CHANGE DETECTION IN HIGH DENSITY URBAN AREA AND RURAL AREA USING HIGH RESOLUTION SATELLITE IMAGE

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ABDULLA AHMAD

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CHANGE DETECTION IN HIGH DENSITY URBAN AREA AND RURAL AREA USING HIGH RESOLUTION SATELLITE IMAGE

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Approval of the Graduate School of Civil Engineering.

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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To My Parents

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I express sincere appreciation to my supervisor Dr. Orhan Ercan for his guidance and insight throughout the research. Thanks also go to Dr.Cumhur Aydin. To my wife,Amnna , I offer sincere thanks for her continuous support and patience during this period.

ABSTRACT

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Satellite imagery is now commonly used, maps can be produced using satellite imagery instead of traditional surveying and aerial photogrammetry, The IKONOS satellite has made revolution in the field of remote sensing. Earth’s features like buildings, streets, cars and walls become visible with high resolution images. Now satellite imagery provides a rapid, high-quality data source to produce maps with more details.

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. It involves the ability to quantify changes using multi-source imagery captured at different epochs. Traditional change detection methodologies are based on visual/manual comparison of temporal datasets.

The purpose of this study is to detect rural/urban changes using ortho-images from IKONOS satellite that captured at different times. The case study locates in Marmaris region as rural area and in Birlik Mah.-ANKARA as urban area in Turkey.

Accuracy assessment of change detection in both rural and urban areas is the final step of the study, by using visual comparison of temporal datasets method (superimpose one over another), measuring the coordinates of known points (such as corner of bulding and cross of the roads) in each layer, and then calculate the root mean square error (RMSE) for each case, the value of RMSE around 1m in both areas.

The outcomes of the study signify that: To use satellite imagery for accurate mapping, it must be rectified to fit a map projection and the accuracy of the image registration process (geometric differences) is the key factor that controls the validity and reliability of the change detection outcome. Satellite data is particularly useful for detecting changes in urban planning, because of periodically (repeated) coverage, low cost and more details. In practical, IKONOS images could be used to produce/update maps at medium/large scale (1:10000, 1:5000).

Keywords: Change Detection, IKONOS, Accuracy assessment, RMSE.

ÖZ

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Uydu görüntüleme yaygın olarak kullanılmaktadır, haritalar geleneksel ve havadan fotoğraf çekme yöntemi yerine uydu görüntülerinden yapılabilmektedirler. IKONOS uydusu uzaktan algılama alanında bir devrim yaratmıştır.yeryüzü özellikleri yapılar, caddeler, arabalar ve duvarlar yüksek çözünürlü görüntüler ile görülebilmektedir. Uydu görüntüleme daha detaylı harita oluşturmada hızlı, yüksek kalitede data kaynakları sağlamaktadır.

Değişikliklerin ortaya çıkarılması bir obje veya bir olgunun değişik zamanlarda gözlenerek farklılıklarını tespit etme işlemidir. Farklı dönemlerde elde edilen çoklu kaynaklı görüntülerin elde edilmesiyle değişimlerin ölçülmesini içermektedir. Geleneksel değişikliklerin ortaya çıkarılması metodları görsel/elde yapılan geçici data setlerinin karşılaştırılmasına dayalı yapılmaktadır.

Bu çalışma kırsal/kentsel değişimlerin değişik zamanlarda IKONOS uydusuyla elde edilen orto-görüntüler aracılığı ile yakalanmasını amaçlamaktadır. Örnek çalışma kırsal olarak Marmaris bölgesinde ve kentsel olarak Birlik Mahallesi – Ankara'da yer almaktadır.

Çalışmanın hem kırsal hem de kentsel alanlarda değişikliklerin ortaya çıkarılmasında doğruluklarının ölçülmesi son aşamadır. Geçici data set'lerinin görsel karşılaştırılması metodu (birbirinin üstüne koyarak), bilinen noktaların her katmanda koordinatlarını ölçerek (bina köşesi ve yol kenarı) , ve her durum için manidarlık sınaması (RMSE)'nin hesaplanarak yapılması. RMSE değeri her iki bölgede de yaklaşık 1 metre'dir.

Çalışmanın sonuçları; hatasız haritalama için uydu görüntülemenin kullanılması, harita projeksiyonuna uygunluğunu sağlamak için düzeltilmesi ve görüntü kayıtlarının doğruluğu işleminin (geometrik farklılıkları) sağlanması değişikliğin ortaya çıkarılmasının geçerliliği ve güvenilirliği için temel anahtarlardır. Periyodik olarak (tekrarlanan) çıkan, düşük maliyetli ve detaylı olmasından dolayı, uydu dataları özellikle kentsel planlamadaki değişimlerin ölçülmesi için yararlıdır. IKONOS görüntüleri orta/büyük ölçeklerdeki (1:10000, 1:5000) haritaların yapılması/yenilenmesi için kullanılabilmektedir.

Anahtar Kelimeler: değişiklikleri kaydetme, IKONOS, doğruluk değerleri, RMSE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURES **Page**

CHAPTER 1

INTRODUCTION

1.1 High-Resolution Satellite Image and Change Detection

`` Remote sensing is a reality. whose time has come. It is too powerful a tool to be ignored in terms of both its information potential and the logic implicit in the reasoning processes employed to analyze the data. We predict it could change our perceptions, our methods of data analysis, our models and our paradigms`` [1].

The origin of modem space borne remote sensing was secret military program; the motivation of the program was used for homeland defence, also there was civilian usage of space imaging from the beginning. The effects of commercial spending and technological developments on remote sensing technology increase the quality of remotely sensed imagery and products available. The competition in space imaging industry led to increasing in resolution of satellite imagery. Satellites like IKONOS and QUICKBIRD are among the highest resolution remote sensing satellites [2].

The existence of high-resolution has expanded the remote sensing applications that lead to increase in demand of remote sensing services (data). There are a number of applications of remotely sensing imagery since the launch of Landsat I in 1972 such as agriculture, forestry, natural disaster monitoring, geology, hydrology, land use and land cover classification and mapping. By using these data, crops can be monitored in shorter intervals, scientists can observe particular areas and forecast trends, highly detailed maps can be generated and updated, and city planners can develop the communities with higher precision [3].

Satellite imagery is now commonly used, maps can be produced by using satellite imagery instead of traditional surveying and aerial photogrammetry, and there are a number of advantages of using satellite images:

- Integration with Geographic Information System (GIS),
- It can be employed over large areas with further details,
- Satellite images provide the latest situation of earth surface in specific time,
- Data acquisition by remote sensing is cheaper and shorter in time consuming than other methods [4].

The first commercial high-resolution satellite, IKONOS, was launched on September, 1999.On the board, there are number of sensors. From a 680 km sun synchronous orbit, its panchromatic sensor able to generate 1-meter resolution with 10-kilometers wide, and its multispectral sensor collects multiband (blue, green, red and near-infrared) bands with 4-meter resolution images with 11-bit resolution, it provides natural-color imagery for visual interpretation. The result of combining the multispectral imagery with the high resolution panchromatic is 1-meter color images. IKONOS provides access to any location on the Earth's surface with 98-minute journeys around the earth and has the benefit of 3-day repeat cycle [5].

The IKONOS satellite has made revolution in the field of remote sensing; it makes satellite imagery more practical and highly desirable. Earth's features like buildings, streets, cars and walls become visible with high resolution images. Now satellite imagery provides a rapid, high-quality data source to produce maps with more details. Also it expands the application of remote sensing to urban and municipal land use and land cover planning including:

- natural resource management
- urban expansion
- transportation network planning
- cadastral mapping
- damage description (tornadoes, flooding, fire)

- target detection (change detection) [6].

Requirements for rural / urban change detection and mapping applications are:

- High resolution to obtain detailed information, and
- Multispectral optical data to make fine distinction among various land use classes [6].

The availability of high-resolution satellite images will increase the remote sensing applications that have traditionally used aerial photogrammetry. In particular, Ikonos images could be used to produce/update maps at medium/large scale (1:10000, 1:5000) [7].

Remote sensing of urban areas provides a tool to monitor changes in space and time. High resolution images allow detailed mapping of urban areas. Repeat coverage of the same regions allows comparison of the situation at different times. Monitoring of the changes makes it possible for decision makers to recognize the trends prior to the creation of problems.

The demand for up-to-date geographic data is increasing due to fast changes in the real world that are taking place as a result of nature and/or human actions. Such changes have to be accurately and reliably inventoried to fully understand the physical and human processes at work. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. It involves the ability to quantify changes using multi-resolution, multi-spectral, and/or multi-source imagery captured at different epochs. Various methodologies of change detection allow the use of digital images in obtaining change maps in a cost-effective and timely manner. Traditional change detection methodologies are based on visual/manual comparison of temporal datasets (such as satellite scenes, aerial images, maps, etc.). The development of Geographic Information Systems (GIS) has facilitated the use of historical data and vectors in performing change detection, as well [8].

1.2 Objectives and Scope

This research aims to assess the accuracy of the changes that detected in rural and urban areas by using high resolution satellite images. The following flowchart summarizes the methodology of the thesis:

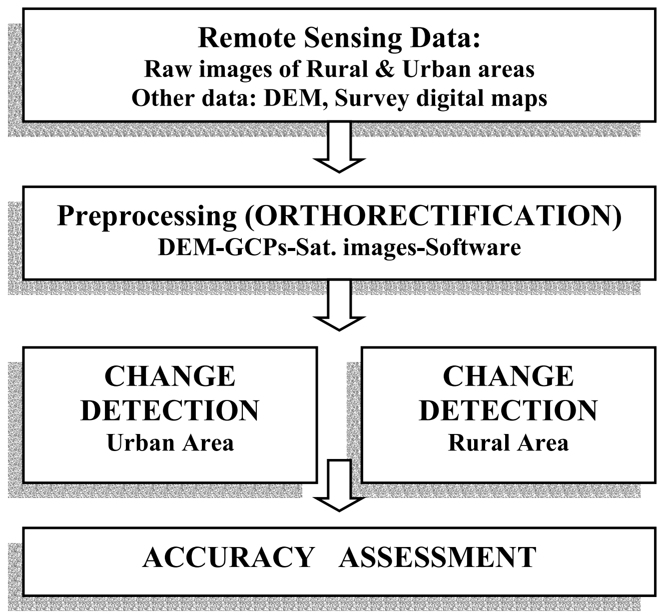


Figure 1.1 Flowcharts Summarizing the Methodological Procedure

As shown in Figure 1.1, the methodology of this thesis consists of**:**

(1) Remote sensing data

It consists of: Digital imagery of study area acquired in different times, and other data such as digital vector maps, digital elevation model (DEM) and ground control points (GCPs).

(2) Pre-Processing

It is correcting the raw satellite imagery, which has large geometric distortion, to create orthorectified image. This process was done by using computer program (ERDAS IMAGINE 8.5).

(3) Change Detection

The changes are identified by comparing the orthoimages that acquired in different times (in rural and urban area) or comparing them with digital vector maps to extracted object changes.

(4) Accuracy Assessment

The coordinates of specific points from orthoimages is measured and compared them with the coordinate of the same points from digital vector maps in many cases and then the RMSE (Root Mean Square Error) of these points is calculated.

1.3 Thesis Organization

This thesis encompasses the following five chapters:

Chapter 1 is an introduction to the study; it describes the general concept of the study.

Chapter 2 presents the basic terms and definitions related to the study; this chapter defines the terms, theories, and methods related to remote sensing, orthorectification and change detection.

Chapter 3 describe the application of remote sensing data and its relation with change detection applications, also this chapter give a brief description about usage of remote sensing data over the world and the future of remote sensing.

Chapter 4 presents the case study; this chapter presents the used data and their location. The obtained results of implementation process are explained and discussed.

Chapter 5 presents the prospects of the study and consists of some concluding remarks and recommendations.

CHAPTER 2
BASIC TERMS AND DEFINITIONS

This chapter deals with terms, definitions and theories of remote sensing, orthorectification and change detection.

2.1 Remote Sensing

``Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information`` [6].

The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem. [6]

2.1.1 Satellite Characteristics: Orbits and Swaths

Satellites provide a great deal of the remote sensing imagery commonly used today. Satellites have several unique characteristics which make them particularly useful for remote sensing of the Earth's surface. The path followed by a satellite is referred to as its orbit. Many remote sensing satellite are designed to follow an orbit (basically north-south) which, in conjunction with the Earth's rotation (west-east), allows them to cover most of the Earth's surface over a certain period of time.

