astrium-geo.com/en/194-resolution-and-spectral-bands*> date retrieved 22.04.2013.

Url-10 <*http://www.digitalglobe.com/about-us/contentcollection#satellites& worldview-2*> date retrieved 22.04.2013.

Url-11<*http://www.satimagingcorp.com/satellite-sensors/worldview-2.html*> date retrieved 22.04.2013.

Url-12 <*http://www.ucalgary.ca/GEOG/Virtual/Remote%20Sensing/energy.html*> date retrieved 14.04.2013.

Url-13 <*http://weather.msfc.nasa.gov/archeology/remote_sensing_spectrum.html*> date retrieved 14.04.2013.

Url-14 <*http://www.seos-project.eu/modules/remotesensing/remotesensing-c01-p05.html*> date retrieved 14.04.2013.

Url-15 < *http://remote-sensing.net/concepts.html*> date retrieved 02.05.2013

Url-16 <*http://www.eumetrain.org/data/3/36/navmenu.php?page=3.2.4*> date retrieved 22.04.2013.

Url-17 <*http://www.crisp.nus.edu.sg/~research/tutorial/optical.htm*> date retrieved 22.04.2013.

Url-18 <*http://web.pdx.edu/~emch/ip1/bandcombinations.html*> date retrieved 22.04.2013.

Url-19 <*http://zulu.ssc.nasa.gov/mrsid/tutorial/Landsat%20Tutorial-V1.html*> date retrieved 22.04.2013.

Url-20 <*http://www.cise.ufl.edu/~mssz/GIS/GIS-Basics.html***>** date retrieved 22.04.2013.

Url -21 <*http://walrus.wr.usgs.gov/infobank/programs/html/definition/shapefile .html*> date retrieved 22.04.2013.

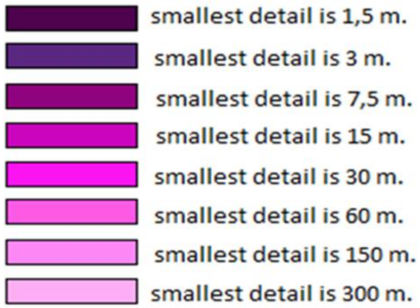
APPENDICES

APPENDIX A: Requirement Matrices for Administrative Content
APPENDIX B: Requirement Matrices for Transportation Content
APPENDIX C: Requirement Matrices for Vegetation Content
APPENDIX D: Requirement Matrices for Hydographic Content

APPENDIX-A

Requirement Matrix for the Administrative Content for Topographic Maps

	Level I	Level II-III	**1 : 5 000**	**1 : 10 000**	**1 : 25 000**	**1 : 50 000**	**1 : 100 000**	**1 : 200 000**	**1 : 500 000**	**1 : 1 000 000**
Administrative	Boundaries	National Boundaries	polyline	polyline	polyline	polyline	polyline	polyline	polyline	polyline
		Province Boundaries	polyline	polyline	polyline	polyline	polyline	polyline	polyline	polyline
		Municipal Boundaries	polyline	polyline	polyline	polyline	polyline	polyline	polyline	polyline
		Town Boundaries	polyline	polyline	polyline	polyline	polyline	polyline	polyline	polyline
		Village Boundaries	polyline	polyline	polyline	polyline	polyline	polyline	polyline	polyline
		District Boundaries	polyline	polyline	polyline	polyline	polyline	polyline	polyline	polyline
	Settlement	Residential/ Urban Built-up Areas	polygon	polygon	polygon	polygon	polygon	polygon	point	point
		Commercial and Services	polygon	polygon	polygon	polygon	polygon	polygon	point	point
		Industrial	polygon	polygon	polygon	polygon	polygon	polygon	point	point
Representation	Buildings	Urban Buildings	individual buildings	individual buildings	important buildings shown individually neighboring buildings are merged	buildings are merged	buildings are merged	buildings are merged	point-based representation	point-based representation