2.1.1.1 Sun-Synchronous Orbit

The path of a satellite in which the orbital plane is near-polar and the altitude is such that the satellite passes over the same latitude at approximately the same local (sun) time each day. The orbit of a sun-synchronous satellite is designed to ensure that the angle between the orbital plane and the sun remains constant, resulting in consistent lighting conditions. Sun-synchronous orbits are well suited for higher resolution imaging and are generally used by Earth resource satellites, in Figure 2.1 the Sun-Synchronous Orbit of satellite is shown.

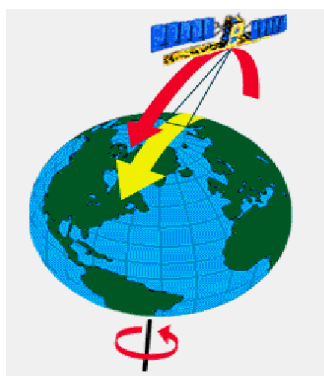


Figure 2.1 Sun-Synchronous Orbits

2.1.1.2 Swath

It is the width of the imaged scene in the range dimension, measured either in ground range or in angle range. Imaging swaths generally vary between tens and hundreds of kilometers wide. Figure 2.2 shows the swath on the earth.

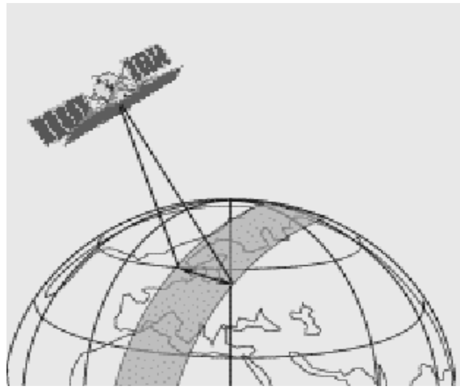


Figure 2.2 Image swath

2.1.1.3 Nadir

Nadir can be both a point and a line. It is the point on the ground vertically beneath the sensor. In other words, when a straight line is drawn between the sensor and the centre of the Earth, the nadir is the point where that line intersects the surface of the earth. When the contiguous nadir points are joined along the ground, they form the nadir line. Figure 2.3 shows the Nadir point and Nadir line [6].

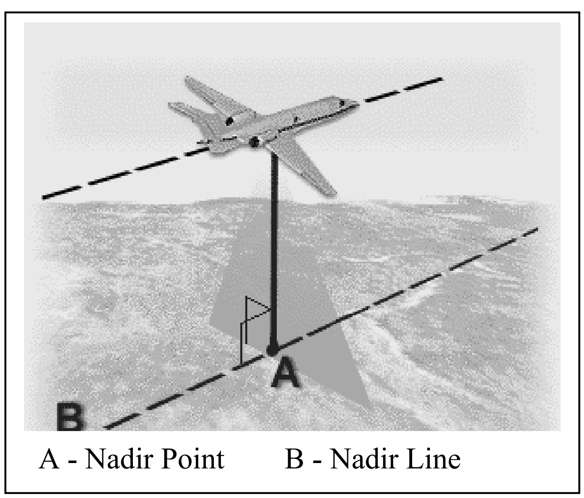


Figure 2.3 Nadir Point and Nadir Line

2.1.2 Remote Sensing Satellites

A satellite with remote sensors to observe the earth is called a remote sensing satellite or earth observation satellite. Meteorological satellites are sometimes discriminated from the other remote sensing satellites. Remote sensing satellites are characterized by their altitude, orbit and sensors. Landsat with an altitude of about 700 km, in a polar orbit, is mainly for land area observation [6].

The important functions of a remote sensing satellite system include the following three major systems:

- Tracking and control system: Determination of satellite orbit, orbital control, processing of housekeeping data etc.
- Operation control system: Planning of mission operation, evaluation of observed data, data base of processed data etc.
- Data acquisition system: Receiving, recording, processing, archiving and distribution of observed data [6].

2.1.3 High Resolution Satellite Imagery

As soon as space imagery of the earth become available, it was obvious to mapmakers that such systems had the potential for three-dimensional map compilation as well as image mapping, map revision, and map inspection. When considering mapping by using satellite images, and geometric correction of remotely sensed data, it is accepted that the resolution of images has an important role. Table 2.1 present main characteristics of high resolution satellites imagery [9].

Key requirement for making an appropriate choice of satellite images are:

- Geometrical resolution
- Availability of multispectral bands
- Specification of multispectral capabilities

- Achievable positioning accuracy
- Revisit rate
- Area covered by single frame

Because of its high spatial resolution, image taken by IKONOS satellite contain valuable details that are of significant interest for mapping applications [10].

Table 2.1 Main characteristics of high resolution satellites imagery

	Multispectral bands	**Multispectral Resolution (m)**	**Panchromatic Resolution (m)**	**Frame Size (km)**
Landsat 7	6	30	15	185
IRS	4	23	5.8	142
Spot 5	4	10	2.5	60
IKONOS	4	4	1	11
QuickBird	4	2.4	0.61	16.5

2.1.4 IKONOS (Commercial Satellite)

When Space Imaging successfully launched the IKONOS satellite in 1999, it made history with the world's first one-meter commercial remote sensing satellite. Moving over the ground at approximately seven kilometers per second, IKONOS collects black-and-white and multispectral data at a rate of over 2,000 square kilometers per minute. IKONOS satellite imagery provides access to any location on the Earth's surface. Through the nearly fifteen, 98-minute journeys it makes around the globe each day, IKONOS collects vital statistics about the Earth's ever-changing features—from fluctuations in land and water resources to the build-out of new urban areas. Commercial and governmental organizations rely on Space Imaging's high-resolution imagery to view, map, measure, monitor, and manage global activities. Applications range from national security and disaster assessment to urban planning and agricultural monitoring. Drawing on the spectacular views from IKONOS, the possibilities are endless. Table 2.2 shows the characteristics of IKONOS [11].

Table 2.2 IKONOS characteristics

Launch Date	24 September 1999 Vandenberg Air Force Base, California
Operational Life	Over 8.5 Years
Orbit	98.1 degree, sun synchronous
Speed on Orbit	7.5 kilometers (4.7 miles) per second
Speed Over the Ground	6.8 kilometers (4.2 miles) per second
Number of Revolutions Around the	14.7 every 24 hours
Orbit Time Around the Earth	98 minutes
Altitude	681 kilometers (423 miles)
Resolution	**Nadir:** 0.82 meters (2.7 feet) panchromatic 3.2 meters (10.5 feet) multispectral **26° Off-Nadir** 1.0 meter (3.3 feet) panchromatic
Image Swath	11.3 kilometers (7.0 miles) at nadir 13.8 kilometers (8.6 miles at
Equator Crossing Time	Nominally 10:30 a.m. solar time
Revisit Time	Approximately 3 days at 1-meter resolution, 40° latitude
Dynamic Range	11 -bits per pixel
Image Bands	Panchromatic, blue, green, red, near infrared

2.2 Orthorectification

Orthorectification is an orthogonal projection of all points of the ground to reference surface. It is the process of removing geometric errors inherent within imagery. Orthoimage has the geometric characteristics of a map, it can be used for the accurate measurement of areas and distances, the objects on an orthoimage are in their true positions. Any measurement taken on an orthoimage reflects a measurement taken on the ground [12].

An Orthorectification process removes image geometric distortions and resamples the imagery to map projection to rectify the image. Different geometric modelling methods can be applied such as:

- Polynomial transformation,
- Finite element analysis (rubber sheeting), and
- Collinearity equations.

The photogrammetry and remote sensing modeling are based on collinearity equations.

2.2.1 Orthorectification Process

The orthorectification process takes the raw digital imagery and applies a Digital Elevation Model (DEM) which is wanted to correct the relief displacements and Ground Control Points (GCPs) used for geometric correction. Figure 2.4 shows the orthorectification projection [13].

The main points of orthorectification projection are:

1. Relief displacement is corrected by transform each pixel of a DEM and finding the equivalent position in the satellite image by using collinearity equations.
2. Exterior orientation parameters.

3. A brightness value is determined for this location based on resampling of the surrounding pixels in the image.
4. The brightness value, elevation, and exterior orientation information are used to calculate the equivalent location in the orthoimage.

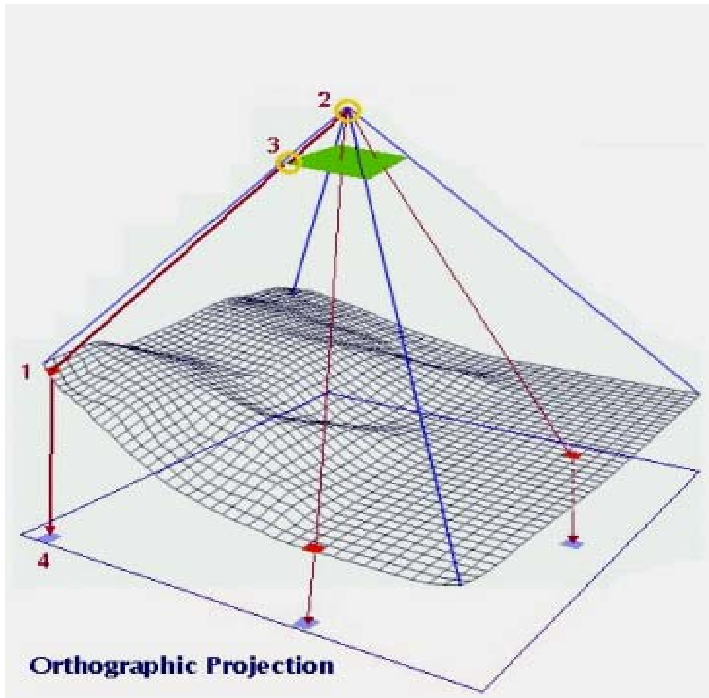


Figure 2.4 Orthorectification projection

2.2.2 Radiometric and Geometric Distortions

Raw satellite imagery involves radiometric and geometric errors, these errors should be corrected. Radiometric distortion is due to the sun's azimuth and elevation, atmospheric conditions such as fog or aerosols and sensor's response (sensitivity).

Geometric distortion is an error on an image, between the actual image coordinates and the ideal (ortho-image) image coordinates. Geometric distortions are caused by various factors. These factors include systematic and non-systematic distortions such as:

- The perspective of the sensor optics.
- The motion of the scanning system.
- The motion of the platform.
- The platform altitude, attitude.
- The platform velocity.
- The terrain relief.
- The curvature and rotation of the Earth.

2.2.3 Ground Control Points (GCP)

Ground control points are used to establish the relationship between the camera or sensor, the images and the ground. GCPs are identifiable features located on the Earth's surface such as road intersections, fire hydrants, land boundaries, and Survey benchmarks, the full GCP has x, y, and z coordinates, z coordinate that represents the elevation at that point. The GCPs can be collected from these sources: Ground Global Positioning System (GPS), total station survey, topographic maps, and digital elevation model (DEM).

In order to establish a relationship between the image and the ground, the theoretical minimum number of GCPs is two XYZ GCPs and one vertical (Z) GCP. With the purpose of computing a unique solution, at least seven known parameters must be available and the number of GCP's should be more than the number of unknown parameters.

The number and distribution of ground control points will influence the accuracy of the image, to increase the accuracy, using more GCPs is recommended. The accuracy of geometric correction is represented by Root Mean Square Error (RMSE), in pixel units, and it should be within (±1) pixel.

2.2.3.1 Root Mean Square Error (RMSE)

It is used to measure how well a specific calculated solution fits the original data. For each observation of phenomena, a variation can be computed between the actual observation and a calculated value. (The method of obtaining a calculated value is application-specific.) Each variation is then squared. The sum of these squared values is divided by the number of observations and then the square root is taken. This is the RMSE value [12].

2.2.4 Digital Elevation Model (DEM)

Digital Elevation Model (DEM) provides a digital representation of a portion of the earth's terrain over a two dimensional surface. A DEM consists of a sampled array of elevations for a number of ground positions that are normally at regularly spaced intervals. The basic data for a DEM is based on terrain elevation observations that are derived from these sources:

- Digitized contours,
- Photogrammetric data capture (aerial photography and satellite imagery), and
- Surveying.

2.2.5 Coordinate Systems

In order to establish the relationship between the camera, image, and the ground, this relationship must be defined with respect to a coordinate space and coordinate system.

2.2.5.1 Pixel Coordinate System

It is coordinate system with its origin in the upper-left corner of the image, the x-axis pointing to the right, the y-axis pointing downward, and the unit in pixels, as shown by axis *c* and *r* in Figure 2.5. The file coordinates of an image are in a pixel coordinate system as shown.

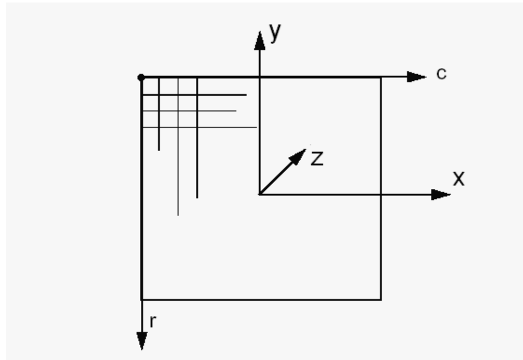


Figure 2.5 Pixel Coordinates and Image Space Coordinate

2.2.5.2 Image Space Coordinate System

It is defined as the three dimensional (X, Y, Z) coordinate system occurring on the image plane with its origin at the image center. As shown in Figure 2.5, its x-axis and y-axis are parallel to the c-axis and r-axis in the pixel coordinate system and z-axis is perpendicular axis on the image plane and its units in millimeters.

2.2.5.3 Ground Coordinate System:

It is defined as the three-dimensional coordinate system (X, Y and Z) that utilizes a known map projection, where Z value is elevation above mean sea level [14].

2.2.6 Interior Orientation

Interior orientation is the internal geometry of a camera as it existed at the time of data capture; it is used to transform the image pixel coordinate system to the image space coordinate system. The internal geometry of a camera is defined by these variables: principal point, focal length, lens distortion, and fiducial marks.

Since digital camera imagery does not have fiducial marks, the interior orientation is done automatically.

2.2.7 Exterior Orientation

It is defined as the position and angular orientation associated with an image at the time of image capture. The positional elements of exterior orientation (Xo, Yo, and Zo) define the position of the perspective center (O), where Zo is the height of the camera above sea level. The angular elements describe the relationship between the ground and the image. Three rotation angles are used to define angular orientation. They are: omega (ω) which is the rotation about the x-axis, phi (Φ) which is the rotation about the y-axis, and kappa (k) which is the rotation about the z-axis. Figure 2.6 shows elements of exterior orientation.

A Global Positioning System (GPS) can be used during the flight, which will record the X, Y and Z position of the camera or sensor and an Inertial Navigation System (INS) can record the omega, phi and kappa angles of the camera at time when image is taken [13].

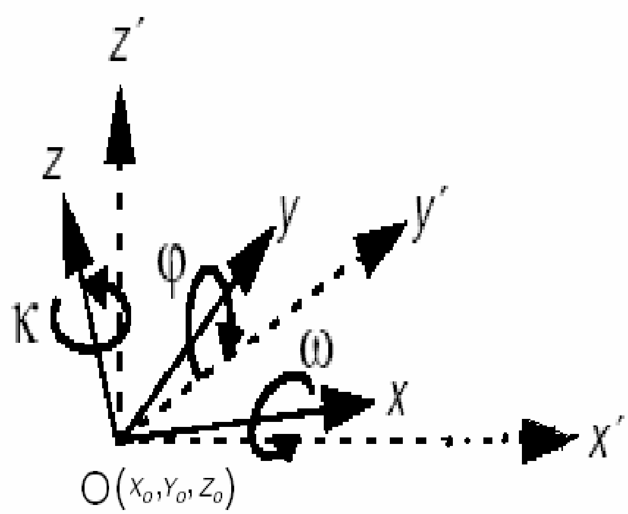


Figure 2.6 Elements of Exterior Orientation

2.2.8 Collinearity Equation

The collinearity equation is a physical model representing the geometry between a camera (projection center), the ground coordinates of an object and the image coordinates. It gives the geometry of a bundle of rays connecting the projection center of a camera, an image point and an object on the ground as shown in Figure 2.7 [16].

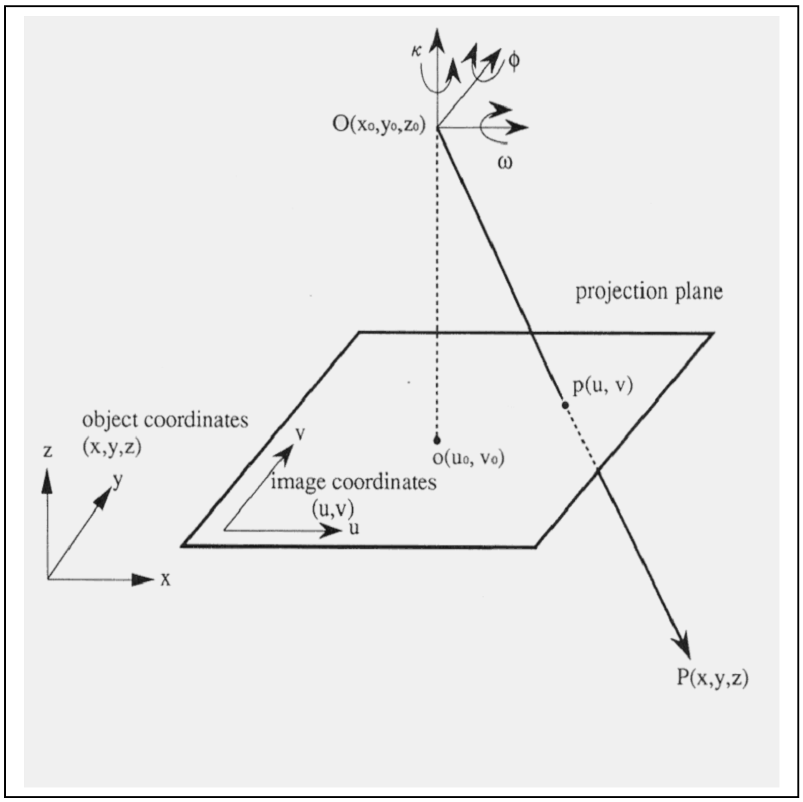


Figure 2.7 Collinearity Equation

Let the projection center be 0 (X_0, Y_0, Z_0), with rotation angles ω, φ, κ around X, Y and Z axis respectively as shown in Figure 2.7, the image coordinates be p (x,y) and the ground coordinates be P(X,Y, Z). The collinearity equation is:

$$Y = (Z - Z_0)\frac{a_2 x + a_5 y - a_8 f}{a_3 x + a_6 y - a_9 f} + Y_0 \quad \text{.......................................} \textbf{(2.1)}$$

$$X = (Z - Z_0)\frac{a_1 x + a_4 y - a_7 f}{a_3 x + a_6 y - a_9 f} + X_0 \quad \text{.......................................} \textbf{(2.2)}$$

Here, **F** is focal length of lens and a_1 to a_9 are given by the following matrix:

$$\begin{pmatrix} a_1 a_2 a_3 \\ a_4 a_5 a_6 \\ a_7 a_8 a_9 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -\sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} \cos\varphi & 0 & -\sin\varphi \\ 0 & 1 & 0 \\ \sin\varphi & 0 & \cos\varphi \end{pmatrix} \begin{pmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad \text{..................} \textbf{(2.3)}$$

2.2.9 Resampling

Resampling is a procedure used to correct the original geometric distorted image, and to determine the digital values to place in the new pixel locations of the corrected output image. The resampling process calculates the new pixel values from the original digital pixel values in the uncorrected image. There are three methods for resampling:

1. Nearest neighbour,
2. Bilinear interpolation, and
3. Cubic convolution.

2.3 Change detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. It involves the ability to quantify changes using multi-resolution, multi-spectral, and/or multi-source imagery captured at different epochs [17].

Change detection is important for monitoring and managing natural resources, urban development, environmental changes, and disaster assessments. The demand for up-to-date geographic data is increasing due to fast changes in the real world that are taking place as a result of nature and/or human actions. Such changes have to be accurately and reliably inventoried to fully understand the physical and human processes at work [18].

Traditional change detection studies are based on visual/manual comparison of temporal datasets (such as satellite scenes, aerial images, maps, etc.).

2.3.1 Manual On-screen Digitization of Change

This method is usually used for high-resolution remote sensor data and scanned aerial photographs. It can be used for updating erroneous government urban infrastructure databases using on-screen photo interpretation of high-resolution imageries.

In this method, multi-date remotely sensed data is saved in a single dataset (superimposed one over another). The development of Geographic Information Systems (GIS) has facilitated the use of historical data and vectors in performing change detection, as well.

2.3.2 Spectral Change Detection Technique

In spectral change detection, images of two dates are transformed into a new single-band or multi-band image, which contains the spectral changes. The resultant image must be further processed to assign the changes to specific land cover types.

2.3.3 Post-Classification Technique

In the post-classification approach, images belonging to different dates are classified and labeled individually. Later, the classification results are compared directly and the area of changes extracted. Supervised and unsupervised classifications are used in this approach. Individual classification of two image dates minimizes the problem of normalizing for atmospheric and sensor differences between two dates. Accuracy dependency of the classification's results is the main disadvantage of this method [17].

2.3.4 Direct Multi-Date Classification Methods

In this method, multi-date remotely sensed data saved in a single dataset (mosaic or superimposed one over another). They are classified with one classifier simultaneously. In the supervised approach the training sets of change and no-change classes are selected to derive the required statistics for classification. In unsupervised classification, selection of a small portion of known changes can be used to derive the classes by cluster analysis. As a disadvantage, these methods need very complex classification, which requires many classes.

2.3.5 Change Detection Using Write Function Memory Insertion

The changes could be visually revealed in the remotely sensed data using the insertion of the individual bands of two image dates (one band of each date) in the digital image processing system. For example insertion of one band of the first date in red and one band of the second date in green can reveal change area in red and green colour, while yellow indicates the area of no-change. The advantage is that the user has the possibility of looking at two and even three dates of imagery at the same time. As a disadvantage, this method cannot provide the quantitative amount of changes from one land cover to another and assessing of changes can be only done qualitatively [17].

CHAPTER 3

APPLICATIONS OF REMOTE SENSING DATA AND CHANGE DETECTION

3.1 Introduction

The collection and application of remotely sensed imagery for natural resources management and development has come a long way since the launch of Landsat I in 1972. Since this time, remotely sensed data has been used quite extensively for such activities as meteorology, oceanography, natural disaster monitoring, forest type and density mapping, geological mapping and agricultural assessment. However, one area in particular where remote sensing has become increasingly popular is land use and land cover classification and the temporal monitoring. Each application itself has specific demands, for spectral resolution, spatial resolution, and temporal resolution.

3.2 High Resolution Image and Change Detection

The existence of available high-resolution imagery in the last years has expanded the quantity and diversity of remote sensing applications. The result of this can only mean an increase in the already extended reach of remote sensing products and services. Satellite imagery is now commonly employed at all levels of government and industry.

With the increasing in the quantity of image, change detection research and applications has dramatically increased in the last decade. This increase can be largely attributed to simple economics: supply and demand. With an exploding global population, environmental strain is becoming a major concern, Urban sprawl, strip mining and deforestation have become a part of life in the new global community.

The first of these commercial high-resolution satellites, IKONOS, was successfully launched on September 24, 1999. With its impressive 1m spatial resolution, the IKONOS satellite system has effectively revolutionized the field of remote sensing; striving to make satellite imagery practical, affordable and highly desirable for urban, suburban and even rural land use planners. The remote sensing industry has expanded the application of remote sensing down to the urban and municipal level. However, for the present, satellite imagery remains largely underused by urban and especially rural planners. However, many very interesting and useful applications have already been identified and successfully applied. These include crop forecasting and yield management, erosion management, construction project planning and tracking, pipeline monitoring, land use zoning, transportation network planning, emergency and natural disaster management, selection and monitoring of drinking water sites, impervious surface analysis, and snow cover and runoff estimation.