Requirement Matrix for the Administrative Content for Remotely Sensed Data

	Level I	Level II-III	**Very High Resolution (≤2,5 m)**			**High Resolution (2,5 m - 10 m)**		**Medium Resolution (10 m - 100 m)**		**Low Resolution (≥ 100 m)**
			0,5 m	**1 m**	**2,5 m**	**5 m**	**10 m**	**20 m**	**50 m**	**100 m**
Administrative	Boundaries	National Boundaries Province Boundaries Municipal Boundaries Town Boundaries Village Boundaries District Boundaries	*Abstract Objects (-)*							
	Settlement	Residential/ Urban Built-up Areas	√	√	√	√	√	√	√	-
		Commercial and Services	√	√	√	√	√	√	√	-
		Industrial	√	√	√	√	√	√	√	-
Representation	Buildings	Urban Buildings	individual buildings	individual buildings	some of individual buildings	detection of building blocks	detection of building blocks	residential/ administrative area	residential/ administrative area	poor or no detection

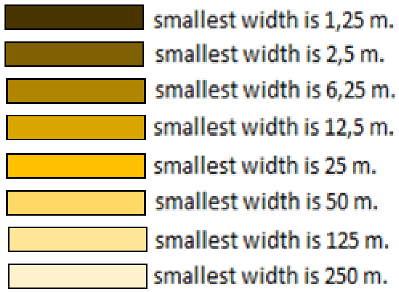
*Boundaries are abstract map elements, thus they are not detected by using remotely sensed data.

APPENDIX-B

Table B.1: Requirement Matrix for the Transportation Content for Topographic Maps

Level I	Level II	Level III	**1 : 5 000**	**1 : 10 000**	**1 : 25 000**	**1 : 50 000**	**1 : 100 000**	**1 : 200 000**	**1 : 500 000**	**1 : 1 000 000**
Road Network	Hard Surfaced Highway	1st class road (S1)	line	line	line	line	line	line	line	line
		2nd class road (S2)	line	line	line	line	line	line	line	line
		3rd class road (S3)	line	line	line	line	line	line	line	line
	Soft Surfaced Highway	1st class road (G1)	line	line	line	line	line	line	line	line
		2nd class road (G2)	line	line	line	line	line	line	line	line
		3rd class road (G3)	line	line	line	line	line	line	line	line
	Road Widths									
	Others	Urban Road	line	line	line	line	line	line	-	-
		Path	line	line	line	line	line	line	-	-
		Park Road	line	line	line	line	line	-	-	-
		Crossroad Area	line	line	line	line	line	-	-	-
		Roundabout	line	line	line	line	line	-	-	-
	Road Constructions	Overpass	line	line	line	line	line	-	-	-
		Underpass	line	line	line	line	line	-	-	-
		Bridge	line	line	line	line	line	point	-	-
		Viaduct	line	line	line	line	line	point	-	-
		Tunnel	line	line	line	line	line	point	-	-
Railway Network	Tracks	Standard gauge railway - multiple track	line	line	line	line	line	line	-	-
		Standard gauge railway - single track	line	line	line	line	line	line	-	-
		Narrow gauge railway - multiple track	line	line	line	line	line	line	-	-
		Narrow gauge railway - single track	line	line	line	line	line	line	-	-
		Metro Underground/Subway	line	line	line	line	line	-	-	-

Level I	Level II	Level III	**1 : 5 000**	**1 : 10 000**	**1 : 25 000**	**1 : 50 000**	**1 : 100 000**	**1 : 200 000**	**1 : 500 000**	**1 : 1 000 000**
	Stops	Tramway	line	line	line	line	line	-	-	-
		Goods lift	line	line	line	line	line	-	-	-
		Railway Station	polygon	polygon	polygon	polygon	polygon	point	-	-
		Underground stop	point	point	point	point	point	-	-	-
Seaway Network	Ferry	Ferry track railway	line	line	line	line	line	line	-	-
		Ferry track passenger	line	line	line	line	line	line	-	-
	Pier	Concrete, Wood, Steel	polygon	polygon	polygon	polygon	polygon	point	-	-
	Port	Fully fledged/Non-fully fledged	polygon	polygon	polygon	polygon	polygon	point	-	-
Airway Network	Airport	Land (military, civilian)	polygon	polygon	polygon	polygon	polygon	point	-	-
		Sea (military, civilian)	polygon	polygon	polygon	polygon	polygon	point	-	-



Road Class	**Road Characteristic**
1st class road (S1, G1)	Platform width ≥ 9m
2nd class road (S2, G2)	Platform width: 7m - 9m
3rd class road (S3, G3)	Platform width ≤ 7m

*The smallest width is 1,25 m for 1 : 5 000 scale and roads are drawn with two lines. Thus, based on this rule, roads should be represented with a single line starting from 1 : 50 000 scale. However, generalization starts at this stage and exaggeration is applied and roads are shown with a double line up to 1 : 100 000 scale.

Table B.2: Requirement Matrix for the Transportation Content for Remotely Sensed Data

Level I	Level II	Level III	Very High Resolution (≤2,5 m)			High Resolution (2,5 m - 10 m)		Medium Resolution (10 m - 100 m)		Low Resolution (≥ 100 m)
			0,5 m	**1 m**	**2,5 m**	**5 m**	**10 m**	**20 m**	**50 m**	**100 m**
Road Network	Hard Surfaced Highway	1st class road (S1)	√	√	√	√	√	√	√	-
		2nd class road (S2)	√	√	√	√	√	√	√	-
		3rd class road (S3)	√	√	√	√	√	√	√	-
	Soft Surfaced Highway	1st class road (G1)	√	√	√	√	√	√	√	-
		2nd class road (G2)	√	√	√	√	√	√	√	-
		3rd class road (G3)	√	√	√	√	√	√	√	-
	Others	Urban Road	√	√	√	√	√	-	-	-
		Path	√	√	√	√	√	-	-	-
		Park Road	√	√	√	√	√	-	-	-
		Crossroad Area	√	√	-	-	-	-	-	-
		Roundabout	√	√	-	-	-	-	-	-
	Road Constructions	Overpass	√	√	-	-	-	-	-	-
		Underpass	√	√	-	-	-	-	-	-
		Bridge	√	√	-	-	-	-	-	-
		Viaduct	√	√	-	-	-	-	-	-
		Tunnel	√	√	-	-	-	-	-	-
Railway Network	Tracks	Standard gauge railway - multiple track	√	√	√	-	-	-	-	-
		Standard gauge railway - single track	√	√	√	-	-	-	-	-
		Narrow gauge railway - multiple track	√	√	√	-	-	-	-	-
		Narrow gauge railway - single track	√	√	√	-	-	-	-	-
		Underground/Subway	√	√	√	-	-	-	-	-

Level I	Level II	Level III	Very High Resolution (≤2,5 m)			High Resolution (2,5 m - 10 m)		Medium Resolution (10 m - 100 m)		Low Resolution (≥ 100 m)
			0,5 m	**1 m**	**2,5 m**	**5 m**	**10 m**	**20 m**	**50 m**	**100 m**
	Stops	Tramway	√	√	-	-	-	-	-	-
		Goods lift	√	√	-	-	-	-	-	-
		Railway Station	√	√	-	-	-	-	-	-
		Underground stop	√	√	-	-	-	-	-	-
Seaway Network	Ferry	Ferry track railway	√	√	√	√	√	-	-	-
		Ferry track passenger	√	√	√	√	√	-	-	-
	Pier	Concrete, Wood, Steel	√	√	√	√	√	-	-	-
	Port	Fully fledged/Non-fully fledged	√	√	√	√	√	-	-	-
Airway Network	Airport	Land (military, civilian)	√	√	√	√	√	-	-	-
		See (military, civilian)	√	√	√	√	√	-	-	-