In addition to the improved services afforded by high spatial resolution, IKONOS also has the benefit of a miniscule 3-day repeat cycle. This allows the consumer to closely monitor and actively track activities and monitor changes on a fairly regular basis. One can also assume that in the not too distant future there will be more comprehensive systems in place that will permit daily monitoring of any place on Earth. This will ensure that town managers and city planners have at their disposal the most current and accurate information possible, if used properly, these applications can facilitate the job of town.

3.3 Application of Remote Sensing

The remote sensing data has unlimited application, the most used applications are:

3.3.1 Agriculture

The production of food is important to everyone and producing food in a cost-effective manner is the goal of every farmer and large-scale farm manager and regional agricultural agency. A farmer needs to be informed to be efficient, and that includes having the knowledge and information products to forge a viable strategy for farming operations.

These tools will help him understand the health of his crop, extent of infestation or stress damage, or potential yield and soil conditions.

Agricultural practices are a global concern; many countries share many of the same requirements in terms of monitoring crop health by means of remote sensing. In many cases however, the scale of interest is smaller - smaller fields in Europe and Asia order higher resolution systems and smaller area coverage. Canada, the USA, and Russia, amongst others, have more open areas devoted to agriculture, and they are in the process of developing crop information systems.

Satellite images are used as mapping tools to classify crops, examine their health and viability, and monitor farming practices. Agricultural applications of remote sensing include the following:

- crop type classification
- crop condition assessment
- crop yield estimation
- mapping of soil characteristics
- mapping of soil management practices
- compliance monitoring (farming practices)

3.3.2 Forestry

The main issues concerning forest management are depletion due to natural causes (fires) or human activity (clear-cutting, burning, land conversion), and monitoring of health and growth for effective commercial exploitation and conservation. Forestry applications of remote sensing include the following:

-Reconnaissance mapping:

Objectives to be met by national forest/environment agencies include forest cover updating, depletion monitoring, measuring biophysical properties of forest stands, forest cover type discrimination and agroforestry mapping.

-Commercial forestry:

Collecting harvest, information, updating of inventory information for timber supply, broad forest type, vegetation density, and biomass measurements, clear cut mapping, regeneration assessment, burn delineation, infrastructure mapping, operations support and forest inventory.

-Environmental monitoring:

- Monitoring the quantity, health, and diversity of the Earth's forests.
- Deforestation (rainforest, mangrove colonies)
- Species inventory
- Watershed protection (riparian strips)
- Coastal protection (mangrove forests)
- Forest health and vigor

3.3.3 Geology

Geology involves the study of landforms, structures, and the subsurface, to understand physical processes creating and modifying the earth's crust. It is exploration and exploitation of mineral resources, Remote sensing is used as a tool to extract information about the land surface structure, composition or subsurface, but is often combined with other data sources providing complementary measurements. Geological applications of remote sensing include the following:

- surficial deposit / bedrock mapping

- lithological mapping
- structural mapping
- sand and gravel (aggregate) exploration/ exploitation
- mineral exploration
- environmental geology
- baseline infrastructure
- sedimentation mapping and monitoring
- event mapping and monitoring
- geo-hazard mapping
- planetary mapping

3.3.4 Hydrology

Hydrology is the study of water on the Earth's surface in ice or snow, or retained by soil. Most hydrological processes are dynamic, not only between years, but also within and between seasons. Remote sensing offers a view of the spatial distribution and dynamics of hydrological phenomena. The hydrological applications of remote sensing include:

- wetlands mapping and monitoring,
- soil moisture estimation,
- snow pack monitoring / delineation of extent,
- determining snow-water equivalent,
- river and lake ice monitoring,
- flood mapping and monitoring,
- glacier dynamics monitoring (surges, ablation)
- river /delta change detection
- drainage basin mapping and watershed modelling
- irrigation canal leakage detection

3.3.5 Sea Ice

Ice covers a substantial part of the Earth's surface and is a major factor in commercial shipping and fishing industries, Coast Guard and construction operations, and global climate change studies.

Remote sensing data can be used to identify and map different ice types, locate leads (large navigable cracks in the ice), and monitor ice movement. With current technology, this information can be passed to the client in a very short time from acquisition. Sea ice information and applications include:

- ice concentration
- ice type / age /motion
- iceberg detection and tracking
- surface topography
- tactical identification of leads: navigation: safe shipping routes/rescue
- ice condition (state of decay)
- historical ice and iceberg conditions and dynamics for planning purposes
- wildlife habitat
- pollution monitoring
- meteorological / global change research

3.3.6 Land Cover & Land Use

Land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, or other. Identifying and mapping land cover is important for global monitoring studies, resource management, and planning activities. Identification of land cover establishes the baseline from which monitoring activities (change detection) can be performed, and provides the ground cover information for baseline thematic maps.

Land use refers to the purpose the land serves: recreation, wildlife habitat, or agriculture. Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know what current changes quantity of land is in what type of use and to identify the land use changes from year to year. Land use applications of remote sensing include the following:

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

3.3.7 Mapping

Mapping constitutes an integral component of the process of managing land resources and mapped information, which is the common product of analysis of remotely sensed data. Natural features and manufactured infrastructures, such as transportation networks, urban areas, and administrative boundaries can be presented spatially with respect to referenced co-ordinate systems, which may then be combined with thematic information baseline, thematic, and topographic maps, which are essential for planning, evaluating, and monitoring.

There is a growing demand for the utilization of remote sensing data in map production, since the following benefits may be provided: stereo coverage, frequent revisits, timely delivery, wide area coverage, virtually global coverage, and storage in digital format to facilitate subsequent updating and compatibility with current GIS technology. Mapping applications of remote sensing include the following:

1. Planimetry
2. Digital Elevation Models (DEM's)

3. Baseline thematic mapping / topographic

3.3.8 Oceans and Coastal Monitoring

The oceans provide valuable food and they serve as transportation routes, and are an important link in the earth's hydrological balance. Understanding ocean dynamics is important for fish stock assessment, ship routing, predicting global circulation consequences of phenomena such as El Nino, forecasting and monitoring storms. Studies of ocean dynamics include wind and wave retrieval (direction, speed, and height), water temperature, and ocean productivity.

Coastlines are environmentally sensitive interfaces between the ocean and land and respond to changes brought about by economic development and changing land-use patterns. Often coastlines are also biologically diverse inter-tidal zones, and can also be highly urbanized. With over 60% of the world's population living close to the ocean, the coastal zone is a region subject to increasing stress from human activity.

Ocean applications of remote sensing include the following:

Ocean pattern identification:

- currents, regional circulation patterns, shears
- frontal zones, internal waves, gravity waves, eddies, shallow water
- bathymetry

Fish stock and marine mammal assessment

- water temperature monitoring
- water quality
- ocean productivity
- aquaculture inventory and monitoring

Oil spill

- mapping and predicting oil spill extent
- strategic support for oil spill emergency response decisions

- identification of natural oil seepage areas for exploration

Shipping

- navigation routing
- traffic density studies
- operational fisheries surveillance

3.4 Earth Observation in the World

Earth observation involves all activities connected with the collection of information on the Earth's surface or atmosphere from instruments on board satellites. Data from Earth observation satellites provide vital information for research and for practical applications at the local, national and global level.

Satellite observations contribute to monitoring global climate and environment and to mapping resources. Within the last ten years, satellite observations have become an essential part of numerous activities, including weather forecasting, sea monitoring, monitoring of forest fires and deforestation, thematic mapping.

3.4.1 Application of Remote Sensing in USA

Remote sensing has become a major technological and scientific tool for monitoring planetary surfaces and atmospheres. Since the space program began, the USA leads the world in this program, In fact, the budgetary expenditures on observing earth and other space programs in USA, now exceed $100 billion. Much of this money has been directed towards practical applications, largely focused on environmental and natural resource management. The paragraphs below summarize the principal uses in six disciplines.

3.4.1.1 Agriculture, Forestry and Range Resources

This application includes the following: Discrimination of vegetatetive types, Crop types, Timber types, Range vegetation; Measurement of crop acreage by species, Measurement of timber acreage and volume by species, Determination of vegetation stress, Determination of Soil conditions and associations, assessment of grass and forest fire damage, and Determination of aerial extent of snow and snow boundaries.

3.4.1.2 Land Use and Mapping

It involves: Classification land uses, Cartographic mapping and map updating, Categorization of land capability, Separation urban and rural, Regional planning, Mapping of transportation networks, and Mapping of land-water boundaries.

3.4.1.3 Geology

Geology applications of remote sensing include the following: Recognition of rock type, Mapping of major geologic units, mapping recent volcanic surface deposits, Mapping Landforms, and Search for surface guides to mineralization.

3.4.1.4 Water Resources

Water Resources application involves the following: Determination of water boundaries and surface water area and volume, Mapping of Floods and flood plains, Determination of water depth, and Inventory of lakes.

3.4.1.5 Oceanography and Marine Resources

This application includes: Detection of living marine organisms, Determination of turbidity patterns, circulation, mapping shoreline changes, mapping of ice for shipping, Study of eddy and waves.

3.4.1.6 Environment

Environment application includes: Monitoring surface mining and reclamation, Mapping and monitoring of water pollution, Detection of air pollution and its effects, Determination of effects of natural disasters, and Monitoring environmental effects of man's activities (lake defoliation, etc).

All of these applications are valid today, and many others have been devised and tested. The literature on remote sensing theory, instrumentation, and applications is now vast.

The United States has been the key player in these applications. Its chief role has been in providing many of the versatile satellites that make the critical land, sea, and air measurements on a global scale. There are number of satellites like LANDSAT 1-7, IKONOS, QUIKBIRD have been launched by USA.

3.4.2 Remote Sensing in Canada

Since 1972, Canada has participated in almost all major international remote sensing satellite programs through the reception, processing and archiving of North American data at the Canadian ground stations. In some cases, Canada has developed the technology to support these programs internationally. As well, in cooperation with international agencies, Canada continues to develop exciting and important new applications with global impact using remote sensing data and technology.

Remote sensing technology is helping Canadians understand forest ecosystems. Satellite images provide remote sensing data on Canada's natural resources and help monitor changes in the environment, also provide services to help clients resolve problems in areas such as:

- The earth sciences
- Infrastructure management
- The environment
- Land management and reform
- Natural-resource monitoring and development
- Development planning; and
- Coastal-zone management and mapping.

3.4.3 Remote Sensing in Europe

Since the early '70s, an increasing number of satellites orbit our planet and make observation data related to sea, land, and atmosphere available globally. The data is used in support to a number of applications; the best known might be the daily weather forecast satellite maps. Europe's first contribution to Earth observation applications began with the European Space Agency's (ESA's) Meteosat weather satellite system launched in 1977. From geostationary, it orbit 36,000 km above the Earth's surface.

With the increase in observation platforms also the number of applications is increasing. For example, since the early '90s, Europe has been exploiting its European Remote Sensing Satellite ERS-1 and ERS-2, for sea ice monitoring, oil-pollution monitoring or in support to disaster management.

Developments in technology are allowing satellites to become more flexible and autonomous in their applications. For example, the ESA small satellite PROBA (Project for On Board Autonomy) was launched in October 2001 with the CHRIS (Compact Height Resolution Imaging Spectrometer) instrument on board, built in the UK by Sira Electro-Optics Ltd. CHRIS will measure vegetation, oceans and atmosphere enabling a wide variety of applications.

3.4.3.1Government Agencies of Earth Observation in Europe

3.4.3.1.1 European Space Agency (www.esa.int)

In March 2002, ESA launched **Envisat**, the largest and most complex Earth observation satellite ever developed in Europe. During its five-year operational lifetime, the spacecraft's advanced payloads will gather huge volumes of data about Earth and ensure the continuity of the data measurements of ESA's earlier **ERS** satellites. Envisat will help scientists gain a better understanding of global warming, climatic changes and the depletion of the ozone layer, as well as changes in the oceans, the ice caps, vegetation and the composition of the atmosphere Work is well under way on ESA's Living Planet Program, which is the agency's next generation of satellite missions.

3.4.3.1.2 British National Space Centre (BNSC) (www.bnsc.gov.uk)

BNSC's Earth Observation National Program aims to help meet diverse customer needs for information services by the cost-effective use of Earth observation scientific and operational opportunities.