APPENDIX-C

Table C.1: Requirement Matrix for the Vegetation Content for Topographic Maps

Level I	Level II	Level III	**1 : 5 000**	**1 : 10 000**	**1 : 25 000**	**1 : 50 000**	**1 : 100 000**	**1 : 200 000**	**1 : 500 000**	**1 : 1 000 000**
Agricultural	Arable Lands	Rice field	polygon	polygon	Polygon	polygon	polygon	√	Representation of nothing but forest area. No differentiation between vegetation.	Vegetation is not shown.
		Olive grove	polygon	polygon	Polygon	polygon	polygon	√		
		Orchard	polygon	polygon	Polygon	polygon	polygon	√		
		Pistachio grove	polygon	polygon	Polygon	polygon	polygon	√		
		Citrus grove	polygon	polygon	Polygon	polygon	polygon	√		
		Tea grove	polygon	polygon	Polygon	polygon	polygon	√		
		Rose grove	polygon	polygon	Polygon	polygon	polygon	√		
		Vineyard	polygon	polygon	Polygon	polygon	polygon	√		
		Meadow	polygon	polygon	Polygon	polygon	polygon	√		
		Bushwood/Scrub	polygon	polygon	Polygon	polygon	polygon	√		
		Nursery	polygon	polygon	Polygon	polygon	polygon	√		
		Kaleyard	polygon	polygon	Polygon	polygon	polygon	√		
Forests and Semi-natural Areas	Forests	Coniferous	polygon	polygon	Polygon	polygon	polygon	Representation of nothing but forest area.		
		Broad-leaved	polygon	polygon	polygon	polygon	polygon			
		Mixed	polygon	polygon	polygon	polygon	polygon			
		Deforested forest	polygon	polygon	polygon	polygon	polygon			
		Burned forest	polygon	polygon	polygon	polygon	polygon			
		Forestry boundary	polygon	polygon	polygon	polygon	polygon			
		Forestation Area	polygon	polygon	polygon	polygon	polygon			
	Individual trees	Coniferous	point	point	point	point	point			
		Broad-leaved	point	point	point	point	point			
		Acute type	point	point	point	point	point			
		Pennywort	point	point	point	point	point			
		Long type	point	point	point	point	point			
		Fan	polygon	polygon	polygon	polygon	polygon	√		
Wetlands	Inland Wetlands	Swamp/Marsh	polygon	polygon	polygon	polygon	polygon	√		
		Reed bed	polygon	polygon	polygon	polygon	polygon	√		
	Coastal Wetlands	Sandy Areas	polygon	polygon	polygon	polygon	polygon	√		

Table C.2: Requirement Matrix for the Vegetation Content for Remotely Sensed Data

Level I	Level II	Level III	Very High Resolution (≤2,5 m)			High Resolution (2,5 m - 10 m)		Medium Resolution (10 m - 100 m)		Low Resolution (≥ 100 m)
			0,5 m	**1 m**	**2,5 m**	**5 m**	**10 m**	**20 m**	**50 m**	**100 m**
Agricultural	Arable Lands	Rice field	√	√	-	-	-	-		
		Olive grove	√	√	-	-	-	-		
		Orchard	√	√	-	-	-	-		
		Pistachio grove	√	√	-	-	-	-		
		Citrus grove	√	√	-	-	-	-		
		Tea grove	√	√	-	-	-	-	General Arable Land	
		Rose grove	√	√	-	-	-	-		
		Vineyard	√	√	-	-	-	-		
		Meadow	√	√	-	-	-	-		
		Bushwood/Scrub	√	√	-	-	-	-		
		Nursery	√	√	-	-	-	-		
		Kaleyard	√	√	-	-	-	-		
Forests and Semi-natural areas	Forests	Coniferous	√	√	-	-	-			
		Broad-leaved	√	√	-	-	-			
		Mixed	√	√	-	-	-			
		Deforested forest	√	√	-	-	-			
		Burned forest	√	√	-	-	-			
		Forestry boundary	√	√	-	-	-		General Forest Area	
		Forestation Area	√	√	-	-	-			
	Individual trees	Coniferous	√	√	-	-	-			
		Broad-leaved	√	√	-	-	-			
		Acute type	√	√	-	-	-			
		Pennywort	√	√	-	-	-			
		Long type	√	√	-	-	-			
	Inland Wetland	Fan	√	√	√	√	√	-	General Wetland	
		Swamp/Marsh	√	√	√	√	√	-		
		Reed bed	√	√	√	√	√	-		
	Coastal Wetland	Sandy areas	√	√	√	√	√	-		