3.4.3.1.3 German Aerospace Center (DLR) (www.dlr.de)

DLR is the aerospace research center and the space agency of the Federal Republic of Germany. DLR's activities include experiments with weightlessness, exploring other planets and observing the terrestrial environment from outer space. At the beginning of 2000, DLR established the Applied Remote Sensing Cluster to unite DLR's various remote sensing activities and expand its capabilities.

3.4.3.1.4 French Space Agency (CNES) (www.cnes.fr)

CNES was created in December 1961 to develop French space activities. Its role is to propose, to the French government, directives concerning space policy and carry out, with its industrial partners, such programs. The areas in which these policies are carried out include space access (Ariane, stratospheric balloons, parabolic flights) and Earth observation (Spot, Topex-Poseidon, Jason, Polder, Envisat and more).

3.4.3.1.5 The Norwegian Space Center (www.spacecentre.no)

The Norwegian Space Center's application program has supported users, research communities and businesses in testing the potential of Earth observation from satellites. Priority is given to the development of applications having public benefit.

3.4.3.1.6 Swedish National Space Board (SNSB) (www.rymdstyrelsen.se)

SNSB is responsible for national and international activities relating to space and remote sensing, primarily research and development. Sweden is a member state in the European Space Agency (ESA), and Sweden has participated in the development of the Earth observation satellites ERS-1, ERS-2 and Envisat, as well as in the meteorological satellites Meteosat, MSG and MetOp. Sweden also has a great interest in GMES, a program that was established by ESA and the European Commission (EC) to exploit more effectively the potential of satellite and other environmental monitoring systems to meet end-user requirements.

3.4.4 Applications of Remote Sensing in Turkey

The remote sensing imagery is widely used in Turkey in many applications such as:

- Planning
- Forestry
- Urban development, planning design
- Geological applications
- Agriculture Monitoring
- Natural Disaster like Earthquake

Also there are many of organizations in the country using the remote sensing data in their works such as the municipalities, the institute of mining and some ministries like agriculture ministry.

3.4.5 Applications of Earth Observation Satellites in China (National Remote Sensing Center of China)

China started to apply Earth observation satellites in the 1970s and has expanded applications to crop yield estimation, weather forecasting, disaster monitoring, resource exploration, ocean study, environment monitoring, and urban planning. Recently, several integrated Earth observation application systems were built for dynamic information services of resource and environment, natural disaster monitoring and assessment, and ocean environment stereoscopic monitoring.

3.4.5.1 Agriculture Remote Sensing

China has established a National Agriculture Monitoring & Crop Yield Estimation System, which is currently providing crop growth monitoring and yield estimation services nationwide. The system uses remote sensing data from meteorological satellites, resource satellites and radar satellites and successfully combined satellite remote sensing technology with traditional agricultural techniques. The accuracy of the crop yield estimation is about 90 %.

3.4.5.2 Forest Resource Inventory

China has a lot of experiences in forest resource inventories using Earth observation technologies. Combining remotely sensed data with ground observations, China has built up a national forest resource inventory system to provide operational services.

3.4.5.3 Remote Sensing for Urban Planning

The high-resolution remote sensing images have great potential in urban applications, such as urban designing and planning, transportation planning, urban expansion assessment, urban green belt investigation, heat island identification, air quality and ecological environment monitoring, urban land resource inventory and land use change detection etc.

3.4.6 IRS (Indian Remote Sensing Satellite)

Remote sensing applications in the country, under the umbrella of NNRMS, now cover diverse fields such as crop acreage and yield estimation, drought warning and assessment, flood control and damage assessment, land use/land cover information, agro-climatic planning, wasteland management, water resources management, under-ground water exploration, prediction of snow-melt run-off, management of water- sheds and command areas, fisheries development, under development, mineral prospecting forest resources survey, Active involvement of the user ministries/ departments has ensured in an effective harnessing of the potential of space-based remote sensing. An important application of IRS data is in the Integrated Mission for Sustainable Development (IMSD) initiated in 1992. IMSD, under which 174 districts have been identified, aims at generating locale-specific action plans for sustainable development.

The first two IRS spacecraft, IRS-1A (March' 1988) and IRS-1B (August, 1991) were launched by Russian Vostok boosters from the Baikonur Cosmodrome. IRS-1A failed in 1992, while IRS-1B continued to operate through 1999.

3.4.7 Remote Sensing in Africa

With the exception of South Africa, the remote sensing, in most countries on the African continent, suffers severely from lack of financial resources and an adequate academic base. Nigeria and Algeria have, however, established space programs and launched imaging satellites with technical help from the United Kingdom. Certain other countries are planning on installation of infrastructure for reception of satellite imagery (e.g. Kenya). The focus of most institutions and governmental agencies appears to be on applications. Understandably, this is a situation driven by necessity. As a result, little effort is given to theoretical studies to advance the state-of- the-art of the remote sensing field, particularly in the areas that would benefit Africa the most. For even the exceptions, too often the human, technological and institutional capacity of the national institutions (academic and governmental) is insufficient to permit full use of the latest remote sensing theories, techniques and applications.

Lack of a strong communications infrastructure throughout the entire continent would appear to be the single most critical factor limiting remote sensing infrastructure development. A case in point: Many remote sensing entities in Africa suffer severe limitations resulting from lack of access to current remote sensing products (data, metadata, models, algorithms etc.) which address latest advancements in the field. This alone deals a severe blow to any attempts to obtain or maintain currency in the field. The extremely limited involvement of African

Remote Sensing scientists in remote sensing activities (workshops, tutorials, experiments, conferences and symposia) on an international scale (which requires funding support for international travel to attend these events) is seen as another major limitation. Networking at these activities presents excellent opportunities to partner with other scientists in joint research endeavors, many of which would lead to joint research programs on the African Continent, where interest exists within the international remote sensing community.

3.4.8 The Future of Earth observation:

The focus of Earth observation applications is moving in response to user needs to manage the environment more effectively, monitor resources efficiently and understand evolving climate conditions. New detection techniques are being developed and more detailed data, such as half-meter resolution civilian satellite images, are becoming available. Access to information through on-line systems is facilitating applications where speed is vital, such as in disaster support. New delivery methods are also being examined that will bring earth observation to the general public, on demand, through third generation mobile phones.

The higher spatial and spectral resolutions, more frequent coverage and increased availability of new sensors will bring remote sensing to a more accessible level within local and state governments and help them deal with several issues in regional planning, resource management, public health and environmental protection.

CHAPTER 4

CASE STUDY

4.1 Study Area

The study area is located in Turkey and consists of two parts: rural area which located in the southwest of Turkey (Marmaris region) and high density urban area in the middle of Turkey (Birlik Mah.-Ankara). All images and maps are based on **UTM** (Universal Transverse Mercator) projection coordinate. Figure 4.1 shows the location of the study areas.

4.2 Software

The following computer programs are used:

- Digital Image Processing software:
  ERDAS IMAGINE 8.5
- Geographic Information System
  Arc View 8.3

4.3 Rural Area

4.3.1 Study Area Location

The study area of Marmaris region covers 4.84 km^2 (2.2 x 2.2 km) and is located between the coordinates 11327 E, 613548 E and 94617 N, 96821 N, UTM zone 35. This area is an agricultural area including buildings and a river crosses the area from south to north, and a forest surrounds the area. There are some changes in the area; such as new buildings and changes in topography of the river.

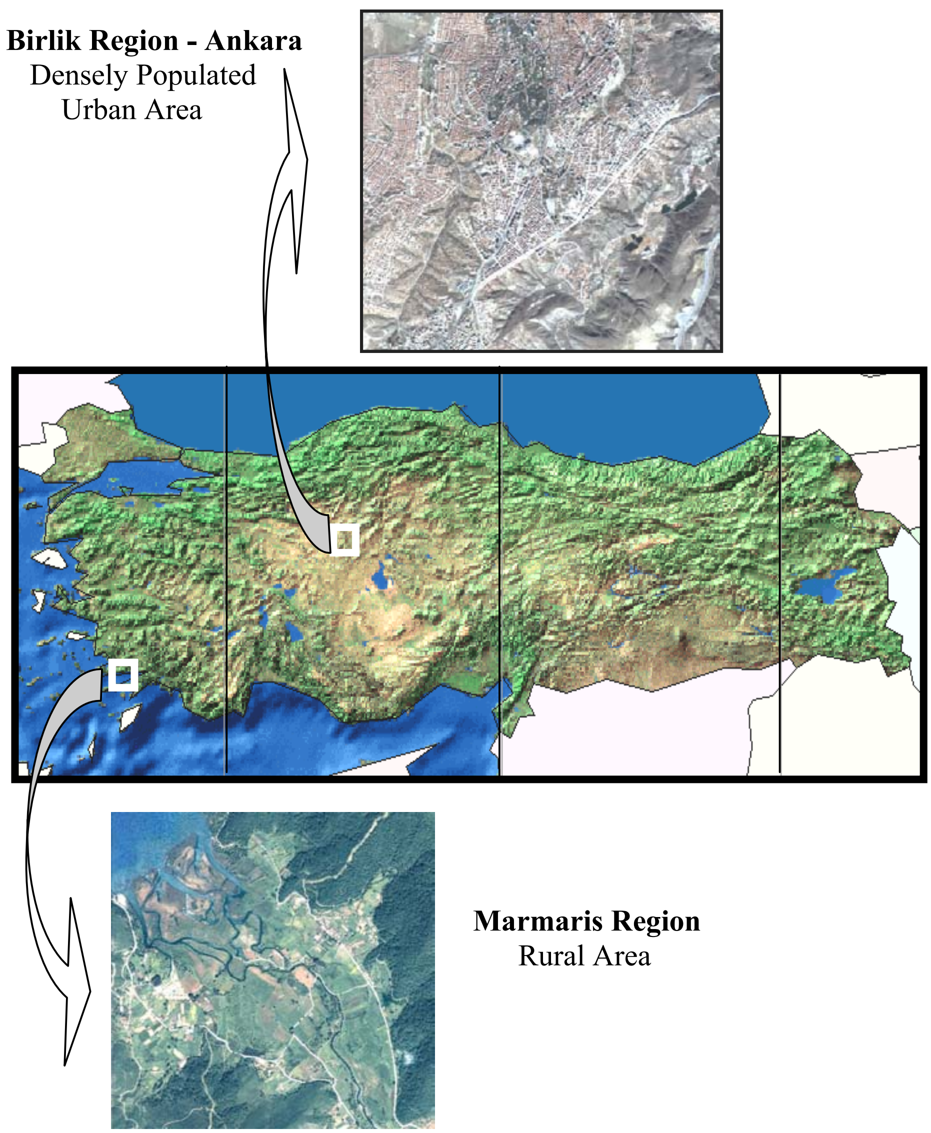
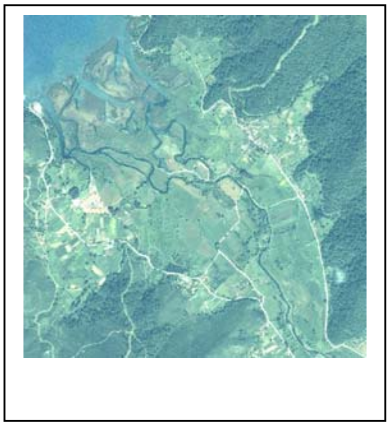


Figure 4.1 Study Area Locations

4.3.2 Material Used

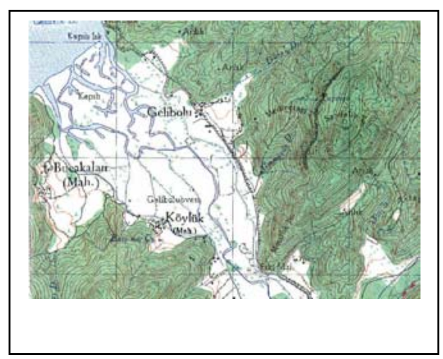
This study was done using two IKONOS images which have been taken on 22/4/2002 and 19/3/2004, digital vector map (1/1000 large scale map) and topographic map (1/25000 Scale map) of the area. Figure 4.2 shows the used maps of rural area.



(a)

(b)

(c)



(d)

Figure 4.2 Maps of Rural Area (Marmaris region):
(a) Raw image (22/4/2002) (b) Raw image (19/3/2004)
(c) Digital survey map (d) Topographic map

4.3.3 Orthorectification

Orthorectification techniques are used to correct geometric variations in images. This process needs well distributed and accurate ground control points (GCP) and DEM, due to this reason; ERDAS IMAGINE 8.3 (OrthoBASE) software is used.

The collinearity equation based orthorectification, which is applied in ERDAS IMAGINE 8.3 (OrthoBASE) software, produces reliable solution for raw image data by incorporating the camera orientation, relief displacement, and the Earth's curvature in its modeling process.

4.3.3.1 Ground Control Points (GCPs)

Ground control points have been collected and measured from 1/1000 surveying map which uses total station survey method to prepare it. The accuracy of GCPs depends on the accuracy of the method of collecting the points which used by total station method. The accuracy of this method is a few centimeters that mean less than one meter or (1 pixel). Figure 4.3 shows the location and distribution of GCPs where Table 4.1 shows the coordinates (X, Y and Z values).

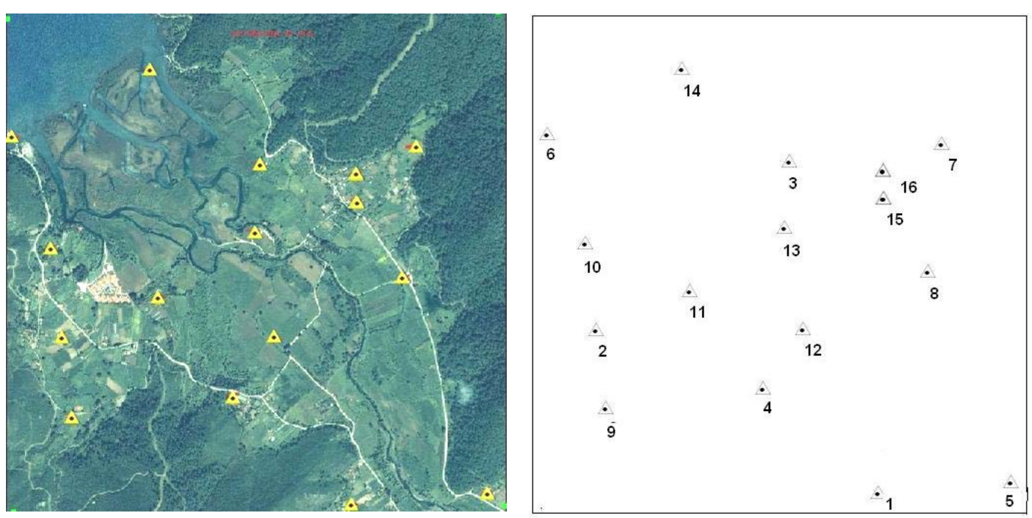


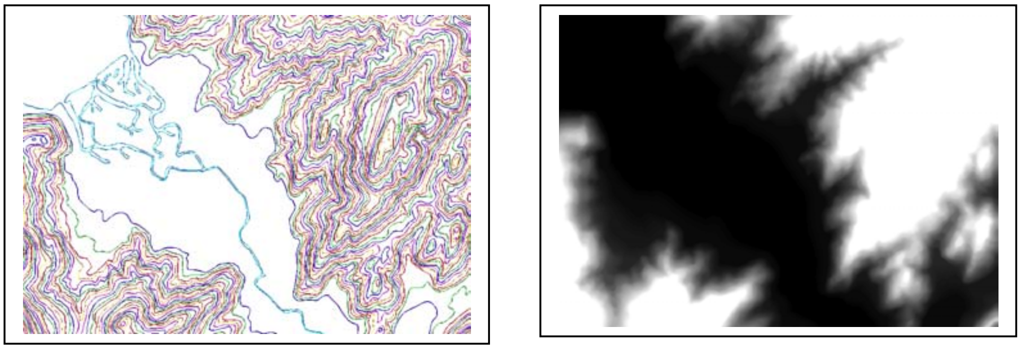
Figure 4.3 The Location and Distribution of GCPs in Marmaris Region

Table 4.1 The Location and Coordinates of GCPs of Rural Area

Point No.	X coord	Y coord	Z coord	Data collection method
GCP-1	11556.471	95378.257	12.078	Total station
GCP-2	11576.161	95017.925	28.901	Total station
GCP-3	12344.379	95107.859	5.357	Total station
GCP-4	12877.074	94610.671	11.566	Total station
GCP-5	13485.178	94659.626	6.946	Total station
GCP-6	12462.859	96143.896	9.059	Total station
GCP-7	11524.068	95771.308	3.679	Total station
GCP-8	11316.026	96258.022	1.217	Total station
GCP-9	13144.654	96221.728	19.867	Total station
GCP-10	13110.091	95637.268	13.925	Total station
GCP-11	11971.114	95535.341	3.453	Total station
GCP-12	12483.014	95346.553	2.018	Total station
GCP-13	12436.667	95835.575	1.472	Total station
GCP-14	11960.207	96557.956	0.183	Total station
GCP-15	12872.847	95970.311	12.222	Total station
GCP-16	12894.419	96091.697	10.889	Total station

4.3.3.2 Digital Elevation Model (DEM)

The DEM has an important role in ortho-image generation process (orthorectification). It was generated from topographic map (1/25000 Scale map), which is the most commonly used source to produce DEMs. The first step to generate DEM is scanning and registering the topographic map, second step is digitizing the contour lines where each contour line is assigned an elevation value, and then the DEM is generated from digital contour map. The DEM is generated with 10 m interval. Figure 4.4 shows Digital countor map and DEM.



(I) (II)

Figure 4.4 DEM of Marmaris Region:

(I) Digital countor map
(II) DEM (Digital Elevation Model)

4.4 Urban area

4.4.1 Study Area Location

The study area of Birlik Mah. Region covers 37.21 Km^2 (6.1x 6.1km) and it is located between coordinates 85536 E, 1632E and 12936 N, 19044 N, UTM zone 36. Birlik Mah locates in western south of Ankara city where the city extends in south and west directions.

4.4.2 Material Used

This study was done using one IKONOS image (2004), digital map (1/1000 large scale map) and digital elevation model (DEM). Figure 4.5 shows the maps of Birlik Mah. Region used in the study.

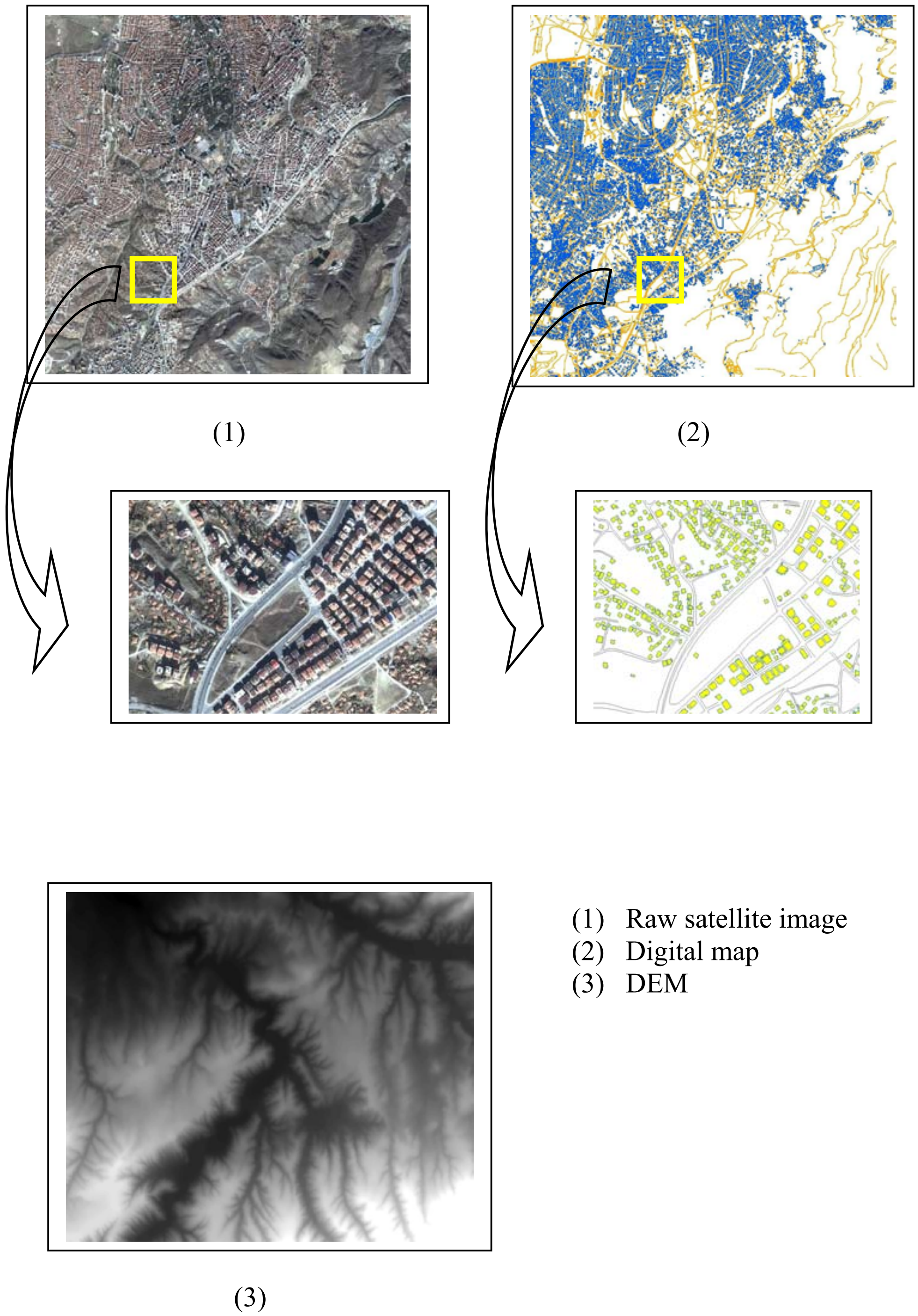


Figure 4.5 The Maps Used in Birlik Mah. Region

4.4.3 Orthorectification

Orthorectification techniques are used to correct geometric variations in images. This process needs good distributed and accurate ground control points (GCP) and DEM. This processing has been done using IMAGINE Otho BASE (ERDAS 8.5) software.

4.4.3.1 Ground Control Points (GCPs)

The accuracy of GCPs depends on the accuracy of the method of collecting the points which used Total station method. In this method, the accuracy is a few centimeters that mean less than one meter or (1 pixel), Figure 4.6 shows the location and distribution of GCPs where Table 4.2 shows the coordinates (X, Y and Z values).

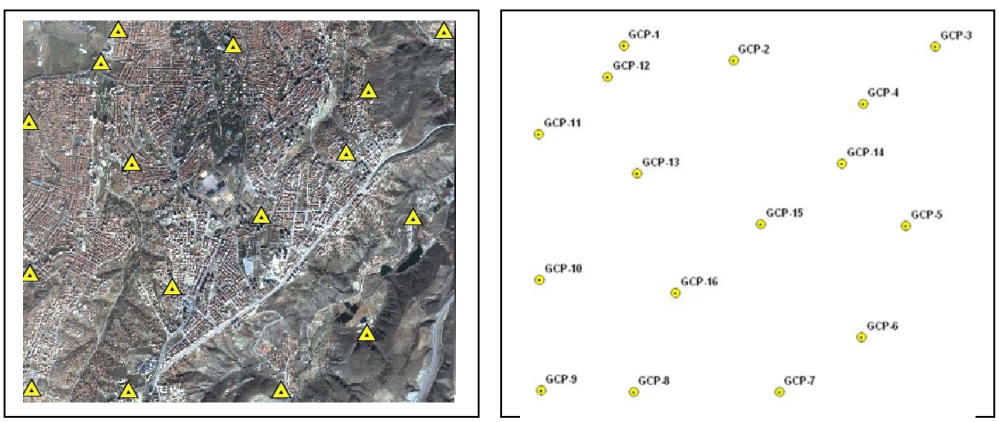


Figure 4.6 The Location and Distribution of GCPs in Ankara-Birlik Mah. Region

Table 4.2 The Location and Coordinates of GCPs

Point No.	X coord (m)	Y coord (m)	Z coord (m)	Data collection method
GCP-1	86883.89	18929.68	934.38	Total station
GCP-2	88502.41	18711.49	982.99	Total station
GCP-3	91485.32	18917.19	952.06	Total station
GCP-4	90418.43	18072.49	1015.67	Total station
GCP-5	91056.16	16261.37	928.33	Total station
GCP-6	90400.13	14620.41	941.61	Total station
GCP-7	89183.17	13806.49	958.18	Total station
GCP-8	87029.35	13802.28	1189.71	Total station
GCP-9	85660.18	13831.63	1208.67	Total station
GCP-10	85644.93	15471.96	1140.06	Total station
GCP-11	85627.51	17619.46	967.73	Total station
GCP-12	86646.61	18467.65	944.12	Total station
GCP-13	87075.12	17042.53	1062.97	Total station
GCP-14	90103.98	17180.68	1077.64	Total station
GCP-15	88901.09	16288.57	1073.84	Total station
GCP-16	87171.71	15276.31	1115.77	Total station

4.4.3.2 Digital Elevation Model (DEM):

The DEM was used in Orthorectification process, which was generated from topographic map (1/25000 Scale map) which is the most commonly used source to produce DEMs.