APPENDIX-D

Table D.1: Requirement Matrix for the Hydrographic Content for Topographic Maps

Level I	Level II	Level III	**1 : 5 000**	**1 : 10 000**	**1 : 25 000**	**1 : 50 000**	**1 : 100 000**	**1 : 200 000**	**1 : 500 000**	**1 : 1 000 000**
Linear	Boundaries	Sea danger boundary	polyline	polyline	polyline	polyline	polyline	polyline		
		Permanent lake boundary	polyline	polyline	polyline	polyline	polyline	polyline		
		Lake boundary	polyline	polyline	polyline	polyline	polyline	polyline		
		Pond boundary	polyline	polyline	polyline	polyline	polyline	polyline		
		Pool boundary	polyline	polyline	polyline	polyline	polyline	polyline		
		Stream boundary	polyline	polyline	polyline	polyline	polyline	polyline		
		River bed boundary	polyline	polyline	polyline	polyline	polyline	polyline		
		Dam lake boundary	polyline	polyline	polyline	polyline	polyline	polyline		
Areal Objects	Running Water	Spring	line	line	line	line	line	line		
		Stream (wet, dry, wide stream bed, important, reformed)	line	line	line	line	line	line		
		River	line	line	line	line	line	line		
		Gravel bed of a river	polygon	polygon	polygon	polygon	polygon	polygon	General information about water objects	
		Canal (concrete , irrigation, drying)	line	line	line	line	line	line		
		Waterfall (height ≤10 m, height ≥10 m)	point	point	point	point	point	point		
		Doline	point	point	point	point	point	point		
	Stagnant Water	Sea	polygon	polygon	polygon	polygon	polygon	polygon		
		Permanent lake	polygon	polygon	polygon	polygon	polygon	polygon		
		Lake with changeable edge	polygon	polygon	polygon	polygon	polygon	polygon		
		Lake	polygon	polygon	polygon	polygon	polygon	polygon		
		Dam lake	polygon	polygon	polygon	polygon	polygon	polygon		
		Pond	polygon	polygon	polygon	polygon	polygon	polygon		
		Fishpond	polygon	polygon	polygon	polygon	polygon	polygon		
		Pool	polygon	polygon	polygon	polygon	polygon	polygon		
		Catchment	polygon	polygon	polygon	polygon	polygon	polygon		

Level I	Level II	Level III	**1 : 5 000**	**1 : 10 000**	**1 : 25 000**	**1 : 50 000**	**1 : 100 000**	**1 : 200 000**	**1 : 500 000**	**1 : 1 000 000**
	Special objects and facilities	Overflowing Area	polygon	polygon	polygon	polygon	polygon	polygon		
		Water distinction point	point	point	point	point	point	point		
		Water pump (wet, dry)	point	point	point	point	point	point		
		Well (wet, dry, artesian)	point	point	point	point	point	point		
		Cesspool Breakwater	point	point	point	point	point	point		
		Water duct (above ground, under ground)	point	point	point	point	point	point		
		Water duct bridge	point	point	point	point	point	point		
		Water duct tunnel	point	point	point	point	point	point		
		Aqueduct	line	line	line	line	line	line	(-)	
		Ditch	line	line	line	line	line	line		
		Flume	line	line	line	line	line	line		
		Fountain (wet, dry)	point	point	point	point	point	point		
		Dyke	point	point	point	point	point	point		
		Waterback	point	point	point	point	point	point		
		Weir (standard weir, valid for cars, not valid for cars)	point	point	point	point	point	point		
		Reservoir	point	point	point	point	point	point		
		Water tower	point	point	point	point	point	point		

Table D.2: Requirement Matrix for the Hydrographic Content for Remotely Sensed Imagery