4.5 Change Detection

In the previous section all images have been orthorectified, and errors associated with image have been removed. The orthoimage has the geometric characteristics of a map and the image qualities of a photograph. The objects on an orthoimage are in their true orthographic positions. Any measurement taken on an orthoimage reflects a measurement taken on the ground. The method of superimpose used to detect the changes that happened in both regions.

4.5.1 Change Detection in Rural Area

As mentioned before there are two ortho-images 2002, 2004 and the digital vector map of the region. When all the three layers are superimposed, the change that happened in topography between (2002 and 2004) by the river stream can be easily detected, and also some buildings that have been constructed in the same period. Figure 4.7 shows these changes.

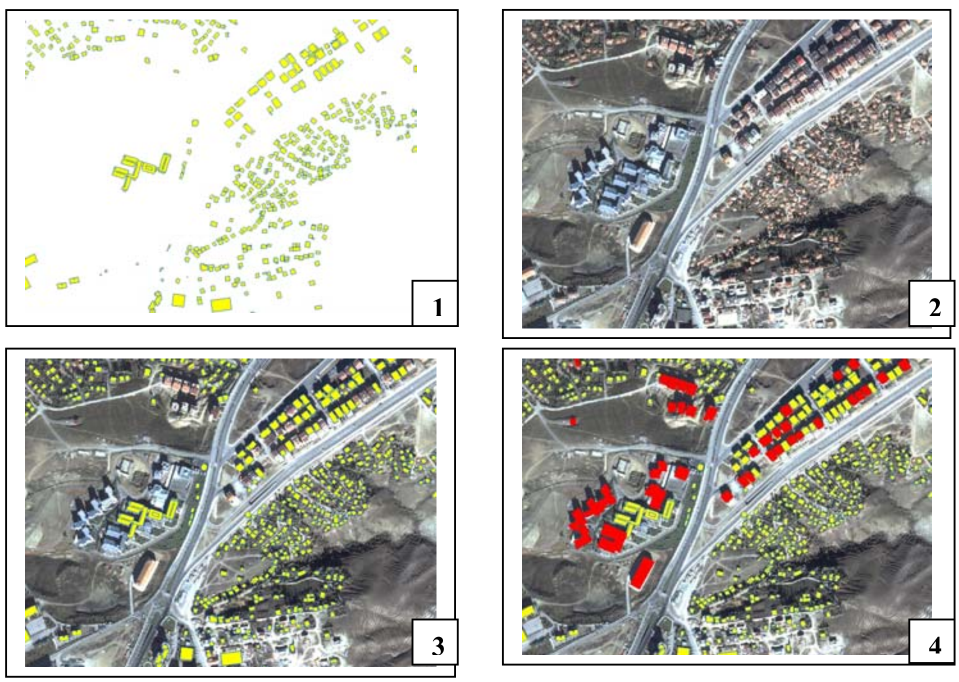
1- Sat. image (2002) 2- Sat. image (2004)
3- Digital vector map 4-changes between 2002 & 2004 (Red color)

Figure 4.7 Changes in Topography of the River Stream

4.5.2 Change Detection in Urban Area

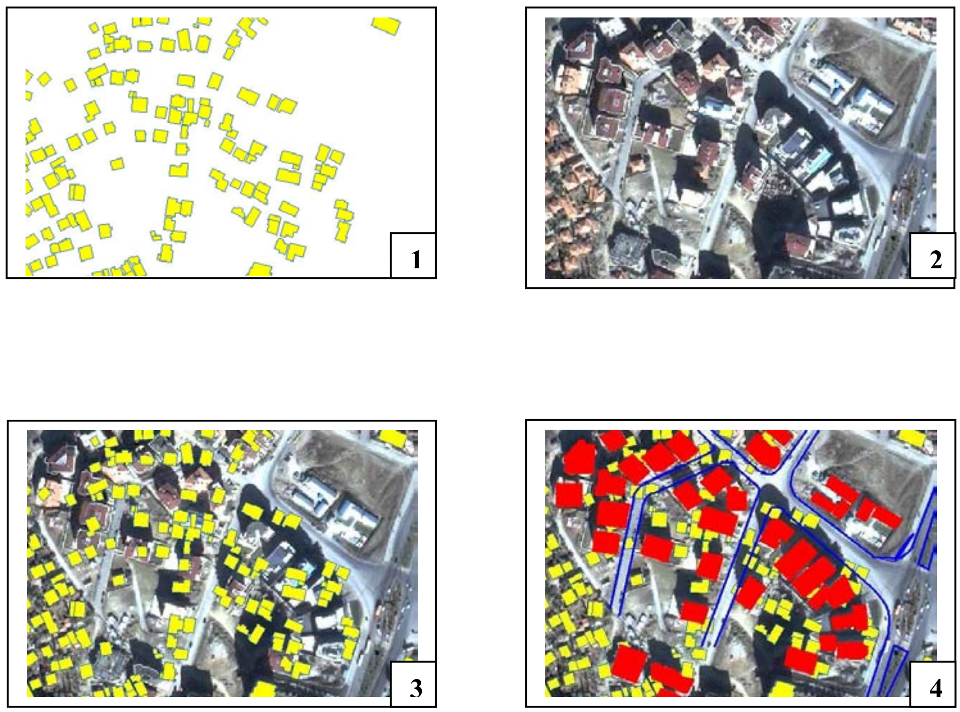
As the Earth's population increases, cities will grow and spread. City growth is an indicator of development. Birlik Mah. region locates in western south on Ankara, where the city sprawls.

The digital vector map (1/1000 scale) and ortho-image (2004) have been used to detect the changes in the region. There are new multistory buildings have been constructed as shown in Figure 4.8, and some parts have been changed completely, new buildings and streets replaced the old and random small buildings as shown in Figure 4.9.



1- Digital vector map
2- Ortho image
3- Digital map & ortho image
4- Changes (Red color)

Figure 4.8 Changes in Urban Area (new building)



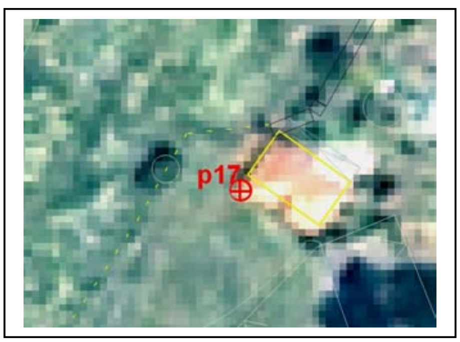
1- Digital vector map
2- Ortho image
3- Digital map & ortho image
4- Changes:
- New buildings (Red color)
- Streets (blue color)

Figure 4.9 Changes in Urban Area (new buildings and streets)

4.6 The Accuracy of Change Detection

As mentioned before, the orthoimage has the geometric characteristics of a map. Any measurement taken on an orthoimage reflects a measurement taken on the ground, so the accuracy of producing or updating a map from orthoimage depends on the accuracy of change detection.

To assess the accuracy, the coordinates of chosen sharp points (corner of building, cross sections of roads) have been measured from multi-date images and vector maps, and then compared to each other to calculate the RMSE (Root Mean Square Error) of each case. Figure 4.10 shows an example of coordinates of two points from vector map and orthoimage when superimpose them in rural and urban areas.



a- point No17 in Rural area
-Coordinates in vector map
(11524.056 , 95771.314)
-Coordinates in image(2002)
(11523.051 , 95769.081)

b- point No 5 in Urban area
-Coordinates in vector map
(86067.133 , 18074.810)
-Coordinates in image
(86067.465 , 18077.002)

Figure 4.10 Coordinates of Two Points in Both Vector Maps and Ortho-images of Rural and Urban Areas

4.6.1 The Accuracy of Change Detection in Rural Area

To assess the accuracy in rural area, there are three cases:

In the first one, vector map is superimposed on the image of 2002 and the coordinates of points in both layers and difference between them have been measured. Table 4.3 shows the coordinates, differences and RMSE of the chosen points.

In case 2, the same was done but with the image of 2004. Table 4.4 shows the coordinates, differences and RMSE of the chosen points.

On the other hand, in case 3, the three layers **(**vector map, image (2002) and image (2004)**)** have been superimposed on each other and the coordinates of points in all the layers and difference between them have been measured. Table 4.5 shows the coordinates, differences and RMSE of the chosen points.

4.6.2 The accuracy of change detection in urban area

To assess the accuracy in urban area, there is one case:
The vector map is superimposed on the image and the coordinates of points in both layers and difference between them have been measured. Table 4.6 shows the coordinates, differences and RMSE of the chosen points.

Table 4.3 Coordinates, Differences and RMSE of Superimpose Vector Map on Image (2002) in rural area

Point	Surveying Map		Satellite Image (2002)		differences		Dif. (m)
ID	East (Y)	North (X)	East (Y)	North (X)	East(Y)	North(X)	Distance
1	13150.282	96230.492	13149.855	96229.958	0.427	0.534	0.684
2	12752.187	96085.808	12751.947	96085.053	0.240	0.755	0.792
3	12462.819	96143.881	12462.352	96143.781	0.467	0.100	0.478
4	12888.852	95957.815	12889.011	95957.975	0.159	0.160	0.226
5	13124.240	95661.504	13124.575	95662.384	0.335	0.880	0.942
6	12436.631	95835.611	12435.973	95836.077	0.658	0.466	0.806
7	13473.284	94659.213	13473.814	94657.888	0.530	1.325	1.427
8	12935.717	94662.038	12935.717	94660.765	0.000	1.273	1.273
9	12728.602	94989.299	12729.024	94988.771	0.422	0.528	0.676
10	12464.654	95031.111	12463.979	95029.928	0.675	1.183	1.362
11	12337.624	95083.861	12336.947	95084.428	0.677	0.567	0.883
12	11579.562	95011.117	11579.981	95009.707	0.419	1.410	1.471
13	11382.209	95388.341	11382.761	95386.889	0.552	1.452	1.553
14	11638.021	95550.298	11638.971	95550.129	0.950	0.169	0.965
15	11854.541	95520.537	11854.381	95519.205	0.160	1.332	1.342
16	11726.669	95620.126	11726.778	95619.074	0.109	1.052	1.058
17	11524.056	95771.314	11523.051	95769.081	1.005	2.233	2.449
18	12480.689	95343.133	12480.586	95342.337	0.103	0.796	0.803

RMSE inY	**0.519**
RMSE in X	**1.051**
RMSE (m)	**0.829**

Table 4.4 Coordinates, Differences and RMSE of Superimpose Vector map on Image (2004) in Rural Area

Point	Surveying Map		Satellite Image(2004)		Differences		Dif.
ID	East (Y)	North (X)	East (Y)	North (X)	East(Y)	North(X)	Distance
1	12468.266	96151.919	12468.585	96150.477	0.319	1.442	1.477
2	12798.861	96070.544	12798.648	96071.462	0.213	0.918	0.942
3	13048.636	96079.406	13049.010	96080.263	0.374	0.857	0.935
4	12814.025	95914.495	12813.446	95916.164	0.579	1.669	1.767
5	13059.880	95826.078	13058.649	95827.383	1.231	1.305	1.794
6	13121.124	95670.297	13119.871	95672.122	1.253	1.825	2.214
7	13485.166	94659.631	13484.479	94658.309	0.687	1.322	1.490
8	12942.833	94665.997	12942.499	94667.370	0.334	1.373	1.413
9	12495.773	94951.528	12495.582	94952.644	0.191	1.116	1.132
10	12468.027	95150.399	12468.568	95151.985	0.541	1.586	1.676
11	12430.864	95030.723	12431.716	95031.752	0.852	1.029	1.336
12	11738.285	95344.018	11736.233	95345.237	2.052	1.219	2.387
13	11549.607	95386.050	11549.868	95385.859	0.261	0.191	0.323
14	11688.407	95590.385	11687.643	95591.331	0.764	0.946	1.216
15	11528.607	95777.754	11529.541	95778.009	0.934	0.255	0.968
16	12436.654	95835.590	12435.106	95836.232	1.548	0.642	1.676
17	12483.157	95346.564	12483.455	95347.464	0.298	0.900	0.948

RMSE inY	**0.798**
RMSE in X	**1.39**
RMSE(m)	**1.046**

Table 4.5 Coordinates, Differences and RMSE of Superimpose Three Layers in Rural Area

Point ID	Surveying Map		Satellite Image (2002)		Satellite Image (2004)	
	East (Y)	North (X)	East (Y)	North (X)	East (Y)	North (X)
1	12799.062	96070.470	12797.625	96071.515	12798.539	96070.470
2	12938.266	96066.938	12937.772	96067.268	12937.442	96066.938
3	12872.768	95970.323	12872.966	95971.116	12872.768	95971.512
4	12436.921	95835.555	12436.015	95836.281	12434.927	95836.825
5	13485.173	94659.532	13485.581	94660.553	13484.561	94658.103
6	12942.868	94666.051	12943.370	94666.051	12942.367	94668.306
7	12551.826	95006.899	12552.125	95007.199	12552.723	95007.797
8	12337.753	95083.939	12337.172	95085.293	12336.012	95086.260
9	11549.556	95385.835	11549.876	95385.515	11549.716	95385.995
10	11707.356	95605.164	11707.817	95604.703	11706.127	95606.701
11	11775.876	95641.729	11775.876	95640.807	11774.647	95642.497
12	11817.817	95551.086	11817.971	95551.086	11817.049	95552.622
13	12468.250	96151.961	12467.462	96152.552	12468.644	96150.976
14	11528.541	95777.670	11528.281	95776.372	11529.580	95777.930
15	13127.363	95672.383	13126.925	95674.136	13126.487	95675.012
16	12048.729	95368.463	12049.243	95368.806	12050.613	95369.148

Continue Table 4.5

Point ID	Dif. in 2 images			Dif. bet. Surv. & Image (2002)			Dif. bet. Surv & Image (2004)		
	East (Y)	North (X)	distance	East (Y)	North (X)	distance	East (Y)	North (X)	distance
1	0.914	1.045	1.388	1.437	1.045	1.777	0.523	0.000	0.523
2	0.330	0.330	0.467	0.494	0.330	0.594	0.824	0.000	0.824
3	0.198	0.396	0.443	0.198	0.793	0.817	0.000	1.189	1.189
4	1.088	0.544	1.216	0.906	0.726	1.161	1.994	1.270	2.364
5	1.020	2.450	2.654	0.408	1.021	1.100	0.612	1.429	1.555
6	1.003	2.255	2.468	0.502	0.000	0.502	0.501	2.255	2.310
7	0.598	0.598	0.846	0.299	0.300	0.424	0.897	0.898	1.269
8	1.160	0.967	1.510	0.581	1.354	1.473	1.741	2.321	2.901
9	0.160	0.480	0.506	0.320	0.320	0.453	0.160	0.160	0.226
10	1.690	1.998	2.617	0.461	0.461	0.652	1.229	1.537	1.968
11	1.229	1.690	2.090	0.000	0.922	0.922	1.229	0.768	1.449
12	0.922	1.536	1.791	0.154	0.000	0.154	0.768	1.536	1.717
13	1.182	1.576	1.970	0.788	0.591	0.985	0.394	0.985	1.061
14	1.299	1.558	2.028	0.260	1.298	1.324	1.039	0.260	1.071
15	0.438	0.876	0.979	0.438	1.753	1.807	0.876	2.629	2.771
16	1.370	0.342	1.412	0.514	0.343	0.618	1.884	0.685	2.005

surv. Map &image(2002)		surv. Map &image(2004)		image (2002) &image(2004)	
RMSE inY	**0.586**	**RMSE inY**	**1.078**	**RMSE inY**	**1.01**
RMSE in X	**0.856**	**RMSE in X**	**1.372**	**RMSE in X**	**1.352**
RMSE(m)	**0.733**	**RMSE(m)**	**1.233**	**RMSE(m)**	**1.193**

Table 4.6 Coordinates, Differences and RMSE of Superimpose Vector Map on Image in Urban Area

Point ID	Surveying Map		Satellite Image		Differences		Dif. Distance
	East (Y)	North (X)	East (Y)	North (X)	East(Y)	North(X)	
1	87041.427	18613.617	87041.348	18613.777	0.079	0.160	0.178
2	88273.340	19028.870	88273.607	19028.803	0.267	0.067	0.275
3	89189.496	18996.337	89188.654	18996.074	0.842	0.263	0.882
4	91299.296	18958.116	91299.362	18958.442	0.066	0.326	0.333
5	86067.133	18074.810	86067.465	18077.002	0.332	2.192	2.217
6	87606.631	17895.030	87606.692	17894.724	0.061	0.306	0.312
7	89130.722	17963.256	89130.877	17963.101	0.155	0.155	0.219
8	89828.473	17206.540	89828.971	17206.602	0.498	0.062	0.502
9	91512.720	17773.490	91512.720	17773.811	0.000	0.321	0.321
10	86195.954	17176.835	86195.731	17177.728	0.223	0.893	0.920
11	87407.560	17084.001	87407.739	17085.295	0.179	1.294	1.306
12	91090.705	16693.487	91090.655	16693.288	0.050	0.199	0.205
13	85781.704	16162.809	85782.219	16163.382	0.515	0.573	0.770
14	88670.298	16455.203	88670.695	16454.938	0.397	0.265	0.477
15	87110.636	15411.962	87111.152	15410.189	0.516	1.773	1.847
16	89555.838	16406.090	89555.838	16406.817	0.000	0.727	0.727
17	88891.891	15300.619	88891.991	15301.367	0.100	0.748	0.755
18	89769.740	14196.730	89769.634	14197.365	0.106	0.635	0.644
19	85792.497	14725.366	85793.309	14726.759	0.812	1.393	1.612
20	86322.633	13218.821	86323.542	13219.989	0.909	1.168	1.480
21	88068.224	14284.563	88068.695	14284.940	0.471	0.377	0.603
22	87896.187	13093.604	87897.233	13093.720	1.046	0.116	1.052
23	91571.708	15702.354	91571.773	15702.746	0.065	0.392	0.397

RMSE inY	**0.456**
RMSE in X	**0.844**
RMSE(m)	**0.678**

CHAPTER 5

PROSPECTS AND CONCLUSIONS

With the advent of commercial high-resolution imagery, the change detection has increased dramatically. No longer are only large-scale changes such as land-use and land-cover variations of interest. Smaller scale changes such as new houses and roads are now observable and are also important to urban planning and monitoring. Change detection is important for monitoring and managing natural resources, urban development, disaster assessments and produce/update maps.

To create maps from high-resolution imagery, the most important thing is the accuracy of the scale map that can be produced or updated from the imagery. From tables (4.3), (4.4), (4.5) and (4.6) in Chapter **4**, the values of RMSE (Root Mean Square Error) from all cases are concluded in following table:

Table 5.1 The Values of RMSE of All Study Cases

Superimpose		**RMSE (m)**	
in Rural area			
Vector map &image 2002	(table 4.3)	**0.83**	Case 1
Vector map &image 2004	(table 4.4)	**1.05**	Case 2
Image 2002 &image 2004	(table 4.5)	**1.19**	Case 3.1
Vector map &image 2002	(table 4.5)	**0.73**	Case 3.2
Vector map &image 2004	(table 4.5)	**1.23**	Case 3.3
in Urban area			
Vector map &image	(table 4.6)	**0.68**	Case 1

Table 5.1 concludes the tables (4.3), (4.4), (4.5) and (4.6) in Chapter 4:

In rural area:

- When superimpose Vector map & image 2002 (Table 4.2) case 1 and (Table 4.4) case3.2; The values of **RMSE** are± **0.83 ,** ± **0.73 m** respectively**.**

- When superimpose Vector map & image 2004 (Table 4.3) case 2 and (Table 4.4) case 3.3; The values of **RMSE** are ±**1.05 ,** ±**1.23 m** respectively**.**

- When superimpose image 2002 &image 2004 (Table 4.4) case 3.1 The value of **RMSE** is ± **1.19 m.**

In Urban area:

- When superimpose Vector map &image (table 4.5) The value of **RMSE** ± **0.68 m.**

According to the accuracy for a map:
The accuracy of any map should be less than 0.2 millimeter multiply the scale of the map

A map accuracy < 0.2 mm X scale map ………….……………………… (5.1)

From equation 5.1; the accuracy of 1/10000 scale map should be < 2.0 meter and the accuracy of 1/5000 scale map should be < 1.0 meter.

When the maximum value of RMSE (**1.23** m) from Table 5.1 is compared with the accuracy of 1/10,000 scale map and 1/5000 scale map, the value of RMSE (<2 m) requires only for 1/10,000 scale mapping.

For economic reasons, Satellite remote sensing should be applied with comparison to other mapping techniques and data collection sources of information such as aerial photogrammetry and field surveying. The economy of these methods can be shown in the following**:**

-IKONOS image

- Raw image 35 USD/km^2,
- DEM production 5 USD/km^2,
- GCP 30 USD/ each
- and orthorectification 4 USD/km^2 with

TOTAL **is 74 USD/km^2**

Producing map sheet scale 1/5000 (6 km^2) = 74 USD * 6 km^2

= **444 USD/ map sheet**

The advantages of using high resolution satellite images are low costs, fast production and no security restrictions, with accuracy ±100cm.

-Photogrammetric vector mapping:

The cost is around 2-3 USD/ha. It depends on country economic conditions and density of details, **average cost is 2.5 USD/ha**.

Producing map sheet scale 1/5000 (6 km^2) = 2.5 USD * 600 ha (6 km^2)

= **1500 USD/ map sheet**

Aerial photogrammetry is used in large scales mapping such as 1/5000 and 1/500, with accuracy ±10cm.

-Ground surveying

It is the most expensive one and use generally for large scale maps between 1/500 and 1/1000. with better accuracy ±1cm.

5.1 Conclusions

The following conclusions can be drawn from this study:

- Digital camera is now used in photogrammetry, the main philosophy of technique in both aerial photogrammetry and remote sensing satellite imagery is the same. Both techniques use digital image and image correlation technique.

- The availability of high-resolution satellite images increases the remote sensing applications to such an extent that may cause traditional methods and aerial photogrammetry to be replaced by the new technology of satellite imagery.

- Satellite images can provide a suitable base-map to which information from other sources can be added. The images now have higher resolution, which means that more detailed maps at larger scales can be produced. Road networks and new houses can also be rapidly and readily updated from satellite images.

- Satellite data is particularly useful for detecting changes in urban planning, land-cover and land-use because of periodically (repeated) coverage, low cost, more details, and the possibility of overlaying images from different dates exactly on top of each other. In urban planning, the scales those range from 1:5,000 to 1:50,000 are used in local governments for planning purposes. In these cases satellite imagery can be considered for creating or updating base-maps.

- IKONOS images can be used to produce/update maps at medium scales (e.g. **1/10,000** scale map)**.**

- To use satellite imagery in large area for accurate mapping, it must be rectified to fit a map projection

- Accuracy of the image registration process (geometric differences) is the key factor that controls the validity and reliability of the change detection outcome.

- Satellite imagery is main data source for all kinds of GIS applications.

5.2 Recommendations for Future Works

Based on the conclusions presented herein, the following recommendations for future works:

- The second generation of IKONOS will be operated with 60 cm accuracy; the high resolution satellite imagery can be used even in produce/update 1/5000 scale map, planning purposes and all kinds of engineering work

- For accuracy aspect and economic reasons, the change detection by high resolution satellite imagery should be used particularly in fighting illegal buildings in rural area, urban development, forestry, and hazard detection such as earthquake damages and flooding area.

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