			Very High Resolution (≤2,5 m)			**High Resolution (2,5 m - 10 m)**		**Medium Resolution (10 m - 100 m)**		**Low Resolution (≥ 100 m)**
	Level I	Level II-III	**0,5 m**	**1 m**	**2,5 m**	**5 m**	**10 m**	**20 m**	**50 m**	**100 m**
Boundaries		Sea danger boundary	√	√	√	√	√	√	√	√
		Permanent lake boundary	√	√	√	√	√	√		
		Lake boundary	√	√	√	√	√	√	Extraction based on the area and width of the feature	
		Pond boundary	√	√	√	√	√	-		
		Pool boundary	√	√	√	√	√	-		
		Stream boundary	√	√	√	√	√	-		
		River bed boundary	√	√	√	√	√	-		
		Dam lake boundary	√	√	√	√	√	√		
Areal Objects	Running Water	Spring	√	√	√	√	√			
		Stream (wet, dry, wide stream bed, important, reformed)	√	√	√	√	√			
		River	√	√	√	√	√	Extraction based on the area and width of the feature		**(-)**
		Gravel bed of a river	√	√	√	√	√			
		Canal (concrete , irrigation, drying)	√	√	√	√	√			
		Waterfall (height ≤10 m, height ≥10 m)	√	√	√	√	√			
		Doline	√	√	√	√	√			
	Stagnant Water	Sea	√	√	√	√	√			
		Permanent lake	√	√	√	√	√			
		Lake with changeable edge	√	√	√	√	√			
		Lake	√	√	√	√	√	General water information based on the area		
		Dam lake	√	√	√	√	√			
		Pond	√	√	√	√	√			
		Fishpond	√	√	√	√	√			
		Pool	√	√	√	√	√			
		Catchment	√	√	√	√	√			

		Very High Resolution (≤2,5 m)			High Resolution (2,5 m - 10 m)		Medium Resolution (10 m - 100 m)		Low Resolution (≥ 100 m)
Level I	Level II-III	**0,5 m**	**1 m**	**2,5 m**	**5 m**	**10 m**	**20 m**	**50 m**	**100 m**
Special objects and facilities	Overflowing Area	√	√	√	-				
	Water distinction point	√	√	√	-				
	Water pump (wet, dry)	√	√	√	-				
	Well (wet, dry, artesian)	√	√	√	-				
	Cesspool Breakwater	√	√	√	-				
	Water duct (above ground, under ground)	√	√	√	-				
	Water duct bridge	√	√	√	-				
	Water duct tunnel	√	√	√	-				
	Aqueduct	√	√	√	-		**(-)**		
	Ditch	√	√	√	-				
	Flume	√	√	√	-				
	Fountain (wet, dry)	√	√	√	-				
	Dyke	√	√	√	-				
	Waterback	√	√	√	-				
	Weir (standard weir, valid for cars, not valid for cars)	√	√	√	-				
	Reservoir	√	√	√	-				
	Water tower	√	√	√	-				

CURRICULUM VITAE

Name Surname: Merve KESKİN

Place and Date of Birth: İstanbul, 24.10.1988

E-Mail: keskinmer@itu.edu.tr

B.Sc.: İstanbul Technical University, Civil Engineering Faculty, Department of Geomatics Engineering, 2006-2011.

Professional Experience and Rewards:

İstanbul Technical University, Civil Engineering Faculty, Department of Geomatics Engineering, Research Assistant, December 2011 - …

List of Publications and Patents:

Bachelor Thesis:

“Comparison of Interpolation Methods for Meteorological Data”, ITU Geomatics Engineering, BSc. Thesis, Prof. Dr. Necla Uluğtekin, Assist. Prof. Dr. Çiğdem Göksel, Assist. Prof. Dr. Ahmet Özgür Doğru, May 2011.

Conference Papers:

M. Keskin, A. O. Dogru (2012): “An Evaluation for the Use of Remote Sensing Data in Map Production”, 4th International Conference on Cartography & GIS, Albena, Bulgaria.

M. Fitrzyk, M. Keskin, K. Kopańczyk, A. O. Dogru (2012):“Mapping the Environment Using Integrated High Resolution Radar Data and Satellite Images From Optical Sensors”, 21st Cartographic School - Satellite Technologies in GIS and Cartography, Wroclaw, Poland.

A. O. Doğru, M.Keskin, K. Ozdoğu, N. İliev, N. N. Ulugtekin, F. B. Balcik, C. Göksel, S. Sozen (2011): “Meteorolojik Verilerin Değerlendirilmesi ve Sunulması için Enterpolasyon Yöntemlerinin Karşılaştırılması” (Comparison of Interpolation Methods for Evaluation and Presentation of Meteorological Data), TMMOB Coğrafi Bilgi Sistemleri Kongresi (Geographic Information Systems Congress), Antalya, Turkey.